Planning the Future of Billfishes

Part 1

National Coalition for Marine Conservation

Planning the Future of Billfishes

Research and Management in the 90s and Beyond

Part 1. Fishery and Stock Synopses, Data Needs and Management

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Planning the Future of Billfishes

Research and Management in the 90s and Beyond

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Proceedings of the
Second International Billfish Symposium
Kailua-Kona, Hawaii, August 1-5, 1988
Part 1: Fishery and Stock Synopses, Data Needs and Management

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Richard H. Stroud, Editor

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Editorial Note

Editorial Note

The designated taxonomic standard in North America for scientific names of fishes is Special Publication No. 12 of the American Fisheries Society (AFS), *A List of Common and Scientific Names of Fishes from the United States and Canada,* published in 1980 (Fourth Edition). This document treats the blue marlin as a single worldwide species *(Makaira nigricans),* treats sailfish as a single worldwide species *(Istiophorus platypterus),* and reassigns the skipjack tuna *(Euthynnus pelamis)* from the genus *Katsuwonus* to the genus *Euthynnus*.

Subsequently, in 1985, the Food and Agricultural Organization (FAO) of the United Nations published a detailed taxonomic revision of the billfishes, *Billfishes of the World,* by I. Nakamura (FAO Fisheries Synopsis No. 125, Vol. 5), which has become the internationally accepted standard for the Istiophoridae, superceding the earlier AFS nomenclature where different.

Accordingly, this symposium's Scientific Advisory Committee adopted the concepts of separate species of Indo-Pacific blue marlin *(Makaira mazara)* and Atlantic blue marlin *(M. nigricans),* as well as of Indo-Pacific sailfish *(Istiophorus platypterus)* and Atlantic sailfish *(I. albicans)*. It also favored use of *Katsuwonus pelamis* for skipjack tuna, following prevailing international acceptance.

Consequently, a broad measure of latitude has been granted to the authors contributing to this symposium concerning their usage of preferred scientific nomenclature for blue marlin, sailfish, and skipjack tuna. Most have elected to follow the more recent international (i.e., FAO) practice in this respect rather than the earlier AFS designations. The matter has been called to the attention of the AFS Names of Fishes Committee for their consideration and evaluation as they prepare for the fifth edition of their report, scheduled for publication in 1990.

Richard H. Stroud
Symposium Editor

Opening of Symposium

Introduction to Symposium
A Special Message
Keynote Address

Frank Carlton and Peter Fithian
Jointly Presiding

Introduction to Symposium

Frank E. Carlton

The reason we have all come to Kona for this Second International Billfish Symposium is clear. We know that, without a better understanding of billfishes — the marlins, sailfish, swordfish, and spearfishes — and of the impact of fishing activities on billfishes the world over, these magnificent and enormously valuable fishes have uncertain futures. We recognize, lacking more effective conservation and management, that the future for billfishes could be one of depleted fisheries and lost opportunities.

The world's billfish populations are threatened by a variety of problems, including insufficient research, rapidly increasing fishing pressure, and management policies guided more by politics than by conservation principles. New and innovative strategies for enhancing billfish science and management are needed. It is the purpose of this symposium to provide a forum for scientists, managers, fishermen, and conservationists from all over the world to meet, discuss, and help plan for the future well-being of billfishes.

This world conference is the long-awaited follow-up to the landmark 1972 Billfish Symposium, also held here in Kailua-Kona. It provides us a rare and invaluable opportunity collectively to measure the progress made in research and management during the last sixteen years, and to determine what is needed to assure a bright future for billfishes and billfishing.

During this symposium, we will consider the critical needs of billfish science and management. Panel One will review trends in the major fisheries. Panel Two will assess the condition of billfish stocks and examine the quality of current stock assessment work. Panel Three will be devoted to identifying the essential data needs for management — biological, statistical, and economic — and to suggesting ways to meet those needs. Panel Four will review and critique national and international strategies for managing billfishes and other highly migratory species.

Additional sessions will feature contributions reflecting the latest research findings in billfish biology, behavior, and ecology, and report on the key social and economic issues relative to the fisheries. These contributed papers are contained in Volume Two of the symposium proceedings.

All of the presentations are designed to set the stage for the concluding session, when the distinguished chairmen of the preceding panels will review the most salient points made during the symposium presentations and discussions. They will also offer recommendations for specific actions to address the needs of billfish conservation at the national, regional, and global levels.

This second billfish symposium would not have been possible without the financial and organizational support of the sponsoring organizations. The major sponsors are: National Coalition for Marine Conservation, National Marine Fisheries Service/National Oceanic and Atmospheric Administration, Inter-American Tropical Tuna Commission, Hawaiian International Billfish Association, U.S. Fish and Wildlife Service (Federal-Aid in Sport Fish Restoration), International Game Fish Association, The Billfish Foundation, Fundacion Mexicana para la Conservacion de los Peces de Pico, Pacific Gamefish Research Foundation, Sport Fishing Institute, Instituto Mexicano de Pesca Deportiva, and Japan Game Fish Association.

All of the sponsors deserve our thanks for making the symposium happen. I would also like to mention that the quality of the symposium

has been greatly enhanced by the participation of the Government of Japan. The cooperation and significant contributions of Councillor Kazuo Shima and his staff at the Fisheries Agency of Japan are gratefully acknowledged and sincerely appreciated.

The members of the Steering Committee included Kirk Beiningen, Francisco Rangel Castelazo, Anthony Fedler, Peter Fithian, William Fox, Jr., Elwood Harry, Peter Larkin, Carl Nettleton, Larry Nielsen, Russell Porter, Eric Prince, Gilbert Radonski, Ronald Schmied, Robert Stevens, Richard Stone, Archie Tuomi, and Christopher Weld. Their help and advice were invaluable.

In addition, much credit for the success of the symposium is due the efforts of Kenneth Hinman, the Program Coordinator, and the indispensable Scientific Advisory Committee of Richard Shomura, David Grobecker, and Grant Beardsley.

Finally, we are all indebted to the panelists and speakers who authored the papers that are featured in the two volumes of the symposium proceedings. They have made a valuable contribution to the future well-being of billfishes.

Frank E. Carlton, M.D. (Emory University, 1961) is a practicing urologist in Savannah, Georgia. He founded the National Coalition for Marine Conservation in 1973, serving as its first president until 1983. From 1973-1977, he was U.S. Commissioner to the ASMFC, and from 1975 to 1983, he was U.S. Commissioner to the ICCAT. He served on the Fisheries Advisory Committee to the U.S. Department of Commerce (1974-1976), on the Ocean Affairs Advisory Committee to the State Department (1975-1977), and on the Atlantic Salmon Treaty Working Group (1980-1982). He was appointed in 1983 as U.S. Commissioner to NASCO. He was co-founder (with R.H. Stroud) in 1976 of the annual Marine Recreational Fisheries Symposium, first serving as vice-chairman, then as chairman from 1978 to present.

A Special Message

Daniel K. Inouye

I extend a warm Aloha to the organizers and participants of the Second International Billfish Symposium on planning the future of billfish: research and management in the 1990s and beyond.

Prior to the establishment of the 200-mile exclusive economic zone (EEZ), the jurisdiction of coastal states (i.e., nations) over the oceans was limited to rather narrow territorial zones. This left the high-seas waters, an area of unrestricted use for all nations, encompassing virtually all of the world's oceans. The declaration of the exclusive economic zone (EEZ) by the Convention on the Law of the Sea in 1982, followed by the United States Presidential EEZ proclamation in 1983, drastically reduced the area of the high seas and created new jurisdictional conflicts. One such conflict relates to rights over highly migratory species.

This conflict led to seizures of U.S. tuna vessels, retaliatory trade embargoes, and the eventual exploitation of strained relations between a number of the South Pacific Islands and the U.S. by the Soviets, who successfully negotiated several bilateral fishing agreements. It is obvious that effective management and conservation of this wide-ranging resource requires unprecedented international cooperation. We are beginning to see signs of such cooperation, for example, in the signing and ratification of the South Pacific Tuna Treaty of 1988. This treaty, its related assistant agreement, and enacting legislation has set a precedent for responsible, cooperative, multilateral conservation and management of an extremely important economic resource.

In light of the increasing pressure by foreign fleets on domestic fish stocks, the strong U.S. market demand for tuna products (which greatly exceeds the domestic harvesting ability), and expanded jurisdiction by coastal nation states over tuna, the time is ripe for reviewing the structure of U.S. fishing regulations.

Billfish and tuna are highly migratory fishes that are widely but rather sparsely distributed throughout the tropical and temperate oceans of the world. Despite foreign competition, rising costs, and environmental regulation, the U.S. tuna industry remains one of our largest and most important fishery-based industries. Six species of tuna (yellowfin, skipjack, albacore, bigeye, northern bluefin, and southern bluefin) are commonly sought by a variety of fishing methods, both in coastal waters and on the open ocean hundreds of miles from land.

The political climate surrounding the tuna fishing industry has undergone rapid change during the last few decades and is presently in a sensitive maturation phase. Concerns facing the tuna industry include regulations to limit porpoise mortality incidental to the tuna harvest, conflicting recreational and commercial claims to bluefin tuna in the Atlantic, product quality and contamination, increased international competition for tuna resources, and import competition for U.S. markets.

We in the Congress are mindful of the economic importance of the international tuna fishery, the nomadic nature of this resource in coastal and international waters, and the importance of ensuring the abundance of tuna populations for future generations. The Congress has, therefore, urged the Department of State to work cooperatively with other nations and international organizations concerned with the fisheries for tuna, at the appropriate time, to enhance scientific studies of the tuna populations in the western Pacific Ocean and to address the

long-term conservation needs of this resource.

In addition, the Magnuson Fishery Conservation and Management Act will come up for reauthorization in 1989. Accordingly, the question arises as to whether changes in the U.S. approach to tuna management, under the FCMA, might be necessary in response to changing patterns of the tuna fishery. While the extremely successful negotiation of the South Pacific Tuna Treaty of 1988 illustrates a move toward better international cooperation, the ability of the U.S. to manage and conserve its own stocks of tuna may be hindered by its tuna policy.

The tuna fleet is the sole remaining U.S. distant-water fishery. Some U.S. vessels fish for tuna within the U.S. EEZ, but many more exploit this resource in foreign waters or on the high seas. Consequently, the U.S. tuna industry is dependent upon tuna caught in waters outside U.S. jurisdiction, with approximately 90% of its catch by weight and value coming from foreign and international waters. Traditionally, the U.S. fleet has relied on fishing operations in waters of the eastern Pacific for the bulk of its catch. In recent years, however, a substantial portion of the effort has been relocated to the southwestern Pacific.

The U.S. has sought to retain open access to tuna by excluding them from among the species managed under the provisions of the Magnuson Fishery Conservation and Management Act (FCMA) of 1976. Present U.S. policy is to negotiate international agreements to manage tuna and secure access for U.S. fishermen to tuna stocks. Nevertheless, almost all other nations have asserted an unilateral right to manage and allocate this resource within their EEZs. The desire of the coastal states to exert jurisdiction over all fisheries, including tuna, found within their EEZs, is in direct conflict with U.S. policy — which considers tunas to be highly migratory species not subject to regulation by coastal states.

Widely differing opinions prevail both on whether any changes to the U.S. tuna policy are necessary, and on what type of changes would best serve both our domestic and international interests. The subject of jurisdiction over highly migratory species will no doubt receive careful consideration in Congress in 1989. Be assured that we, as the policymakers, will be diligent in our pursuit of the most effective and efficient legal regime to develop, protect, and conserve wisely these most valuable ocean resources.

Daniel K. Inouye received the A.B. degree (1950) from the University of Hawaii and the J.D. degree (1952) from George Washington University, and practiced law in Honolulu until elected to the Hawaiian House of Representatives (1954), then Senate (1958). Elected to the U.S. Senate from Hawaii in 1963, where he has since served continuously. He served in the U.S. Army (1943-1947), rising from private to captain, and was decorated with the Distinguished Service Cross and the Bronze Star. He has received many civilian awards. He is a member of the Senate Committee on Appropriations and of the Senate Commerce Comittee, being the ranking member of the subcommittee on the merchant marine with jurisdiction over marine fisheries matters.

Looking to the Future of Billfishes

Winthrop Rockefeller

I am neither a scientist nor a professional fisheries manager. I am merely a recreational fisherman who has spent the last several decades wondering why the populations of billfishes appear to be declining. Nobody seems to be able to determine why, or to know how to arrest this alarming trend. In fact, so little definitive information is actually known about these species that a group of us gathered together to form a research and conservation organization, which is now known as The Billfish Foundation. More about that later.

My remarks today might well seem like carrying coals to Newcastle or even preaching to the choir, since most if not all of you, whether fishermen, scientist, or professional fisheries manager, clearly recognize the potential problems facing billfish populations. Because of your awareness, you can testify as to the current and increasingly precarious status of billfish stocks worldwide. To recreational fishermen, billfishes are symbols of their sport, and the concern for their wellbeing has triggered a worldwide coalescence of interest to guarantee their future.

Man has sought the bounty of the sea and the land since the beginning of time in order to attempt to assure his own survival. As man developed he found ways, with the aid of mechanization, to reduce the amount of time necessary to provide for his basic needs. As he had to work fewer hours each week, his thoughts turned towards recreational activities. Among them were hunting and fishing, to name just a few, so he began to practice for recreation what only a few short millennia before had been done only for survival.

With the advent of pleasure boating came the opportunity to experience big-game-fish angling and, soon, the first billfishes were caught for fun instead of survival. Of course, there were limitations to what early anglers could achieve with their primitive tackle. Initially, it was such a rare occurrence that one could land a billfish with linen line and some of the archaic equipment available that the idea of release rarely crossed anybody's mind. Given that some of these early pioneers did press for conservatory efforts, for the most part, their recommendations fell upon deaf ears.

As Goethe once said, "There is something inevitable about an idea whose hour has struck." I believe that we must all agree that the idea of conserving our precious marine resources has been ticking away for a long time now, and that the hour has finally struck in a big way.

A major step towards the future was taken in August of 1986 . . . the culmination of years of dreaming by a lot of people concerned about whether there would be any billfish left by the year 2001. The International Billfish Research and Conservation Foundation was born. The new organization is dedicated to a single principle . . . that of assuring a future for billfishes through scientific research.

We are hard-headed about the belief that something must be done right now to assure a future for the billfishes. We are also realistic enough to know, since these fish are migratory in nature, that a global cooperative effort will be required. Hence, we are an international organization.

From translations I have read of articles in Japanese newspapers, there is no doubt in my mind that Japanese commercial interests wonder if our goals are to put them out of business. To that I say an unequivocal "no." It is not appropriate for a conservation organization to tell a nation, whose people depend so heavily on fish for

survival, that they may no longer fish. What is appropriate, however, is to seek their cooperation in minimizing the by-kill of a group of fish which are not essential to their basic survival. It is to everyone's advantage to do so.

I offer our hand, right now, to anyone who will join us, in cooperation and collaboration, to solve this common dilemma. Shall we start now to work together to achieve a mutually beneficial goal? Or, will we have to sit idly by, waiting for the species to be designated as "endangered" before those who resist are forced to comply?

No other group of fishes has so totally captured the imagination and enthusiasm of anglers in all walks of life as have these majestic billfishes. Their universal appeal is regularly exploited by book and magazine publishers, who seek and take every opportunity to feature the most eye-catching billfish photographs on the covers of their publications that deal with fish and fishing.

Young and old alike, from rural and urban communities alike, share a common dream of having the opportunity of one day "setting the hook" in a record shattering marlin or sailfish. The more sophisticated individuals among them draw inspiration from author/anglers like Ernest Hemingway and Zane Grey who, in their widely read epics, so articulately romanticized the beauty, cunning, and stamina of these magnificent fish.

Apart from their aptly heralded fighting qualities, the inherent scarcity of billfishes has undoubtedly contributed substantially to the special mystique that surrounds billfish angling. These are truly "rare event" species, but their basic scarcity has been a major contributing factor to their inaccessibility to scientists. In turn, it is largely responsible for the conspicuous void of biological information about the group as a whole. The Billfish Foundation is dedicated to filling this void. It is my hope that this symposium will be the beginning of a global effort to take up the challenge of compiling the basic biological information necessary to manage these species effectively.

As top of the food web, i.e., as apex predators, billfishes are innately much less abundant than prey species and smaller predator game fishes. From the moment they are spawned, they are predatory, whether it be upon other species or their own; the odds of a larval marlin surviving to adulthood are extremely slim. In spite of such limited odds, anglers in pursuit of trophies exhibit uncommon persistence, with patience seemingly known only in one's job. Surveys conducted by the U.S. National Marine Fisheries Service (NMFS), in 1986, indicated that the "average" Atlantic coast billfish angler fished approximately 28 days to catch a blue marlin *(Makaira nigricans)*, 17 days to catch a white marlin *(Tetrapturus albidus)*, and 6 days to get one sailfish *(Istiophorus platypterus)*. The fabled devotion and avidity of billfish anglers is further evidenced by the amount of money they spend on their sport. A 1977 study, again conducted by NMFS, indicated an average angler expenditure of $1,300 for each billfish landed! More than this, a whole series of boating and fishing equipment industries has been developed to cater to this very specific type recreational fishing. This is a staggering amount of money — even by "Rockefeller" standards!.

Their inherent scarcity, combined with uncertainty as to the broader ecological implications associated with decreased supplies of any top predator, dictates an urgent need to reduce intensive exploitation of billfish stocks. This dictum can be ignored only at the risk of future catastrophe befalling billfish stocks.

Although they tend to be full of caveats, contradictions, and unanswered questions, the general trend among the few published scholarly papers that deal with billfish biology and stock assessment clearly show declining, unstable, or fluctuating populations of most, if not all, billfish species. The brief illusion of respite from foreign fishing fleets, enjoyed by fish stocks along the U.S. east coast (Gulf of Mexico) exclusive economic zone (EEZ), following the enactment of the Magnuson Fishery Conservation and Management Act of 1976, was soon overwhelmed by the exponential growth of domestic tuna and swordfish *(Xiphias gladius)* longlining fleets.

For example, commercial landings of marlin from the Gulf of Mexico in 1986 were 141,700 pounds, or 15 times greater than the 9,407 pounds reported in 1982. The fact that billfishes are being marketed increasingly to the American public as faddish, gourmet-quality table fare poses a most ill-omened menace to the future wellbeing of these species. Absent prompt intervention, the long-term prognosis appears particularly dim (in the Atlantic) for both blue marlin and white marlin stocks, although somewhat brighter for sailfish.

Commercial exploitation, as much as we may

all agree about its necessity, both directed and incidental to tuna longlining, has been identified, to the extent we are able with current data, as one of the key factors in the declining populations of these species. Recreational fishing currently accounts for only a small fraction of the total harvest of the billfish stocks. The level of pressure put on the resource by anglers can only decline, given the increasing interest in releasing, even with more anglers coming into the fishery. For example, in 1983, about 57% of all white marlin and 36% of all blue marlin being landed in fishing tournaments that were monitored along the Atlantic Coast were released. Since then, dozens more tournaments have changed to modified or full release formats, and the number continues to grow with every passing month.

We must of course recognize that a variety of factors affect the overall fishing success rate from year to year and area to area. It must be emphasized, even so, that billfish angling success is inexorably tied to prevailing levels of billfish abundance; therefore, the more fish the better the fishing. Unfortunately, sport fishermen have seen a conspicuous reduction in hookups and, therefore, in catch, that has coincided with the onset of commercial longlining activities that severely reduce local billfish abundance. Conversely, a study has indicated that sport fishing success responds positively over time to the absence of intensive commercial exploitation. Consequently, any management plan which is to be endorsed by sport fishermen must assign priority to measures designed to minimize the impact of commercial fishing upon the billfish species of significant angling interest.

At the same time, anglers must agree to the imposition of minimum size limits and/or other restrictive regulations which reduce the kill of sport-caught billfishes. It is also imperative to upgrade vastly the woefully inadequate store of current biological and economic data pertinent to the management of billfish fisheries. The uniqueness of billfishes, their biology, fisheries, and management, cannot be overemphasized. Basic fisheries theory, that works well for assessing and managing other groups of fishes, may not necessarily apply to billfish. After all, I haven't seen many reports on the biology and stock assessment of the ancient coelocanth — another rare-event species.

These recommendations must be supplemented by the ancillary development of public information programs necessary to bring about serious consideration by policy makers, politicians, and of course, the public at large.

As the last decade of this century looms nearer, in these times of incredible technical sophistication, we must recognize how poorly we understand the movement, life patterns, and mortality of the billfishes we seek. In this regard, the "enhanced billfish research program" of the International Commission for the Conservation of Atlantic Tunas (ICCAT) has taken a critical first step toward initiation of a coordinated international research effort, which must be extended to cover the entire range of all billfish species.

How the enhanced billfish research program came into being is representative of the resolve of those concerned with the future of these magnificent fish. As most if not all of you surely know, ICCAT is an international organization comprised of 22 member-nations who manage and conserve Atlantic tunas and tuna-like fishes, including mackerels and billfishes. Historically, for what might well seem like obvious reasons, ICCAT has had little incentive to do anything with respect to fishes of minor commercial value. When faced with pressure from the United States delegation to obtain data necessary for the proper management of billfishes, ICCAT balked. The reason given for resisting a departure from their traditional role of tuna management was an insufficiency of financial resources. In the face of financial restrictions within ICCAT, organized sport fishing groups in the U.S. pledged to provide the necessary funds for the enhanced billfish research program. Consequently, the program will proceed under the aegis of ICCAT, but is being funded predominately by private sources.

The enhanced billfish research program is obviously a rather modest undertaking in the overall international scale of things. At the same time, other significant progress has been made at the domestic level in the United States through the Atlantic Billfish Management Plan. As a matter of fact, the ICCAT's enhanced research program for billfish, the Atlantic Billfish Management Plan, the Billfish Foundation, and this symposium all seek to resolve a critical issue that they hold in common. That issue is a desire to stimulate the formulation of the appropriate biological and economic information needed to permit prudent management of billfish populations on the basis of biological and economic principles, instead of political whim.

The Atlantic Billfish Plan (excluding

swordfish) reflects nearly 12 years of effort to design and implement management and conservation measures for Atlantic billfishes. Some of the provisions of the plan include restrictions on commercial sale and retention, as well as size limits and mandatory reporting in the recreational fishery. Approval of this plan is now pending.* Other countries are formulating or implementing their own management schemes. Considering the highly migratory aspect of the species, all nations should strive to work together to conserve billfishes on the high seas.

Being the son of a politician, I know well that someone cannot be elected to office by only one party's voters . . . it takes voters from all parties to accomplish the goal. An effort of appropriate global magnitude will require support from many parties and many states and nations.

We all live together on this small planet, dependent on its natural resources to support our survival. Yet, like neighbors anywhere in each of our countries, we keep squabbling about the petty things while letting the big ones fall between the cracks. This symposium, however, is an opportunity to change much of that before it is too late, and to do it in a manner that should, for the most part, work to everyone's advantage. It is to everyone's advantage to have healthy billfish populations; populations that are exploited, to be sure, but not to the point where they cannot sustain themselves.

It is to everyone's advantage to have international cooperation for the management and conservation of this species group. After all, an international fish needs international attention. Research and development is what is needed here. If we can put a man on the moon, we certainly can figure out a way to avoid user conflicts by reducing the by-catches of billfishes while still maintaining longline operations.

Because I am obviously a proponent of recreational billfishing, I'm sure that some folk here are expecting me to suggest that commercial longline fishing should be stopped. I do not. What I am suggesting, however, is that commercial fisheries interests should join with the recreational interests in devoting a significant amount of effort and a reasonable amount of money toward finding ways to minimize the billfish by-kill. Again, it is to everyone's advantage to do so. Research and development is what we need here. An analogous example of what can be done in this regard is the development of the turtle excluder device for commercial shrimp trawlers. This device allows the capture of shrimp while excluding the capture of the unwanted by-catch of turtles. It is possible to resolve such vexing problems, and it is to everyone's advantage to do so.

We have gathered here to try to find a strategy to assure a future for the pelagic billfishes; to air our thoughts, concerns, and opinions; and to share what we have learned so that our efforts here might accomplish something special for the future of the billfishes. I hope, during these days, that we have and will continue to come closer together in seeking this common goal.

Allow me, if you will, to leave you with one rather important thought. If we are capable of working together, great benefits can be realized from rational management of resources. If we cannot, will there by anything at all left to manage? The decision is yours and mine to make. The right decision will guarantee that we may avail ourselves of the richness of these bountiful oceans for centuries to come. The wrong decision cannot only guarantee that billfish will be lost, but it may guarantee our own eventual extinction as a species, as well.

Thank you for having given me your attention regarding this serious matter. I hope you will find this a most useful and fortuitous symposium, and be able to take at least one more step in a positive direction, for the billfishes. It is truly to everyone's advantage to do so.

Winthrop P. Rockefeller was educated in Europe and is a 1974 graduate of Texas Christian University's School of Range Management. He is chairman and chief executive officer of Winrock Farms, Inc., Arkansas, and board chairman of several commercial enterprises. He is a current or former officer or board member of more than 20 different business, professional, and civic organizations. Among them, for example, he is past president of the Arkansas Cattlemen's Association; board member of Ducks Unlimited, The Nature Conservancy, and the Winrock International Institute for Agricultural Development; and is chairman of the U.S. Virgin Islands Blue Marlin Tournament. He is president and chairman of the International Billfish Research and Conservation Foundation.

*Editor's note: The Plan was approved by the U.S. Secretary of Commerce, effective October 18, 1988.

Panel 1

Trends in the Fisheries

Peter Goadby, Chairman

Trends in the Fisheries for Billfishes in the Atlantic Ocean

Grant L. Beardsley

The fisheries for billfishes (i.e., marlins, sailfish, and spearfish) in the Atlantic Ocean can be grouped into three broad categories: the commercial fishery, the recreational fishery, and the artisanal fishery. The commercial fishery is almost exclusively the high-seas tuna longline fishery in which billfishes are usually incidental catches. The fishery is conducted by numerous nations, many of whom are not physically located adjacent to the Atlantic Ocean. The main participants in the fishery are Japan, Korea, Taiwan, and Cuba. The recreational fishery is centered in the western Atlantic, primarily in the U.S., and is exclusively by rod and reel. The artisanal fishery is conducted with a variety of gears and is located mainly off western Africa, the east coast of South America, and in the Caribbean Sea. The discussions in this chapter will be limited to the commercial and recreational fisheries. There are few data on catch or effort from the artisanal fisheries. Because of their extent and their year-round operation, however, they are major harvestors of billfishes, principally sailfish *(Istiophorus platypterus)*.

The Commercial Fishery

Effort

The commercial fishery essentially began in 1956, when Japanese tuna longline vessels entered the Atlantic and began to fish in the tropical waters of the western Atlantic for yellowfin tuna *(Thunnus albacares)*. This operation expanded rapidly and, by the mid-1960s, operated throughout the Atlantic from 40°N to 40°S latitude; almost 100 million hooks were being set annually (Fig. 1). Effort declined rapidly, however, and the fishery began to shift away from tropical waters and yellowfin tuna, first to albacore *(T. alalunga)* and then to bluefin tuna *(T. thynnus)* and bigeye tuna *(T. obesus)*. It was also in the mid-1960s when Korea and Taiwan began to fish in the Atlantic and, by the mid-1970s, their's were the dominant fleets in the Atlantic. Taiwanese vessels gradually shifted into temperate waters to concentrate on albacore (Fig. 2). Korean vessels concentrated their fishing effort in more tropical waters (Fig. 3).

There are other countries that fish for tunas with longline gear in the Atlantic, and they take significant numbers of billfishes as bycatches. In the 20-year span from 1964 to 1984, two major changes occurred in billfish landings. First, the total catch of blue marlin *(Makaira nigricans)* and white marlin *(Tetrapturus albidus)* fell dramatically, from 11,738 metric tons (mt) in 1964 to 3,180 mt in 1984. Second, the catch was more evenly distributed among the various participating nations (Fig. 4). In addition, the longline fishery for swordfish *(Xiphias gladius)* also captures billfishes. The rapidly expanding U.S. fishery for swordfish in the Caribbean and tropical Atlantic has become a substantial catcher of billfishes as has the developing U.S. fishery for yellowfin tuna in the Gulf of Mexico and Caribbean. In most cases, however, billfishes are not retained in these fisheries, which is not the case with the other longline fisheries.

Catch

Data on the catch of billfishes by the commercial and recreational fisheries in the Atlantic are derived from the data archives at the International Commission for the Conservation of Atlantic Tunas. They include data for most nations

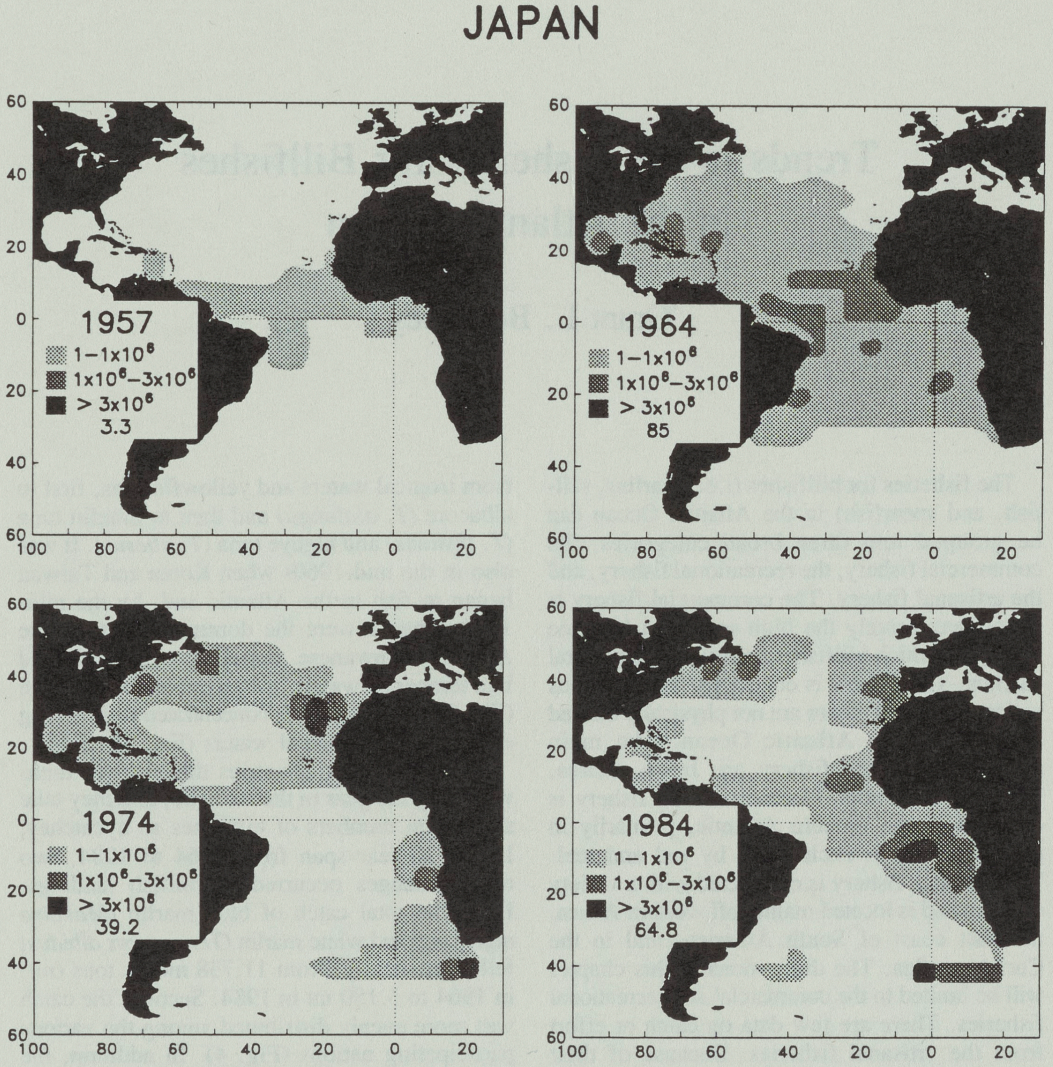

Figure 1. Distribution and concentration of fishing effort by the Japanese tuna longline fishery in the Atlantic Ocean. Effort is expressed in number of hooks. The number at the bottom of the insert is the total number of hooks, in millions, fished in that year.

operating longline gear in the Atlantic. The catch of blue marlin and white marlin show similar patterns over the history of the fishery (Figs. 5,6). Landings rose rapidly as the Japanese fleet began to expand following their entry into the Atlantic in 1956. Landings peaked in the early and mid-1960s. Total catches declined rapidly, however, and, from the mid-1960s to the mid-1970s, were stable at about 50% of the catch during peak years. In the late 1970s, another decline occurred and, for the past ten years, landings have been stable at about 2,000 mt for blue marlin and 1,000 mt for white marlin.

Landings of sailfish and longbill spearfish *(Tetrapturus pfluegeri)* also rose rapidly but, unlike the two marlins, catches remained at fairly high levels for almost ten years (Fig. 7). Catches dropped in the mid-1970s, rose again in the 1980s, and, in the last three years, landings were greater than at any other period in the fishery.

Landings have been affected by several factors.

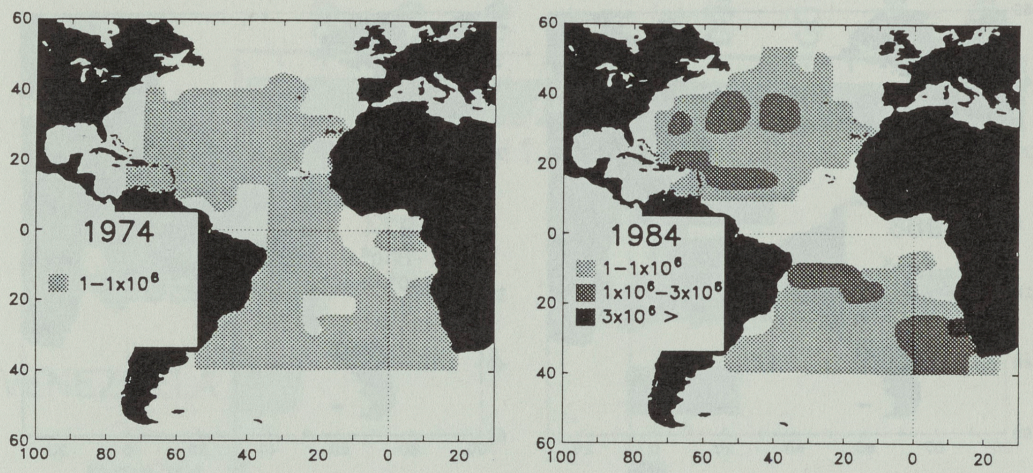

Figure 2. Distribution and concentration of fishing effort by the Taiwanese tuna longline fishery in the Atlantic Ocean. Effort is expressed in number of hooks.

Certainly, changes in abundance and, possibly, distribution of the stocks have played a significant role. Changes in the character of the longline fishery, however, have also had an important effect on landings. Over the years, fleet composition has changed dramatically. Even more significantly, the target species of the important fleets has changed, substantially affecting the bycatch of billfishes.

Catch Per Unit of Effort

Historical trends in catch per unit of effort (CPUE) for blue marlin, white marlin, sailfish, and spearfish are shown in Figures 8, 9, and 10. Data are from the Japanese fishery only.

CPUE for blue marlin peaked very early in the fishery, then declined sharply over the next several years. Two trend lines are depicted. One shows effective CPUE through 1980 which adjusts for areal changes and shifts in target species. The other is nominal CPUE, which does not adjust for these factors. The sharp decline in CPUE stopped in the late 1960s, but a gradual decline continued up into the late 1970s. Nominal CPUE showed a slight increase in the early 1980s.

The decline in white marlin CPUE is similar to that for blue marlin — an early peak in the early and mid-1960s then a long, fairly steady decline to very low levels in the 1980s. Adjusting the data for changes in target species, and for shifts between areas, dampens the declines in CPUE for both blue marlin and white marlin. The overall picture of sharp and deep declines is clear, nevertheless. Substantial changes in gear deployment and in fishing strategy by the Japanese in the early 1980s makes extending CPUE adjustments beyond 1980 very difficult.

Almost all catch data from the Japanese fishery combine sailfish and spearfish catches. Even so, catch records from Japanese research cruises were used to make rough estimates of the catch composition of the two species from the commercial fishery. CPUE for both sailfish and spearfish peaked much later than for the two marlins, but both species demonstrate the same long term declines in CPUE as do the two marlins.

The geographical distribution of CPUE for blue marlin (Fig. 11) for 1964, 1974, and 1984 reflects very high concentrations off Brazil and in the Caribbean and surrounding areas in 1964. In 1974, these concentrations completely disappeared. In 1984, the concentration in the Caribbean had appeared once again, although much smaller in extent than in 1964. The distribution and areas of concentration of CPUE for white marlin are similar to those for blue marlin (Fig. 12). In the early years, concentrations were located off Brazil and in the Caribbean. In 1974, these

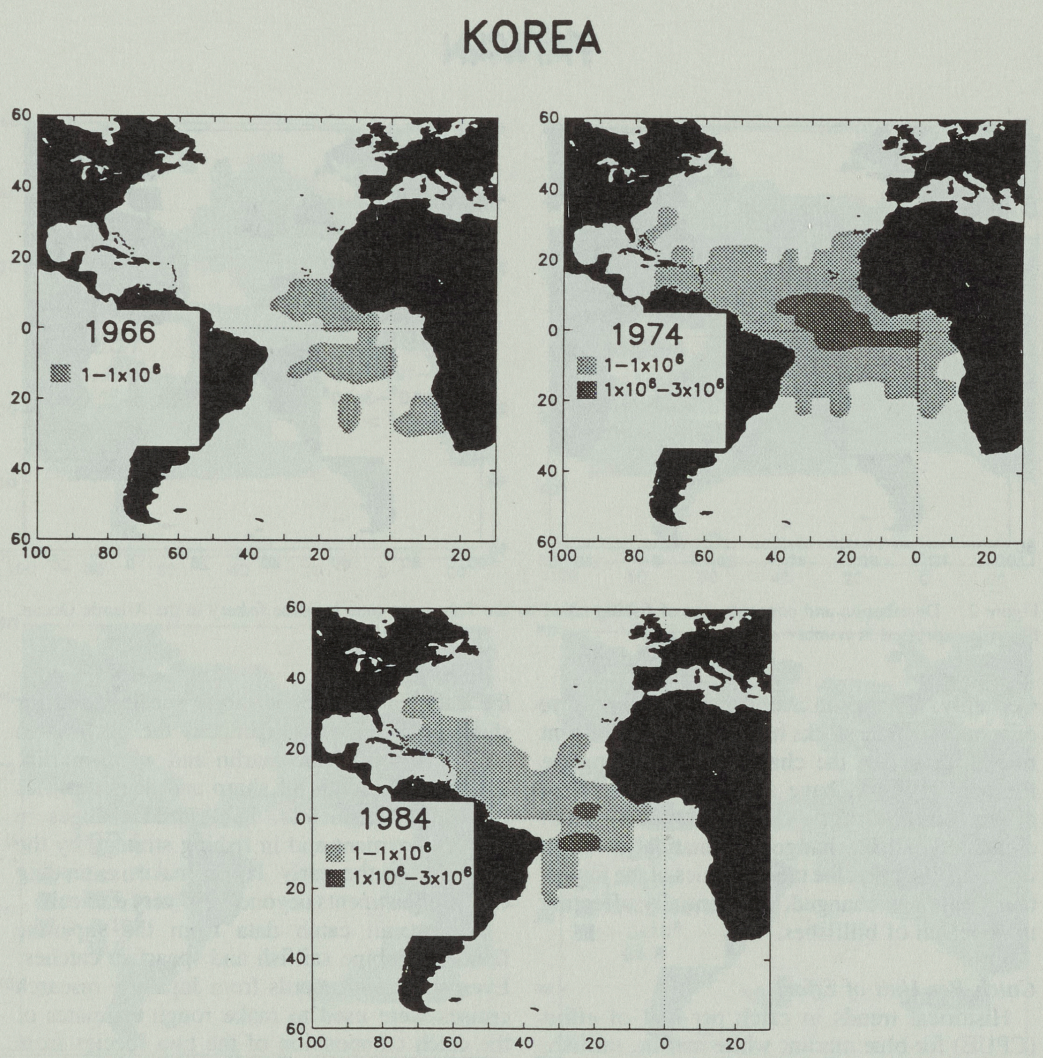

Figure 3. Distribution and concentration of fishing effort by the Korean tuna longline fishery in the Atlantic Ocean. Effort is expressed in number of hooks.

areas were sharply reduced with a new area of high CPUE located in the Gulf of Mexico and along the Yucatan. By 1984, even these areas showed only low catch rates. CPUE for sailfish (Fig. 13) show early concentrations off Brazil and then low levels throughout the Atlantic.

The Recreational Fishery

Effort

The recreational fishery for billfishes in the Atlantic has undergone a tremendous evolution over the past half century. The days of calcutta poles, linen lines, and slow, cumbersome fishing platforms have been replaced by modern technology in every area. The modern sportfishing vessel is a state-of-the-art, electronic-laden fishing machine, and the gear and fishing techniques have been honed to perfection through years of development and field testing. Participation in marine recreational fishing has more than tripled, from 4.6 million anglers in 1955 to 14.1 million in 1985. Most of this fishing occurred in the Atlantic and Gulf of Mexico.

Participation in fishing for billfishes has certainly kept pace with this measured increase

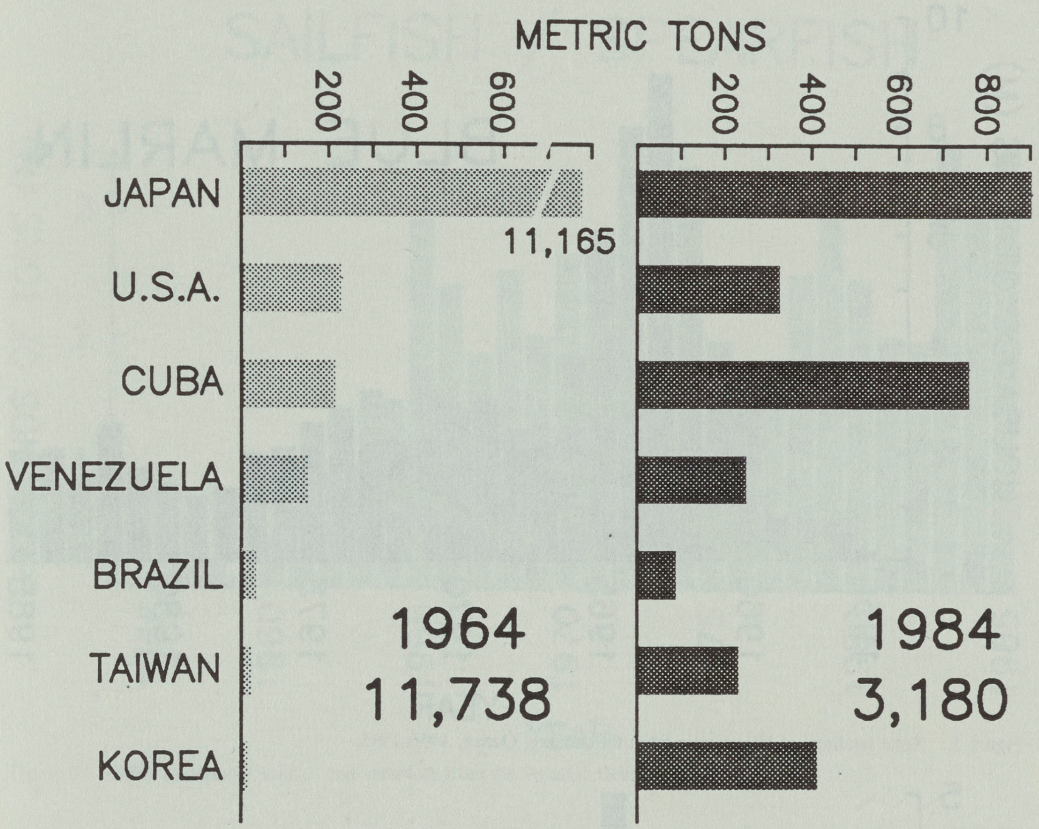

Figure 4. Total landings of blue marlin and white marlin from the Atlantic Ocean by the major fishing nations in 1964 and 1984.

and has probably surpassed it. Only 20 years ago, for example, fishing for billfishes in the Gulf of Mexico was a pioneering activity. Now, such fishing is conducted from every suitable port from the Texas-Mexican border to the southern tip of Florida. New fishing areas have been disovered and widely publicized off western Africa, Brazil, the Canary Islands, the Azores, throughout the Caribbean, and in the Bahamas, to mention only a few.

The fishery has moved steadily away from the aura of "elitist" or "rich man's sport." Small-boat anglers are now a significant part of this fishery throughout the Atlantic. The billfish fishery in the Atlantic is no longer the stepchild of marine angling. It is a major industry having significant influence in the conservation and management decision-making processes.

We are unable to track actual landings and fishing effort from the recreational fishery the way we can with the commercial fishery. Nevertheless, some idea of the rapid increase in participation in this fishery can be determined from sampling data from the National Marine Fisheries Service's billfish survey. Begun in 1971, in the Gulf of Mexico, it now covers almost all of the U.S. Atlantic and Gulf coasts, as well as the Bahamas and many areas of the Caribbean (Fig. 14).

The number of tournaments sampled increased rapidly until 1983, when a peak of 111 was reached and over 70,000 tournament fishing hours were recorded. Much of this increase was in the Gulf of Mexico. In the early 1970s, for example, 4 to 6 tournaments were sampled in the Gulf each year. In 1986, data were recorded from 49 tournaments. Much of the non-tournament sampling has also been in the Gulf of Mexico, but the data do not indicate an increase in fishing effort comparable to that occurring in

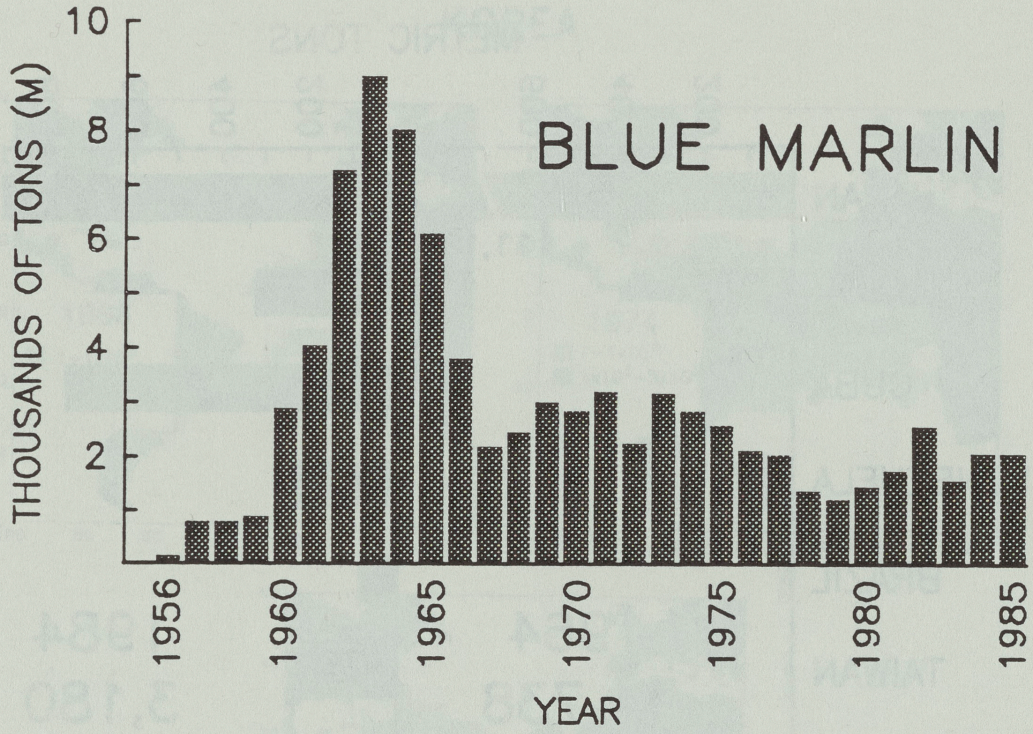

Figure 5. Total landings of blue marlin from the Atlantic Ocean, 1956-1985.

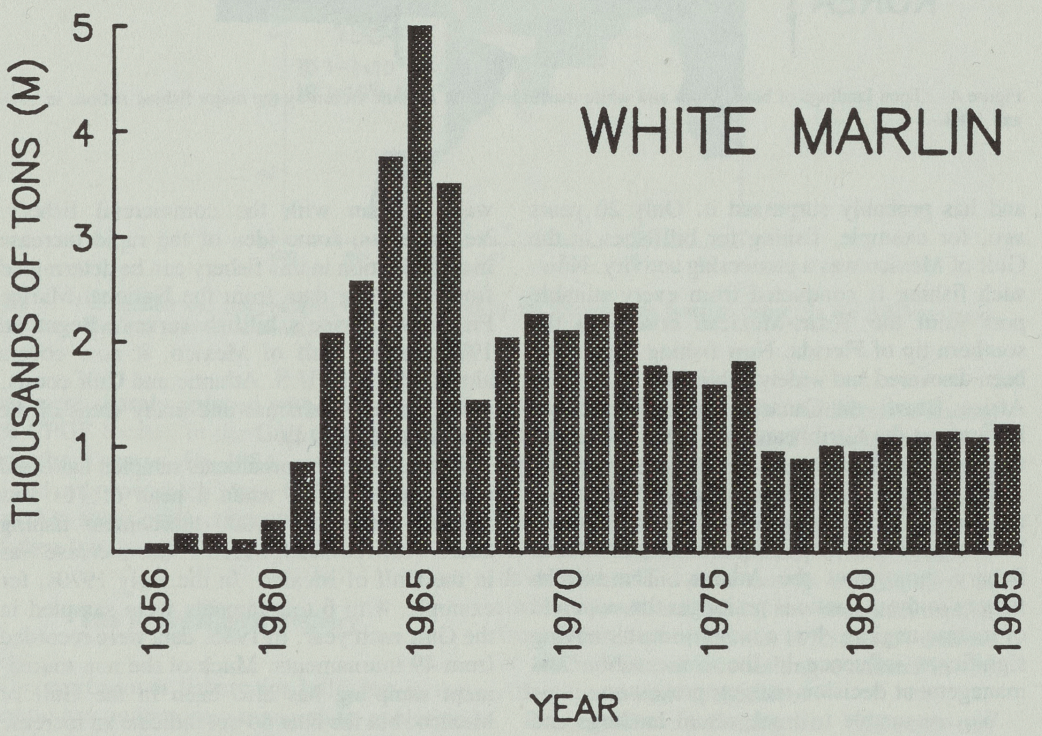

Figure 6. Total landings of white marlin from the Atlantic Ocean, 1956-1985.

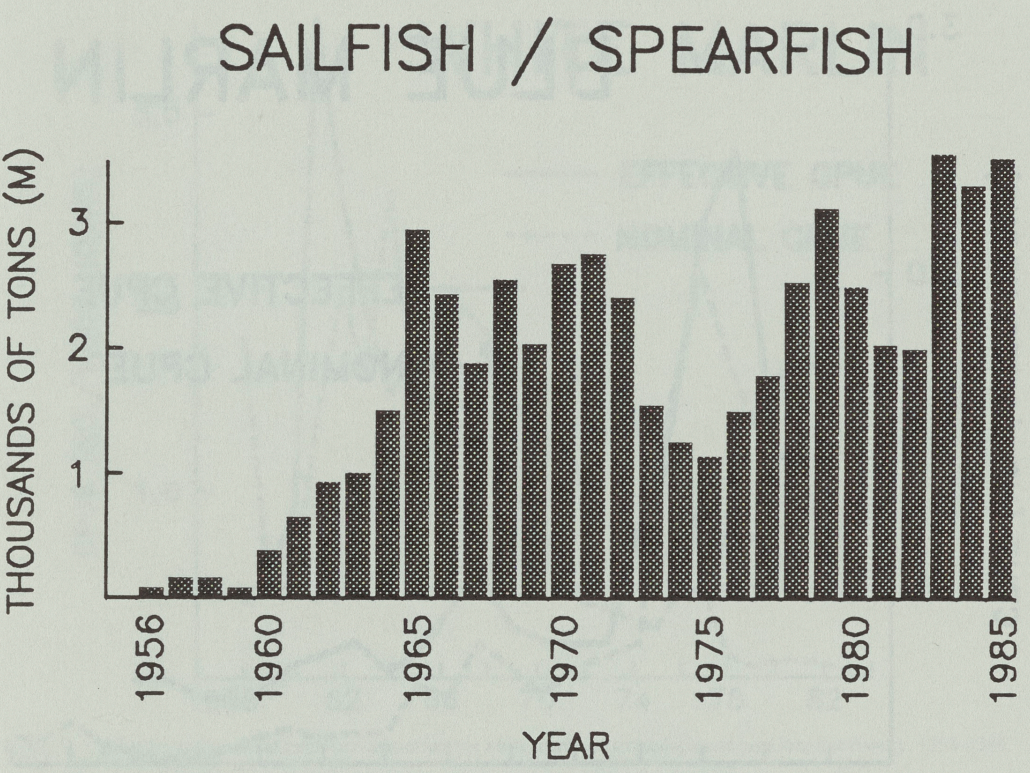

Figure 7. Total landings of sailfish and spearfish from the Atlantic Ocean, 1956-1985.

tournaments. It seems clear, however, that overall fishing effort in all areas has increased substantially.

Catch

Good, reliable data on the total catch of billfishes in the U.S. recreational fishery are woefully lacking. A survey was conducted for the Atlantic and Gulf coasts of the U.S. in 1977, with follow-up surveys in 1981 for the Gulf and 1983 for the Atlantic. The 1977 survey indicated that 6,745 blue marlin had been caught in the U.S. recreational fishery, along with 15,649 white marlin, and 60,008 sailfish. Of these totals, an average of about 70% were released. The most significant trend in catches in the U.S. fishery in recent years has been the widespread move toward release or tag-and-release of all billfishes, particularly in tournaments.

Catch Per Unit of Effort

Catch and effort data from the U.S. recreational fishery have been collected since 1971. If we examine trends from areas where sampling has been fairly consistent over the past 17 years, both in the Bahamas and in the Gulf of Mexico, catch per unit of effort (CPUE) for blue marlin has been fairly stable over the period (Fig. 15). For white marlin, however, the last three years have produced very low CPUE values, well below the long-term average. It should also be noted that these data series begin 6 to 7 years after peak landings of the two marlins occurred in the Atlantic and Gulf.

Summary

The evolution of the fishery for Atlantic billfishes shows several major features — a sharp decline in total landings and CPUE from the traditional commercial fishery; a great increase in the recreational fishery, particularly in the U.S.; and new fisheries developing rapidly in the tropical Atlantic and Gulf of Mexico, principally by the U.S., for tunas and swordfish. These fisheries surely take substantial numbers of billfishes. Finally, artisanal fisheries in tropical areas, from which we have little information, likely also take signficant numbers of billfishes.

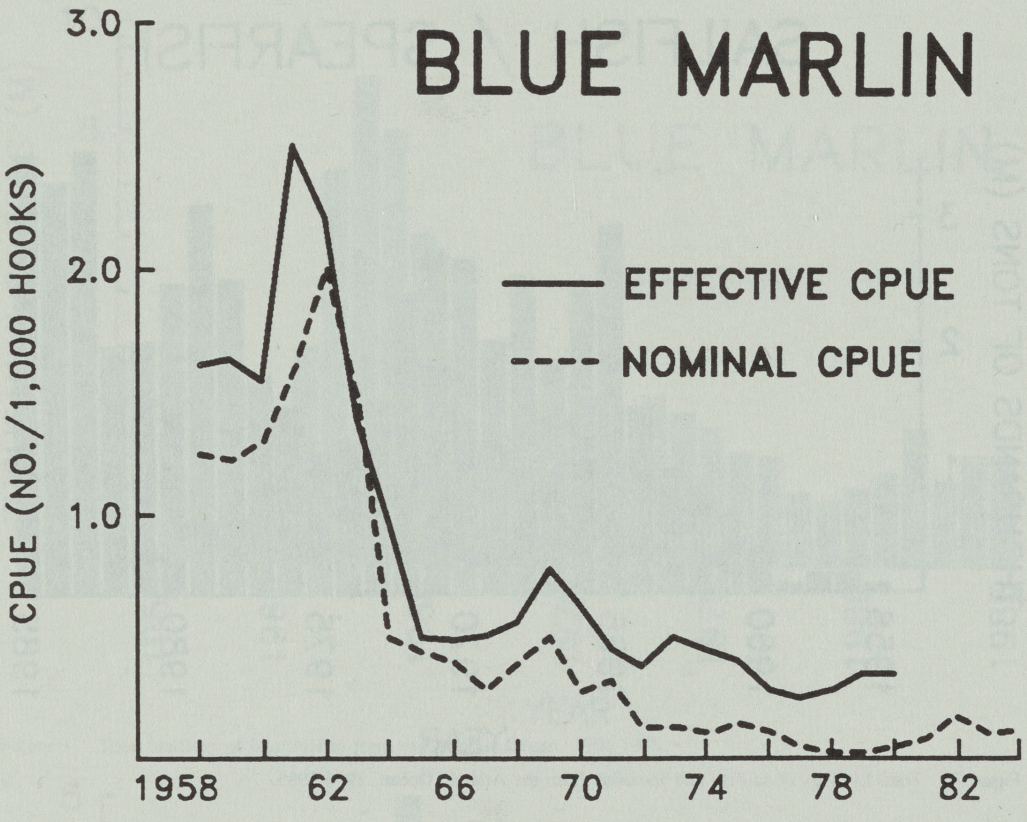

Figure 8. Effective and nominal catch-per-unit-effort for blue marlin from the Japanese tuna longline fishery, 1954-1984.

It is a vast, complicated, and extremely important fishery and warrants a significant commitment of our research resources to determine the basic dynamics of the stocks and their reaction to, and their ability to sustain, fishing pressures.

Grant L. Beardsley received his BA degree from Davidson College, NC, and his MS and PhD degrees in fisheries biology from the University of Miami. He has specialized in research on the biology and stock dynamics of Atlantic billfishes and tunas for over 20 years. Currently, he is the senior scientist for recreational fisheries at the NMFS Southeast Fisheries Center in Miami.

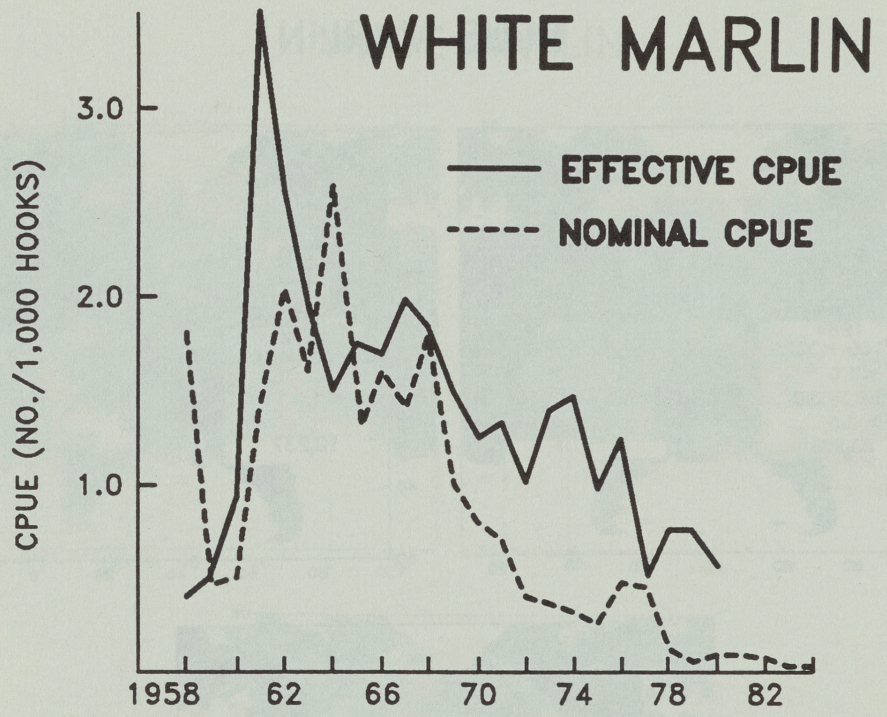

Figure 9. Effective and nominal catch-per-unit-effort for white marlin from the Japanese tuna longline fishery, 1958-1984.

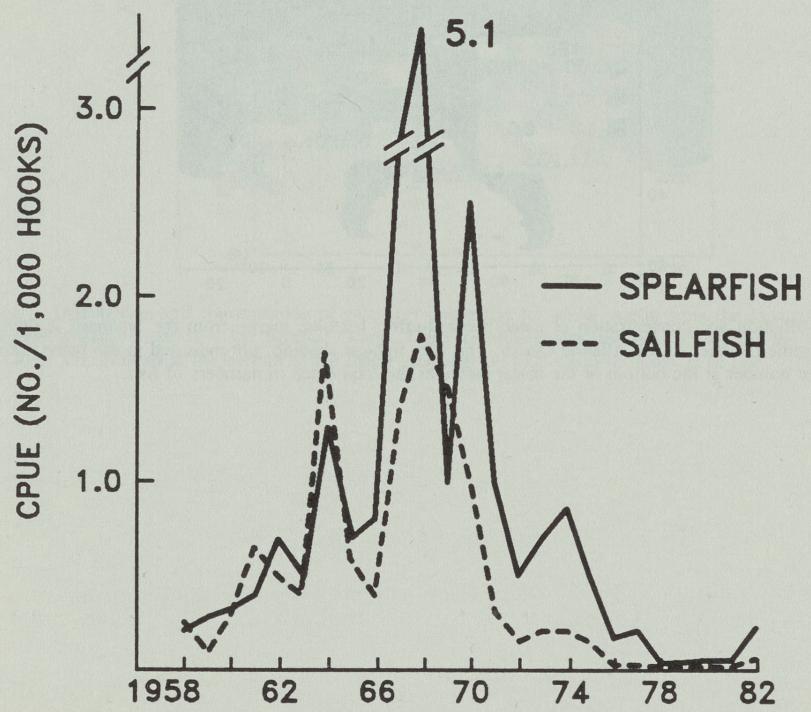

Figure 10. Nominal catch-per-unit-effort for sailfish and spearfish from the Japanese tuna longline fishery, 1958-1984.

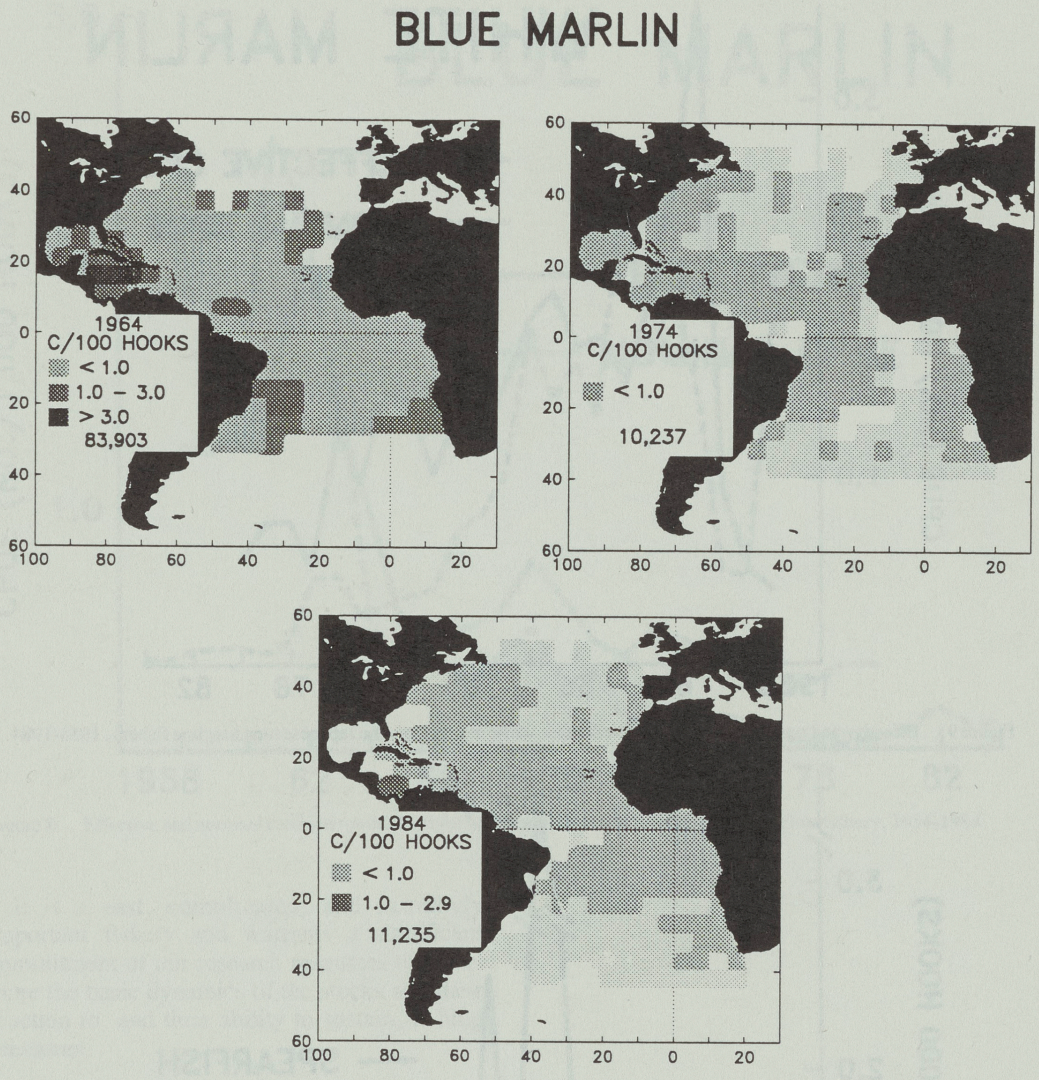

Figure 11. Distribution and concentration of catch-per-unit-effort for blue marlin from the Japanese, Taiwanese, and Korean tuna longline fisheries in the Atlantic Ocean. The very lightest shading, not indicated in the insert, shows effort but no catch. The number at the bottom of the insert indicates the total catch in numbers of fish.

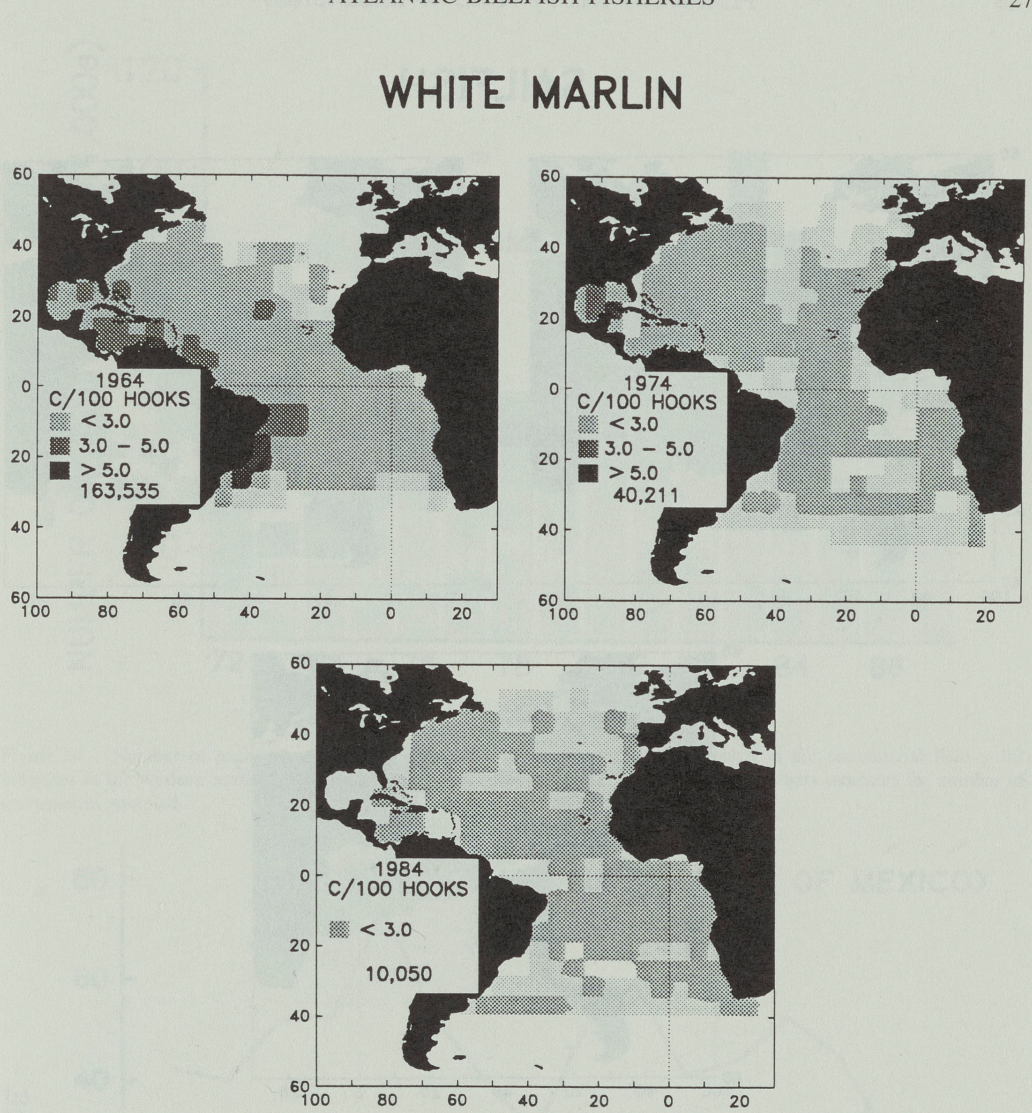

Figure 12. Distribution and concentration of catch-per-unit-effort for white marlin from the Japanese, Taiwanese, and Korean tuna longline fisheries in the Atlantic Ocean. The very lightest shading, not indicated in the insert, shows effort but no catch. The number at the bottom of the insert indicates the total catch in numbers of fish.

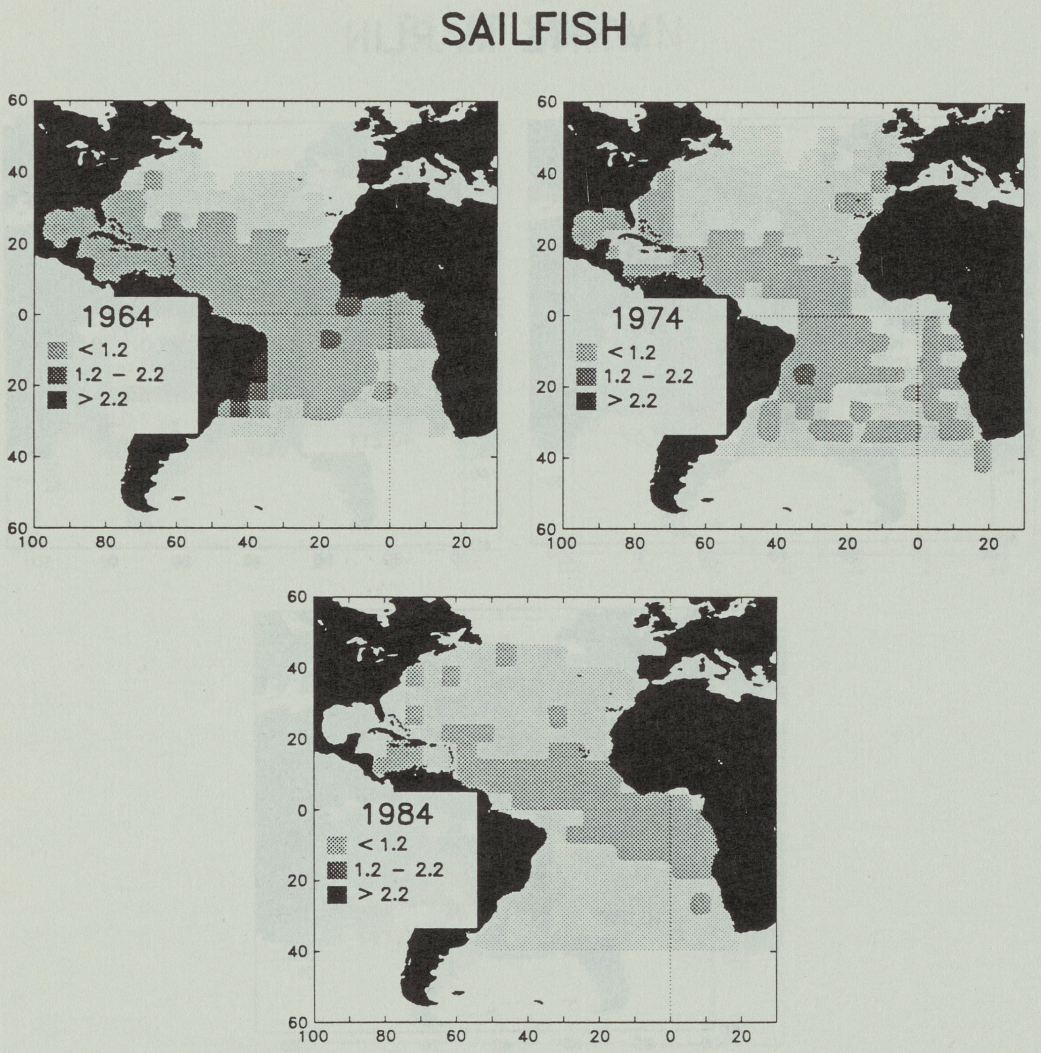

Figure 13. Distribution and concentration of catch-per-unit-effort for sailfish from the Japanese, Taiwanese, and Korean tuna longline fisheries in the Atlantic Ocean. The very lightest shading, not indicated in the insert, shows effort but no catch.

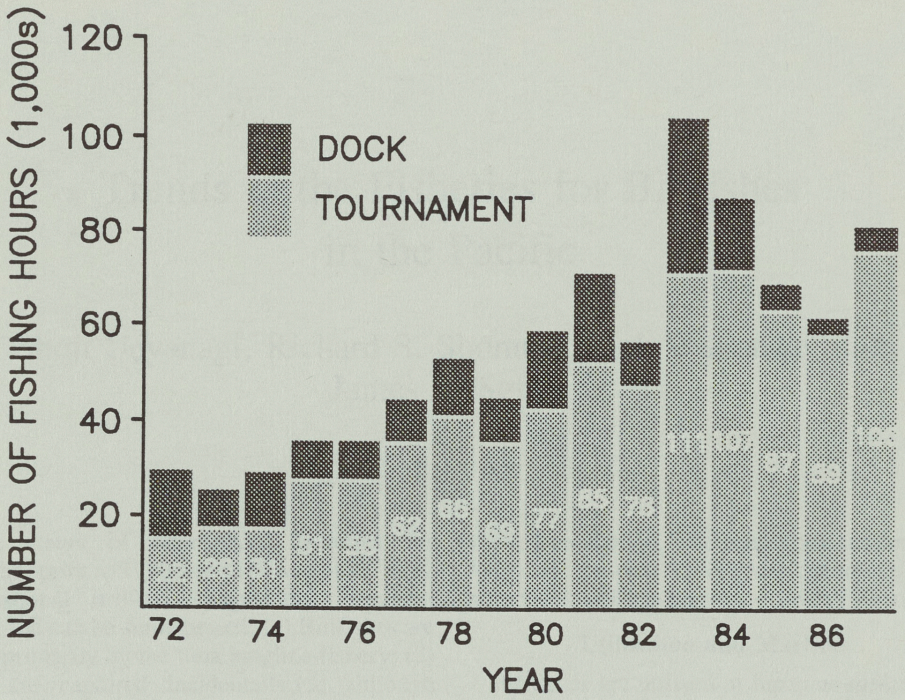

Figure 14. Number of tournament and non-tournament (dock) fishing hours sampled in the recreational fishery for billfishes in the western north Atlantic Ocean from 1972 through 1987. The number in the bars indicates the number of tournaments sampled.

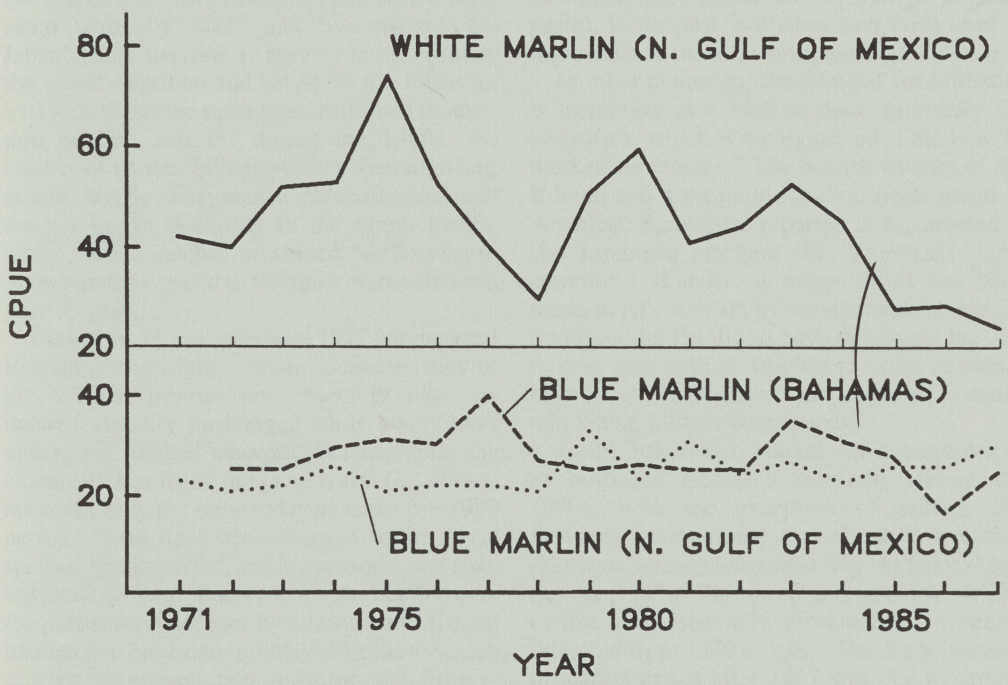

Figure 15. Catch-per-unit-effort in numbers of blue marlin and white marlin hooked per thousand fishing hours in the recreational fishery at specified areas in the western north Atlantic Ocean, 1971-1987.



Trends in the Fisheries for Billfishes in the Pacific

Shoji Ueyanagi, Richard S. Shomura, Yoh Watanabe, and James L. Squire

The status of commercial fisheries for billfishes prior to 1970 was reviewed at the 1972 International Billfish Symposium (Ueyanagi 1974) and can be summarized: (1) Billfishes are taken primarily by the tuna longline fishery; (2) most are captured incidentally;(3) although billfish catches may be incidental to the tunas, they are nevertheless regarded highly in Japan with some species commanding high prices in the markets as *sashimi* (sliced raw fish usually eaten with soy sauce and horseradish); (4) Japan's tuna longline fishery covered virtually the entire distributional range of the billfishes by 1965, about the same time its billfish production peaked; and (5) during the 1960s, the catches of various billfish species were high but, around 1963, blue marlin *(Makaira mazara)* catches began declining in the South Pacific region, while catches of striped marlin *(Tetrapturus audax)* tended to fluctuate markedly from year to year.

During the 16 years since the 1972 International Billfish Symposium, certain characteristics of the billfish fisheries and resources have remained virtually unchanged while others have undergone marked changes. For example, the characteristics listed in (1), (2), and (3), above, are essentially the same today as in the pre-1970 period. There have been changes in the target species, fishing areas, fishing seasons, and fishing methods (e.g., fishing at greater depths) over the past several decades by distant-water fishing nations that have undoubtedly affected the catch and species composition in the longline fishery. Thus, interpretation of the billfish resources based on nominal catch-and-effort data must be viewed cautiously. The present discussion will focus on the post-1970 years, although some references will be made to the pre-1970 period.

Utilization and Markets

Billfishes are utilized in Japan as *sashimi,* as an ingredient for *sushi,* or sold as *kirimi* (fillet) to be broiled or baked. They are also processed into *kasuzuke* (fish preserved in *sake* lees) or *misozuke* (fish preserved in *miso,* a soybean paste). In the past, billfishes have been used as ingredients in manufacturing sausage and ham.

In other countries, the demand for billfishes is increasing as a food product, especially for swordfish, which is highly prized in the U.S.A. markets as "steaks." The billfish catches of the Korean and Taiwanese longline fleets based in American Samoa are reported to be directed at the Japanese markets (G. Yamasaki pers. commun.). Finally, a major effort has been made in recent years by recreational fishing interests in the Pacific to have fishermen tag and release their billfish catches in order to obtain information on migration pathways and to maintain viable billfish populations.

At the Tokyo Fish Market, the average prices of billfishes increased markedly during the 1970s, with the exception of sailfish *(Istiophorus platypterus)* and shortbill spearfish *(Tetrapturus angustirostris);* Fig. 1 (Tokyo Metropolis 1987). The price increase for striped marlin was especially pronounced — nearly threefold from 1970 to 1985. The sharp increase in market prices after 1967 was due to certain technological developments in the Japanese tuna longline fishery. In a quest for southern bluefin

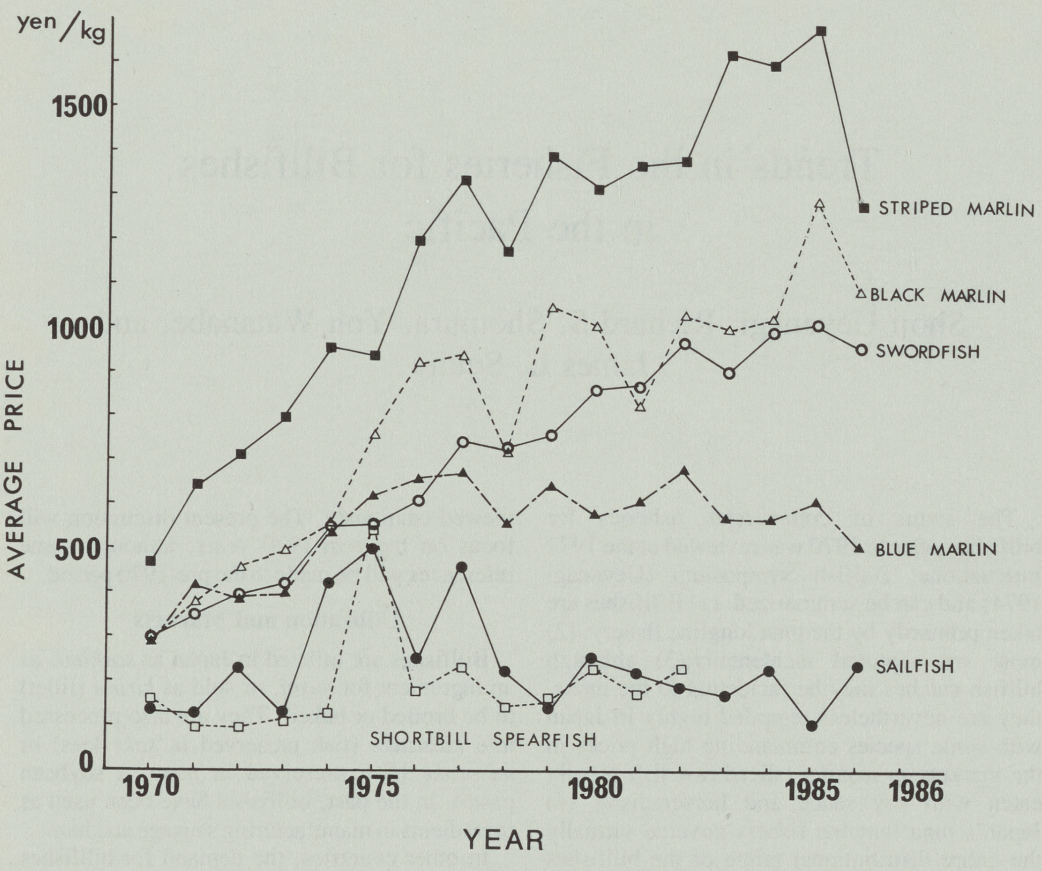

Figure 1. Average prices of billfishes (fresh) at the Tokyo Fish Market, 1970-1986.

tuna *(Thunnus maccoyii),* the Japanese longline began outfitting their vessels with freezers capable of quick-freezing fish to ‹-55°C. The frozen fish were then maintained in fishholds at ‹-40°C. Billfishes brought back to Japan under such refrigerated conditions were in great demand in the *sashimi* market; this was especially true for striped marlin. The rate of increase in prices slowed around 1977; prices remained relatively stable in the early 1980s.

Review of the Fisheries

Trends in Catch

Based on total landings, catches of striped marlin were low [7,000 to 9,000 metric tons (mt)] in 1955-1960, high (ca. 23,000 mt) in 1964-1971, and then relatively low (10,000 to 15,000 mt) in 1972-1985 (Fig. 2A). A more detailed examination of the available data is required to determine whether the post-1972 decline in striped marlin catches reflects a true reduction in abundance or results from a change in fishing strategy (e.g., use of deeper fishing longline gear).

Catches of black marlin, *Makaira indica* (Fig. 2A), and blue marlin (Fig. 2B) declined as well. Black marlin catches were 5,000 to 6,000 mt annually from 1955 to 1958, then slowly declined to around 3,000 mt in 1985. Except for a notable peak in 1961-1963, blue marlin catches fluctuated between 12,000 and 19,000 mt since 1964.

The combined annual catch of sailfish and shortbill spearfish was 3,000 mt in the 1950s (Fig. 2B). The catch increased to nearly 13,000 mt in 1965, remained at that level until 1969, then steadily declined to 3,100 mt in 1985. The 1976-1978 catch of sailfish and spearfish is not included in Figure 2B because the data are questionable.

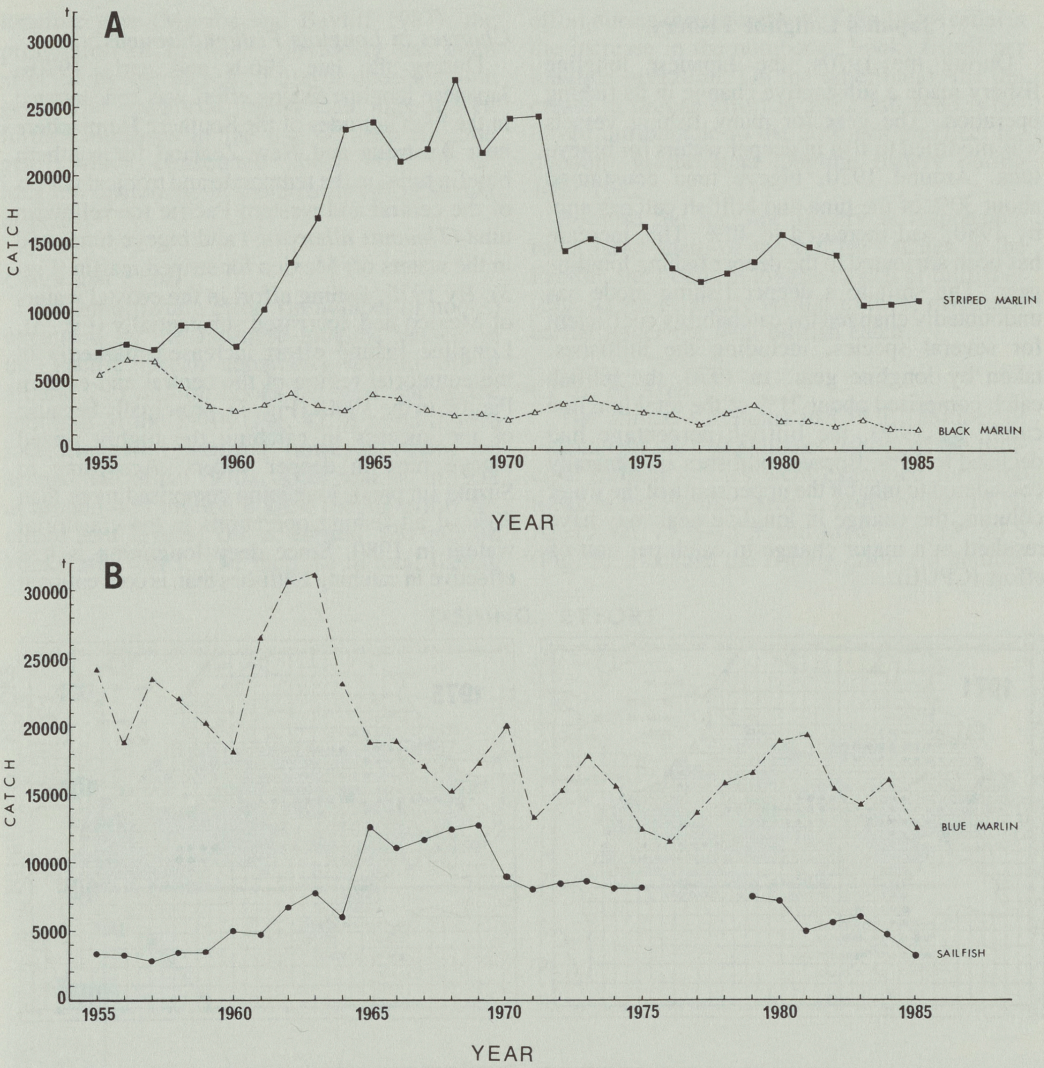

Figure 2. Annual catch of billfishes in the Pacific Ocean, 1955-1985: (A) striped marlin and black marlin;(B) blue marlin and combined catches of sailfish and shortbill spearfish. Data are from Shomura (1980) and the FAO (1976, 1979, 1984, 1987).

Trends in the Longline Fishery

The commercial catch of billfishes by the longline fishery, which primarily targets various tuna species, increased as the fishing grounds expanded. Since the 1960s, most of the catch has been made by the longline fishery. The expansion of the longline fishery has been described by Ueyanagi (op. cit.). The Japanese longline fishery in the Pacific gradually began expanding eastward in the early 1950s. By 1965, the fishery had extended throughout the tropical and subtropical waters of the Pacific and, thus, covered virtually the entire distributional range of the various billfish species. The habitats of the billfishes caught by longline ranged from temperate to tropical waters and from coastal to offshore waters. During the late 1960s and early 1970s, the Japanese longline fleet began focusing on the southern bluefin tuna and bigeye tuna *(Thunnus obesus);* thus, the Japanese fleet's effort in the subtropical zones was reduced. The longline fleets of Korea and Taiwan, however, filled that void in the South Pacific (Ito and Yamasaki in press).

Japan's Longline Fishery

During the 1970s, the Japanese longline fishery made a substantive change in its fishing operation. The gear for many fishing vessels was modified to fish in deeper waters for bigeye tuna. Around 1970, bigeye tuna constituted about 30% of the tuna and billfish catches and, by 1980, had increased to 40%. This increase has been attributed to the deeper fishing longline gear. The shift to a deeper fishing mode has undoubtedly changed the catchability coefficient for several species, including the billfishes, taken by longline gear. In 1970, the billfish catch comprised about 21% of the total longline catch; by 1980, the billfish percentage had declined to 13%. Because billfishes are generally considered to inhabit the upper strata of the water column, the change in longline gear may have resulted in a major change in catch per unit of effort (CPUE).

Changes in Longline Fishing Grounds

During the late 1960s and early 1970s, Japanese longline fishing effort was concentrated in the high latitudes of the Southern Hemisphere near Australia and New Zealand for southern bluefin tuna, in the temperate and tropical waters of the central and western Pacific for yellowfin tuna *(Thunnus albacares)* and bigeye tuna, and in the waters off Mexico for striped marlin (Fig. 3). By 1975, fishing effort in the coastal waters of Mexico had decreased substantially (Fig. 3). Longline fishing effort increased markedly in the equatorial region of the central and eastern Pacific in the 1980s (Fig. 3), principally because of the success in catching the highly prized bigeye tuna in deeper waters. According to Suzuki (in pres), longlining comprised more than 50% of all fishing operations in the equatorial waters in 1980. Since deep longlining is less effective in catching billfishes than is conventional

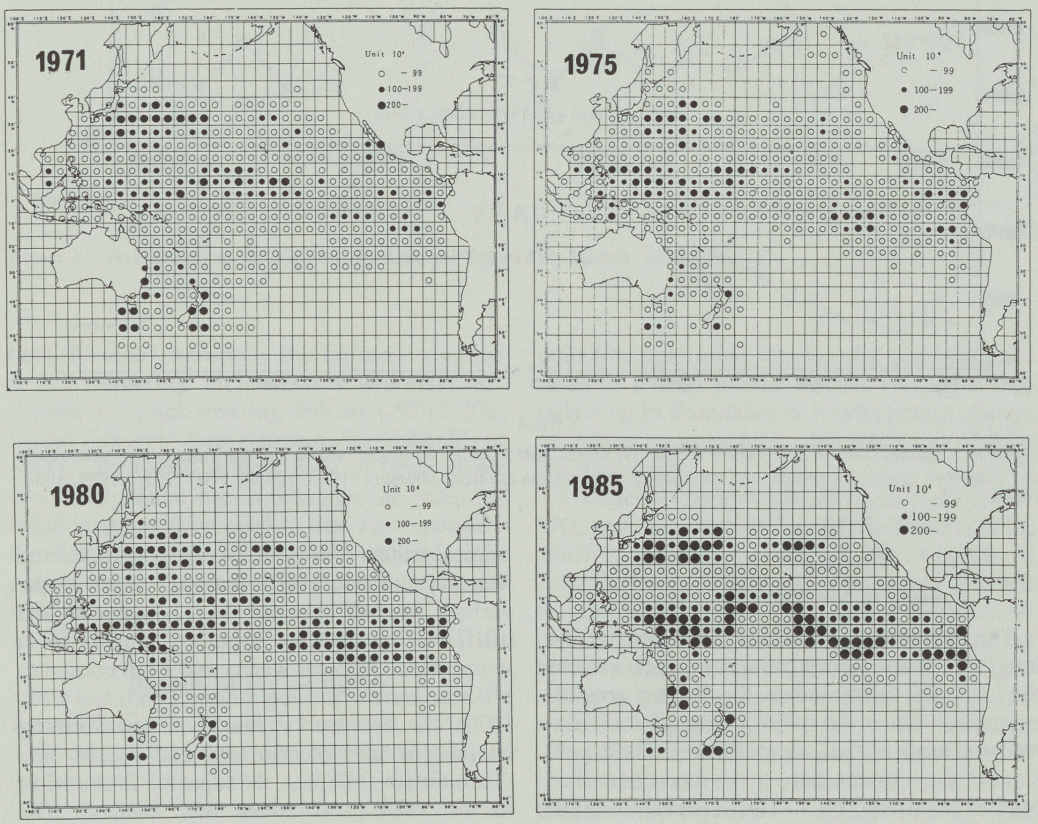

Figure 3. Comparisons of the distribution of estimated total fishing effort (in number of hooks) expended by the Japanese tuna longline fishery for 1971, 1975, 1980, and 1985 (from the Fisheries Agency of Japan 1973, 1977, 1982, unpub. data).

longline gear (Miyabe and Bayliff 1987), the production of billfishes obviously has been affected by the increased use of deep longline gear. The equatorial region later experienced further increases in the use of deep longline gear, which constituted about 90% of all longline operations in the area in 1985 (Suzuki in press).

Catch and Effort

The total fishing effort (in number of hooks) expended by the Japanese longline vessels in the Pacific Ocean apparently leveled off at around 280 million hooks per year during the first half of the 1970s (Fig. 4). A trend toward increased effort occurred, however, during the second half of the 1970s. After peaking in 1981 at around 400 million hooks, fishing effort declined and leveled off at around 330 million hooks after 1983. The increase in total fishing effort during the second half of the 1970s reflects the increase in the number of hooks fished per longline operation. On the other hand, the decrease in fishing effort in 1982 and 1983 is believed attributable to the 20% *gensen* (fleet reduction) in the tuna longline fishery during 1981-1982.

Because the longline fishery is responsible for a large share of the billfish catches in the Pacific, the trends in longline catch of billfishes (Fig. 4) are generally similar to those discussed earlier under the total billfish catch.

CPUE by Area

The annual variations in CPUE (number of fish caught per 1,000 hooks fished) of the principal billfish species were examined for three areas in the Pacific: Area 1, north of lat. 15°N; Area 2, lat. 15°N-15°S; and Area 3, lat. 15°-30°S (Fig. 5). Because the fishing effort (in number

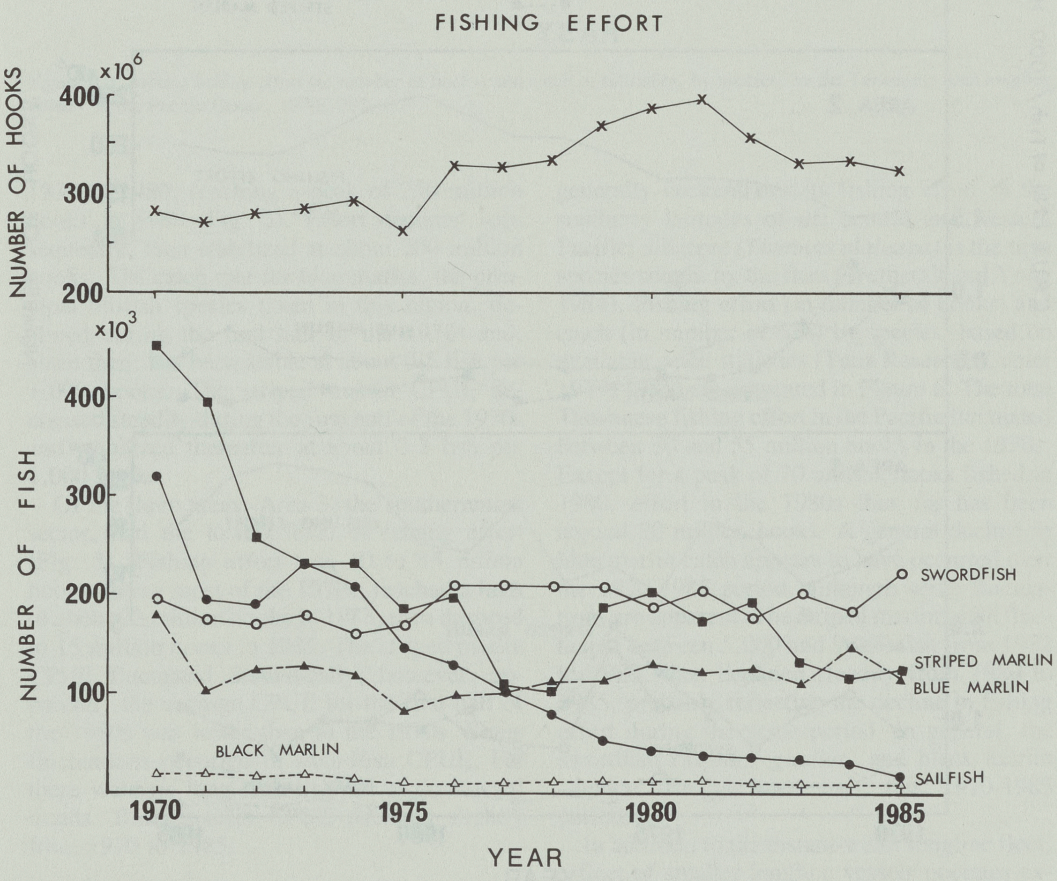

Figure 4. Annual fishing effort (in number of hooks) and catch of billfishes by the Japanese tuna longline fishery in the Pacific Ocean, 1970-1985.

of hooks) used to obtain CPUE is nominal, unstandardized effort, the CPUE values are not intended to reflect accurately the absolute resource levels, and interpretations based on these statistics should be viewed with caution.

In Area 1, fishing effort initially decreased during 1970 to 1975, thereafter stabilizing at 80 to 100 million hooks (Fig. 5). The CPUE for striped marlin decreased markedly and, by 1975, was only one-half that in 1970; thereafter, the CPUE fluctuated between 0.5 and 1.0 fish per 1,000 hooks. Swordfish CPUE was generally stable at around 1.0 fish per 1,000 hooks. In Area 2, fishing effort increased steadily from

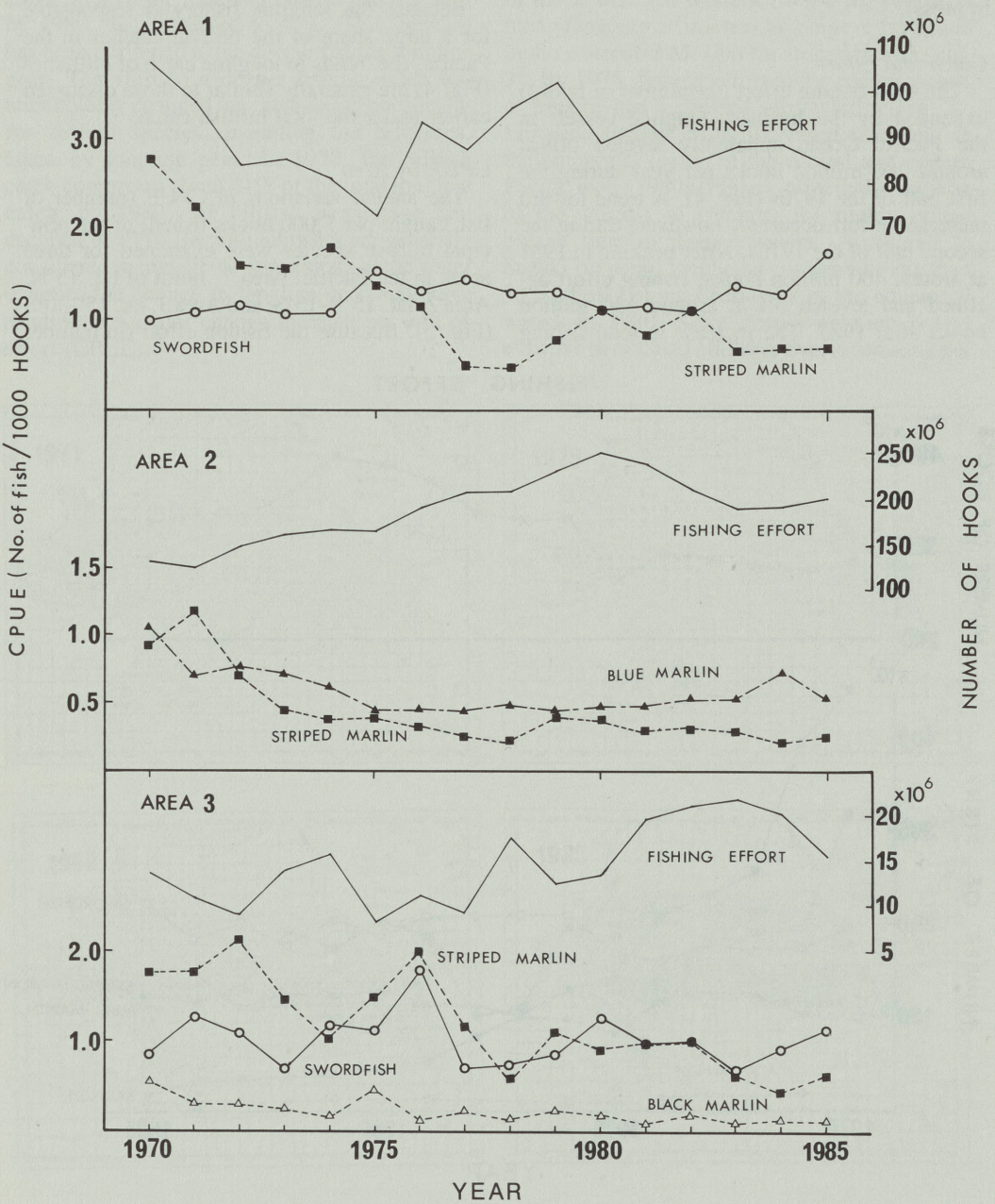

Figure 5. Annual fishing effort and catch per unit effort for principal billfish species by area, 1970-1985: Area 1, north of lat. 15°N; Area 2, lat. 15°N-15°S; and Area 3, lat. 15°-30°S.

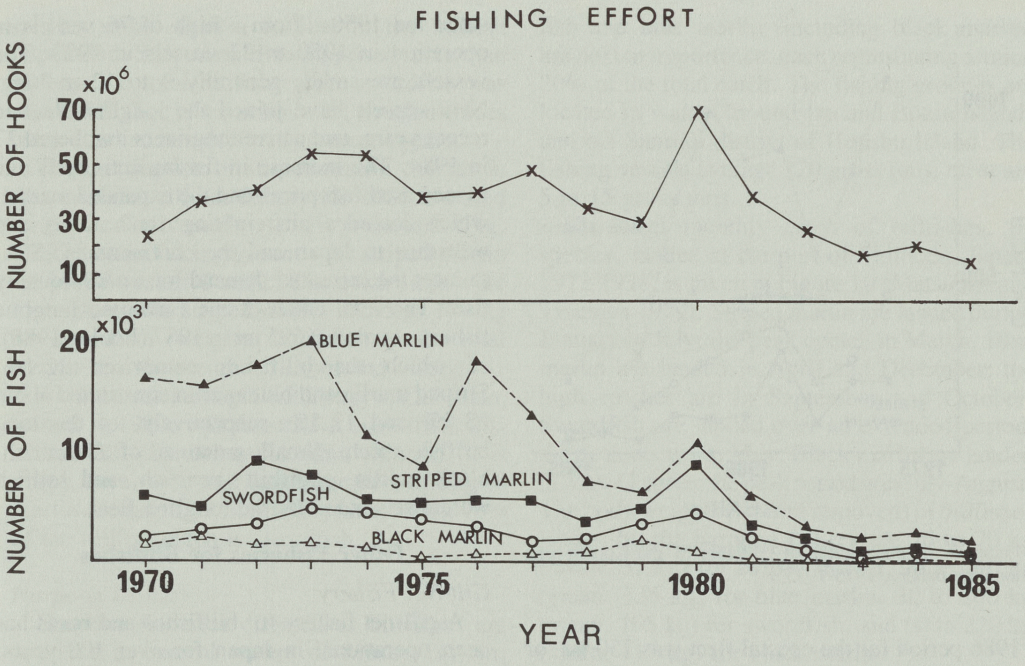

Figure 6. Annual fishing effort (in number of hooks) and catch of billfishes, by species, by the Taiwanese tuna longline fishery in the Pacific Ocean, 1970-1985.

1970 to 1980, reaching a peak of 250 million hooks in 1980 (Fig. 5). Effort declined subsequently, then stabilized at about 200 million hooks. The catch rate for blue marlin, the principal billfish species taken in this region, declined during the first half of the 1970s and, since then, has been stable at about 0.5 fish per 1,000 hooks. The striped marlin CPUE decreased steadily during the first half of the 1970s and stabilized thereafter at about 0.3 fish per 1,000 hooks.

Of the three areas, Area 3, the southernmost sector, had the lowest level of fishing effort (Fig. 5). Fishing effort was 10 to 15 milion hooks during most of the 1970s, reached a high of about 22 million hooks in 1983, then dropped to 15 million hooks in 1985. The striped marlin CPUE fluctuated dramatically; however, apparently the average CPUE for the first half of the 1980s was lower than in the 1970s. Some fluctuations occurred in swordfish CPUE, but there were no long-term upward or downward trends. Black marlin CPUE declined slightly from 1970 to 1985.

Taiwan's Longline Fishery

The Taiwanese distant-water longline fleet generally concentrates its fishing effort in the southerly latitudes of the central and western Pacific; albacore *(Thunnus alalunga)* is the tuna species sought by the fleet (Wetherall and Yong 1984). Fishing effort (in number of hooks) and catch (in number of fish) by species, based on available catch statistics (Tuna Research Center 1979, 1986) are presented in Figure 6. The total Taiwanese fishing effort in the Pacific fluctuated between 30 and 55 million hooks in the 1970s. Except for a peak of 70 million hooks fished in 1980, effort in the 1980s thus far has been around 20 million hooks. A general decline in blue marlin catch appears to have occurred over the 1970-1985 period, although some fluctuations are apparent. The striped marlin catch fluctuated between 5,000 and 9,000 fish from 1972 to 1980, then declined steadily from 1980 to 1985, probably reflecting the decline in fishing effort during the same period. In general, the swordfish *(Xiphias gladius)* and black marlin catches also declined over this 1970-1985 period.

In addition to the distant-water longline fleet, a fleet of smaller longline vessels operates exclusively in the coastal waters of Taiwan. The average annual catch by species for the 1975-

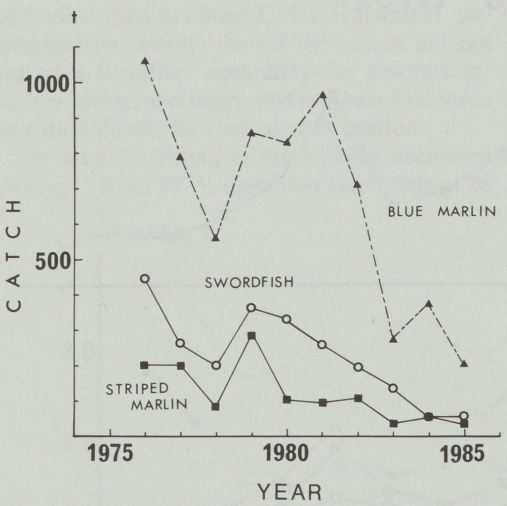

Figure 7. Annual catch of billfishes by the Korean tuna longline fishery, 1975-1985.

1986 period for the coastal fleet was 750 mt for striped marlin, 1,700 mt for blue marlin, 900 mt for black marlin, and 1,300 mt for sailfish (G. Sakagawa pers. comun.).

Korea's Longline Fishery

In general, the Korean longline fleet has operated throughout the tropical and subtropical Pacific. Effort was generally directed toward the yellowfin and bigeye tunas; thus, the Korean fleet tended to operate in more tropical waters than the Taiwanese longline fleet. Based on available statistics (Fisheries Research and Development Agency 1980, 1981, 1985), total fishing effort (in number of hooks) expended by the Korean longline fleet in the Pacific fluctuated between 60 million and 100 million hooks from 1975 to 1980. The annual catch of billfishes, by weight and by species, for 1976-1980, based on FAO (1979, 1984, 1987) statistics, is shown in Figure 7. The blue marlin catch declined markedly: from >1,000 mt in 1976 to about 200 mt in 1985. Striped marlin and swordfish catches also declined from 1976 to 1985.

Other Longline Fishing Effort

In addition to the large longline fleets of Japan, Korea, and Taiwan, other longline operations include a small fishery based in Hawaii, one longliner based in American Samoa, one longliner in Tonga, and a fleet in Indonesia. Hawaii's longline fleet has declined in numbers since the 1950s, from a high of 76 vessels in operation in 1950 to 22 vessels in 1980. The vessels are small, generally 9 to 12 m long. New vessels have joined the longline fleet in recent years, and active longliners numbered 37 in 1984. The increase in fishing activity is due to increased fish prices and the expanded market, which includes airfreighting fresh tunas and billfishes to Japan and the continental U.S.A. to meet the increased demand for *sashimi*-quality fish. The total catch of the Hawaiian longline fishery equaled 1,695 mt in 1987 (Pooley 1988), of which the billfishes comprised 22.1%. Striped marlin and blue marlin constituted about 68.9% and 12.5%, respectively, of the total billfish catch. Small amounts of swordfish, black marlin, shortbill spearfish, and sailfish were also landed by the longline fleet.

Other Fisheries for Billfishes

Gill-Net Fishery

A gill-net fishery for billfishes and tunas has been operational in Japan for over 100 years. During the early years, fishing was confined to coastal waters. Since the 1970s, however, the fishery has expanded offshore as a result of the development of the ome ami (drift gill-net) gear and a shift in target species. The principal fishing areas of the ome ami fishery during the first half of the 1970s were the waters off the Sanriku district of Honshu Island, off Boso Peninsula, the South China Sea, and the Yellow Sea. In the ome ami gill-net fishery, a standard operation uses 12 km of net (17 to 18 cm mesh size). Using netting of >12 km per operation and mesh sizes of <15 cm by Japanese flag vessels is prohibited by regulations imposed by the government. Fishing vessels are 50 to 500 gross tons (usually, 90 to 100 gross tons). The vessels are used in other fisheries (e.g., salmon drift gill net, squid gill net, saury stick-held dip net, tuna longline, and squid jigging.

The gill-net fishery's catches of billfishes, tunas, and other species from 1970 to 1986 are listed in Table 1. The total billfish catch from 1973 to 1986 fluctuated between 3,600 and 10,200 mt. Some fluctuations have been attributed to changes in target species and in the number of vessels operating in the fishery. During the early 1970s, billfishes were the target species by the gill-net fishery; however, since the early 1980s, there has been a shift to target the tunas, especially albacore. Thus, the decline in the billfish catch may reflect the shift in target

species rather than a decline in the billfish population. Striped marlin comprised more than 50% of the total billfish catch; swordfish was about 25%. The blue marlin catch, which includes black marlin, has declined in recent years.

The distribution of striped marlin catches in the ome ami gill-net fishery for 1985 is based on catches by vessels over 10 gross tons (Fig. 8). The main fishing grounds for striped marlin are in the western Pacific. The catch sizes were 15 to 90 kg for striped marlin and 5 to 170 kg for swordfish (weights are based on the total weight less the weight of snout and viscera).

A commercial drift gill-net fishery in California, started in 1980, was directed at swordfish, discussed fully by Sakagawa (this volume). It is noted, here, only that small numbers of striped marlin are taken in this fishery; more than 90% of the billfish catch is swordfish.

Harpoon Fishery

Harpoon fisheries directed at billfishes are operated in coastal waters of Japan, Taiwan, and California. The annual billfish catch by the Japanese harpoon fishery, 1959-1971, fluctuated between 2,200 and 4,600 mt. It declined markedly after 1972, then has been stable at a level of less than 1,200 mt (Fig. 9). The average catch over the last 10 years was around 800 mt. Striped marlin are the main target of this fishery, making up about 50% of the total billfish catch. Swordfish and blue marlin (including black marlin) are next in importance, each representing around 20% of the total catch. The fishing grounds are located in waters around Izu and Bonin Islands and off Sanriku district of Honshu Island. The fishing vessels average <20 gross tons; most are 5 to 15 gross tons.

The total monthly catch of billfishes, by species, landed at the port of Shimoda, Japan, 1972-1978, is given in Figure 10 (Matsuoka and Tsuchiya 1979). Striped marlin are landed during January to July; the peak occurs in March. Blue marlin are landed in April and December; the high catches are in September and October. Swordfish are landed over an extended period; the peak occurs in May. Black marlin are landed in May-October; the peak period is in July-August. The body weights (viscera removed) of billfishes landed by the harpoon fishery are 20 to 70 kg (mean, 55 kg) for striped marlin, 90 to 260 kg (mean, 135 kg) for blue marlin, 30 to 200 kg (mean, 105 kg) for swordfish, and 60 to 220 kg (mean, 117 kg) for black marlin.

The average annual catch of the Taiwanese harpoon fishery for billfishes, during the period 1975-1986, was 130 mt for striped marlin and around 500 mt each for blue marlin, black marlin, and sailfish (G. Sakagawa pers. commun.).

A commercial harpoon fishery directed toward swordfish has operated in California waters since about 1913. Striped marlin can be taken

Table 1. Catch statistics of the Japanese gill-net fishery[1], 1970-1986.

Year	Striped marlin	Swordfish	Blue marlin[2]	Sailfish	Subtotal	Tunas	Skipjack tuna and frigate mackerel	Total[3]
1970	3	—	—	126	129	44	169	328,687
1971	10	1	—	54	65	32	146	347,611
1972	243	55	8	55	361	135	626	296,867
1973	3,265	720	268	98	4,351	348	548	311,628
1974	3,112	1,304	230	83	4,729	614	350	325,539
1975	6,534	2,672	795	149	10,150	951	507	295,050
1976	3,561	3,488	580	117	7,746	2,403	920	295,270
1977	4,424	2,344	998	398	8,164	1,599	1,864	322,777
1978	5,593	2,475	884	343	9,295	6,393	2,078	306,326
1979	2,532	983	513	347	4,375	4,464	1,012	301,484
1980	3,467	1,746	868	137	6,218	4,728	1,134	296,929
1981	3,866	1,848	1,165	362	7,241	12,749	2,571	327,649
1982	2,351	1,257	954	333	4,895	14,292	4,314	350,631
1983	1,845	962	931	276	4,014	6,611	3,933	291,950
1984	2,257	971	240	110	3,578	8,045	5,110	362,607
1985	2,323	1,026	401	146	3,896	10,599	2,471	376,129
1986	3,536	1,170	176	233	5,115	8,012	6,344	351,888

[1]including ome ami gill-net, spanish mackerel gill-net, flying fish gill-net, saury gill-net, herring gill-net, etc.
[2]including black marlin
[3]including other fishes (sharks, cods, atka mackerel, flat fishes, spanish mackerel, etc.)

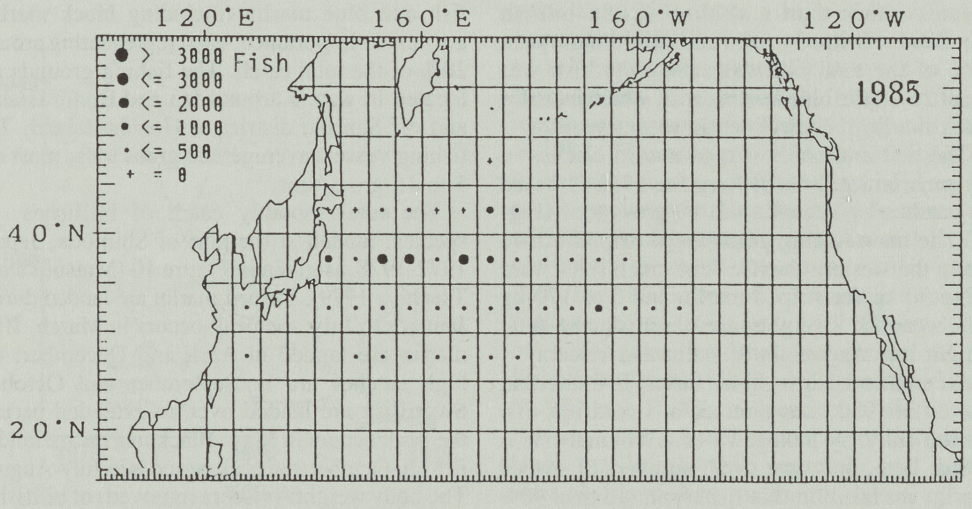

Figure 8. Distribution of striped marlin catch of the Japanese gill-net fishery for 1985.

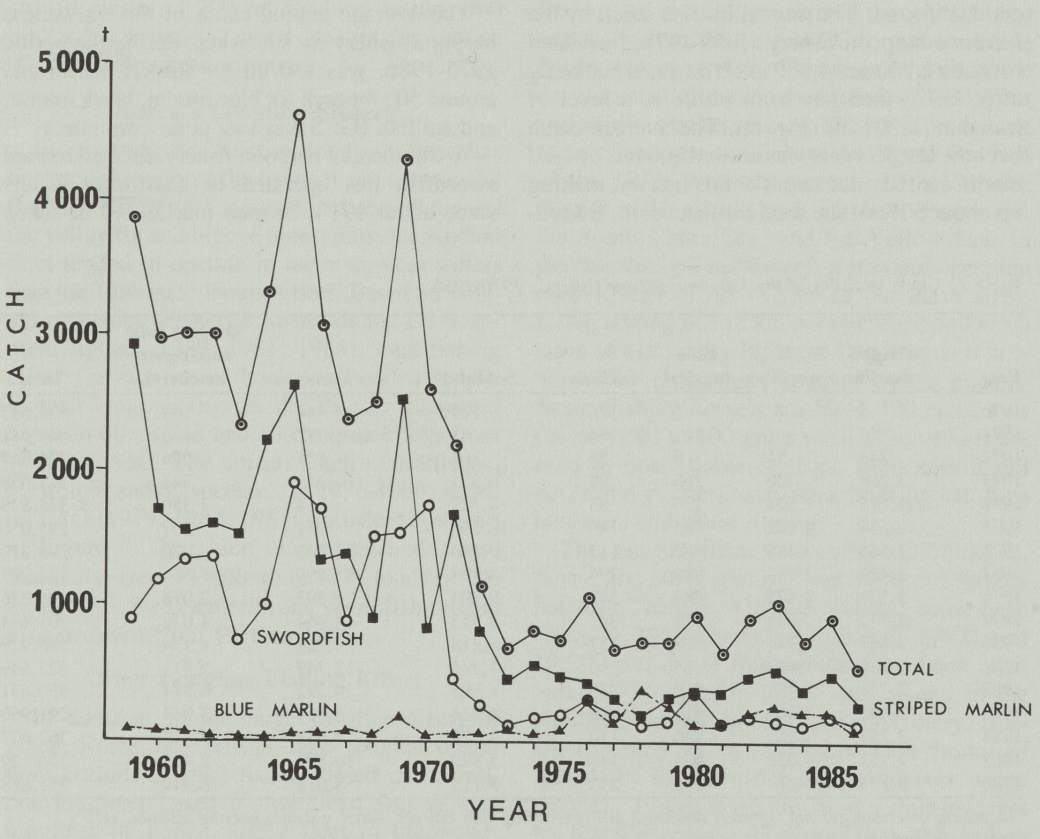

Figure 9. Total annual catch of billfishes landed by the Japanese harpoon fishery, 1959-1985.

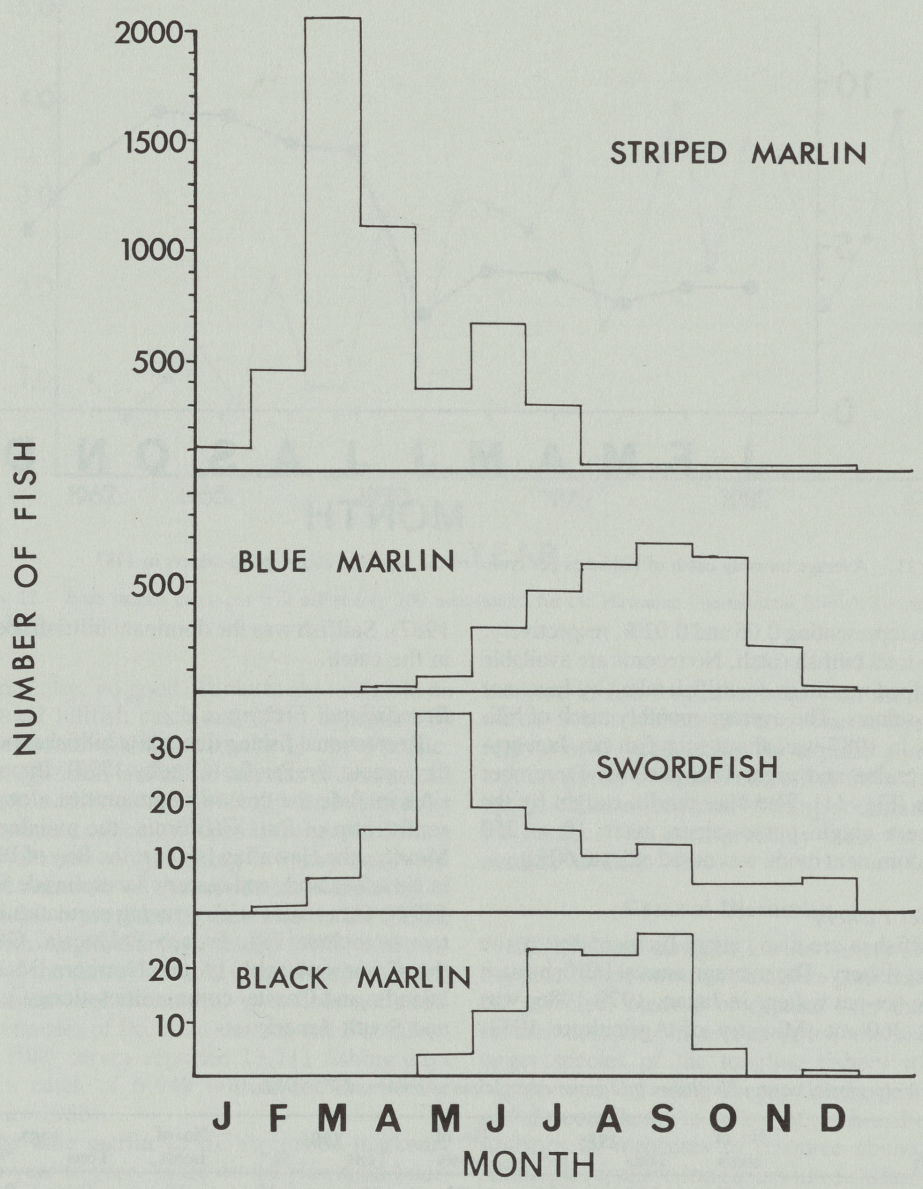

Figure 10. Monthly total catch of billfishes, by species caught by the Japanese harpoon fishery and landed at Shimoda, 1972-1978. Data are from Matsuoka and Tsuchiya (1979).

in this fishery, but the sale of this species is prohibited by the State of California. Thus, there are presently no reported landings of striped marlin (Anonymous 1979).

Purse-Seine Fishery

The incidental catch of billfishes by Japanese single purse-seiners operating in the tropical waters of the western Pacific from 1985 to 1987 is shown in Table 2. The billfishes made up only 0.1% of the total purse-seine catch. Blue marlin were the dominant species caught by the purse-seiners; they represented 99.3% of the total billfish species taken, sailfish and black

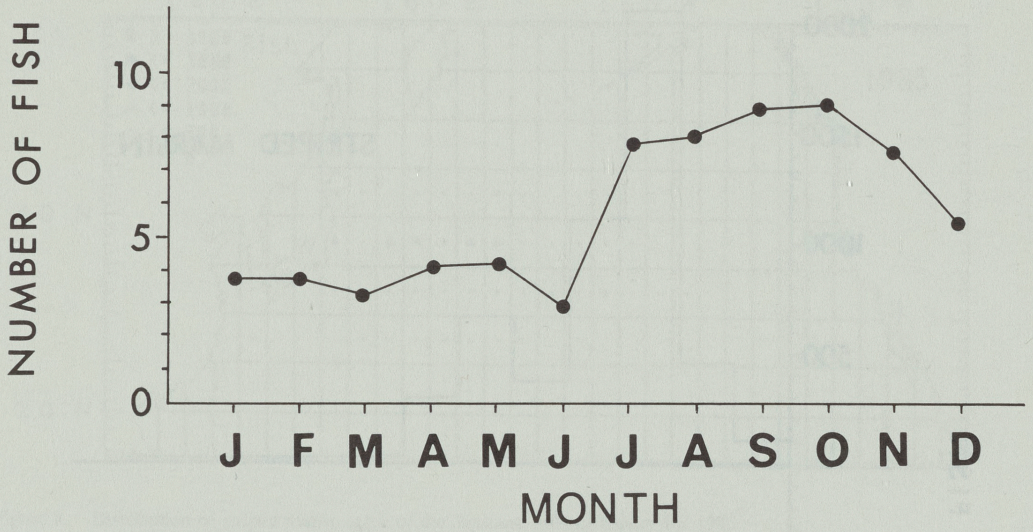

Figure 11. Average monthly catch of billfishes per cruise of the Japanese single purse-seiners in 1987.

marlin representing 0.05 and 0.02%, respectively, of the total billfish catch. No records are available on striped marlin or swordfish taken by Japanese purse-seiners. The average monthly catch of billfishes in 1987 was about four fish per January-June cruise and eight fish per July-December cruise (Fig. 11). The blue marlin caught by the Japanese single purse-seiners were 10 to 250 kg; a dominant mode was noted at 50 to 60 kg.

Set Net Fishery

Billfishes are also caught incidentally by the set-net fishery. The average annual billfish catch by the set-net fishery in Japan, 1970-1986, was about 360 mt (Ministry of Agriculture 1982, 1987). Sailfish was the dominant billfish species in the catch.

Recreational Fishing

Recreational fishing directed at billfishes occurs throughout the Pacific (Goadby 1970). Important sites include the coastal communities along the southerntip of Baja California, the mainland of Mexico, the Hawaiian Islands, the Bay of Plenty in New Zealand, and eastern Australia (de Sylva 1974). Other sites with growing recreational interests include Fiji, French Polynesia, Guam, the Commonwealth of the Northern Mariana Islands, and Coastal communities along Central and South America.

Table 2. Incidental catch of billfishes by Japanese single purse-seiners, 1985-1987.

Month	1985 No. of boats	1985 Tons	1985 %*	1986 No. of boats	1986 Tons	1986 %*	1987 No. of boats	1987 Tons	1987 %*
January	18	14.1	0.14	23	11.7	0.10	18	9.1	0.10
February	20	12.9	0.12	19	6.5	0.06	18	10.3	0.11
March	18	12.1	0.13	29	9.1	0.06	22	8.2	0.07
April	21	10.0	0.09	25	11.0	0.08	16	6.7	0.08
May	20	9.9	0.09	18	8.6	0.09	19	9.0	0.08
June	19	8.9	0.08	21	12.9	0.12	20	5.8	0.05
July	19	9.9	0.10	14	11.8	0.16	11	7.8	0.12
August	14	10.2	0.13	18	13.1	0.15	18	15.5	0.15
September	19	15.4	0.15	13	11.3	0.17	11	10.4	0.17
October	10	6.5	0.12	25	19.8	0.15	15	13.8	0.15
November	19	8.3	0.08	19	8.0	0.08	17	9.9	0.09
December	17	12.4	0.14	25	15.4	0.11	17	7.0	0.06
TOTAL	214	130.5	0.11	249	139.2	0.10	202	113.5	0.10

*%: Billfish catch/total catch

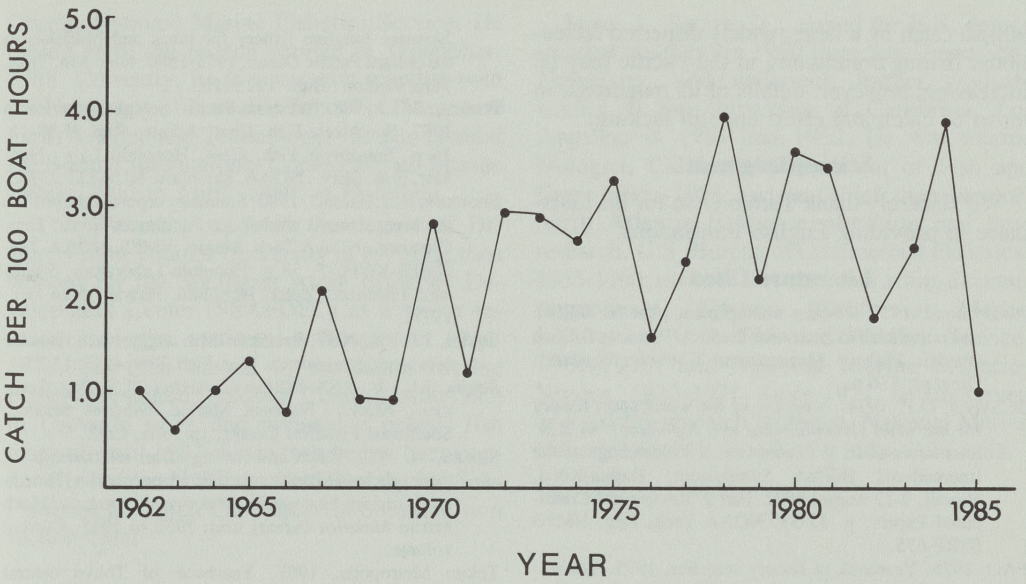

Figure 12. Blue marlin catch per unit effort (per 100 boat-hours) for the Hawaiian International Billfish Tournament, 1962-1985.

Presently, no good estimates are available on the total billfish catch and effort expended by recreational fishing vessels in the Pacific. Although catch-and-effort statistics of commercial fishing activities are generally maintained by government offices, data on recreational fishing activities are sadly lacking in many countries. Some measure of the trends in availability of billfishes is provided by the results of the Pacific Billfish Angler Survey (Squire 1987). Unfortunately, the survey is based on a select population of recreational fishermen, so it does not allow for estimates of Pacific-wide total catch or effort. The 1986 survey reported 13,711 fishing days and a catch of 6,949 billfish for the Pacific (Squire 1988).

The blue marlin CPUE fluctuated markedly from year to year, based on the Hawaiian International Billfish Tournament records from 1962 to 1985 (Fig. 12). An eightfold range in blue marlin CPUE occurred. Although recreational fishing data provide some indication of the status of stocks, caution should be exercised in interpreting those data. Some of the fluctuations are attributable to changes in availability and abundance; however, man-induced changes should not be overlooked. The general trend in recreational fishing is toward use of lighter line and tackle. Because catch-and-effort statistics are usually based on landed catch, the presumed increase in fish loss associated with the lighter tackle is not accounted for in the analysis. A high-priority need exists for a more complete assessment of the catch and effort for billfishes by the entire recreational fishing community in the Pacific. This need probably exists for other oceans, as well.

General Discussion

Billfishes are taken by a wide variety of fishing gear types; however, longline gear has been the principal method of capture over the past several decades. In recent years, the shift in target species of the longline fishery toward bigeye tuna, by using deeper fishing gear, has added a complexity to the use of catch-and-effort statistics as measures of resource abundance. Although Japanese longliners have shifted their fishing effort to high-priced tuna species, they have been replaced in some areas by Taiwanese and Korean longliners.

The gill-net, purse-seine, and recreational fisheries have experienced changes in billfish catches. The catch of billfishes by the Japanese gill-net fishery declined in recent years, principally because of a shift in target species to albacore. A newly developed tuna purse-seine fishery in the western central Pacific has resulted in the capture of small quantities of billfishes by the Japanese single purse-seine vessels. Finally, the

billfish catch by a large, widely dispersed recreational fishing community in the Pacific may be increasing; however, details of its magnitude in terms of catch and effort are still lacking.

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Trends in Atlantic Swordfish Fisheries

Steven A. Berkeley

Swordfish *(Xiphias gladius)* have a long history of commercial exploitation in the Atlantic Ocean and Mediterranean Sea. Well-known since the time of Aristole, swordfish have been fished commercially since at least the 1870s off the east coasts of the United States of America (U.S.) and Canada, and still earlier in the Mediterranean.

The recreational fishery for swordfish has a considerably shorter history, having begun in the U.S. in the 1920s. This surface troll fishery relied on sighting fish basking on the surface and carefully and persistently presenting the bait until the fish either struck it or sounded. The world record rod-and-reel caught swordfish was taken in this manner off Chile, and weighed 1,182 pounds. Probably fewer than 20 swordfish per year were caught this way (Beardsley 1977).

In 1977, shortly after swordfish were "discovered" off southeast Florida, a new sport fishing technique was developed. This method consisted of drift fishing at night using dead baits, usually large squid, with chemical light sticks attached to the leaders, fished at varying distances below the surface. This technique proved highly effective, producing 60 swordfish in the first Miami Swordfish Tournament in 1977, and probably more than 500 for the year (Beardsley 1977). This new technique was adopted quickly elsewhere but fishing success declined rapidly, nevertheless, largely the result of competition with the concurrently burgeoning commercial longline fishery. By 1983, the recreational fishery was essentially gone.

Nominal commercial swordfish landings have increased dramatically in recent years from about 13,000 mt in the early to mid-1970s to an all time high of just over 35,000 mt (Atlantic and Mediterranean) in 1985 (Table 1). Part of this apparent two to three-fold increase in landings is an artifact of improvements in the data base for recent years, largely a result of increased interest in and scrutiny of swordfish fisheries (e.g., Swordfish Workshop, Southeast Fisheries Center, Miami, Florida, June 7-9, 1977; ICCAT Billfish Workshop, Miami, FL, 1981; U.S. Fishery Management Plan for Atlantic Swordfish, 1984; Swordfish Stock Assessment Workshop, Miami, Florida, 1986; ICCAT Swordfish Workshop, Madrid, Spain, October 6-13, 1987). For obvious reasons, revisions are most likely to be made for the most recent years, and are almost always upwards.

Much of the increase is real, nevertheless, and is a result of a complexity of interacting factors including increased demand, value, and effort in the directed fisheries; increased bycatch in tuna-directed fisheries [due to a shift in target species from yellowfin tuna *(Thunnus albacares)* to bigeye tuna (*Thunnus obesus)*]; geographic expansion of various fishing fleets; and significant improvements in gear, fishing methods, electronics, and navigational equipment.

Major swordfish harvesting nations in the Atlantic are Spain, Italy, United States of America, and Japan, which together accounted for more than 75 percent of the swordfish landed in 1986. The vast majority of these landings came from the north Atlantic and Mediterranean. Trends in Atlantic swordfish fisheries for each of the major swordfish producing areas and/or fisheries are discussed following.

The Fisheries

Eastern North Atlantic Ocean

Spain is the major harvester of swordfish in the eastern north Atlantic, accounting for more than 80 percent of total landings for this area. Thus, trends in the eastern north Atlantic reflect trends in the Spanish fishery.

The Spanish fishery began prior to the turn of the century as a coastal longline fishery off southwest Spain. Landings from this fishery, based in Andalusia, were generally less than 1,000 mt (Garces and Rey 1982). A very rapid fleet expansion began in 1966 as a new longline fishery developed off northwest Spain, based in Galicia (Rey et al 1987). Landings increased dramatically to over 3,000 mt and fluctuated at about that level until about 1980, when another period of rapid expansion began. The southern fleet, which had been fishing coastal grounds near the Iberian peninsula, began extending its operation southward along the coast of Africa and into the Gulf of Guinea, as far south as the equator. The northwest fleet began moving west, fishing as far west as 40°W longitude by 1983 and 45°W longitude by 1985.

In 1985, there were 125 vessels in the northwest fleet, from under 100 up to 750 tons, mostly 100 to 250 tons (Rey et al 1987). The southwest fleet consists of 85 smaller longliners, mostly less than 100 tons and many less than 50 tons.

Total effort for Spain's northwest fleet was over 17.1 million hooks in 1985, and approximately 5.0 million hooks for the southwest fleet (Rey et al 1987), total effort having increased dramatically since 1979 (Fig. 1). Number of hooks per set varies between 800 for the smallest longliners and 2,600 for the largest, averaging about 1,200 to 1,600 fished on 31 to 46 km (17 to 25 nmi) of mainline. Bait is usually mackerel *(Scomber* sp.), although sardines *(Sardinella anchovia)* and even chunks of sharks may be used. No artificial lights are used. Trips last 30 to 45 days for the largest boats and 7 to 20 days for the smaller ones.

Major fleet movement, as experienced by Spain, generally occurs in response to declining catches or size of fish. Mean weight for the Spanish Atlantic fishery declined more or less continuously since 1975 (Fig. 2), although it appears to have stabilized since 1983 (Rey et al 1987). The increase in mean size in 1982 is probably due to the movement of the fleet to new fishing grounds. Mean weight decreased 36 percent between 1975 and 1985, from 88.1 kg to 56.1 kg whole weight.

Catch-per-unit effort (CPUE) has shown a surprising stability in this fishery (Fig. 3), fluctuating around 320 kg per thousand hooks without trend since 1973 (Rey et al 1987). However, CPUEs have been maintained only by continuous fleet movement to new fishing areas, where higher CPUEs have offset declining catch rates in the traditional fishing areas (Mejuto and Garces 1987).

Senegal and Spain entered into an agreement in 1983 and 1984 to allow Spanish longline vessels to fish off the coast of Senegal provided each vessel carried an observer (Caveriviere and Cayre 1985). Gear configuration was somewhat different than described by Rey at al (1987) (e.g., each branch line had 4 gangions with

Table 1. Atlantic swordfish landings (1,000 mt)[1].

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986[2]
Total	**12.6**	**13.2**	**13.4**	**13.6**	**13.0**	**13.4**	**19.2**	**19.5**	**22.9**	**19.4**	**23.2**	**25.4**	**31.5**	**35.1**	**35.0**
Atlantic	7.1	8.8	8.8	9.7	8.8	8.5	13.7	14.4	17.5	13.7	17.9	19.6	20.6	22.2	21.7
Brasil	0.1	0.1	0.3	0.3	0.4	0.4	0.3	0.4	1.5	0.6	1.0	0.8	0.5	0.4	0.7
Canada	0.0	0.0	0.0	0.0	0.0	0.1	2.3	3.0	1.9	0.6	0.6	1.1	0.5	0.6	0.7
China (Tai.)	0.8	1.1	0.8	0.9	0.9	0.7	0.6	1.3	0.6	0.5	0.6	0.4	0.3	0.3	0.3
Cuba	0.1	0.5	1.1	0.5	0.6	0.7	0.6	0.4	0.6	0.4	0.7	1.2	1.4	1.5	1.5
Japan	1.8	1.0	1.4	1.5	0.8	0.8	0.9	1.0	2.1	2.2	3.7	1.9	3.8	4.3	2.4
Korea	0.4	1.0	0.7	0.5	1.1	1.2	1.3	0.6	0.7	0.4	0.7	0.5	0.4	0.3	0.1
Panama	0.0	0.4	0.1	0.1	0.3	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Espana	3.2	3.8	2.9	3.7	2.8	3.3	3.6	2.6	3.8	4.0	4.6	7.1	6.3	7.4	8.0
USA	0.2	0.4	1.1	1.7	1.4	0.9	3.7	4.6	5.6	4.5	5.1	4.8	4.5	4.6	4.9
Uruguay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.7	1.5	2.5	1.7	1.7
USSR	0.2	0.2	0.1	0.3	0.2	0.1	0.2	0.1	0.2	0.0	0.1	0.0	0.2	0.1	0.1
Others	0.2	0.2	0.1	0.1	0.2	0.2	0.1	0.4	0.5	0.2	0.3	0.3	0.4	1.0	1.4
Mediterranean	5.5	4.4	4.6	3.9	4.2	4.9	5.5	5.1	5.4	5.7	5.3	5.8	10.9	12.9	13.3
Algerie	0.0	0.1	0.2	0.5	0.4	0.4	0.3	0.5	0.6	0.8	0.9	0.9	0.9	0.9	0.9
Italy	3.7	2.8	3.3	3.0	3.3	3.3	4.0	3.5	3.7	3.4	2.6	2.7	7.6	9.6	9.6
Malta	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.1	0.1
Maroc	0.2	0.2	0.2	0.1	0.2	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Espana	1.3	1.1	0.7	0.1	0.1	0.7	0.7	0.8	0.8	1.1	0.9	1.3	1.2	1.2	1.2
Others	0.1	0.1	0.0	0.0	0.1	0.2	0.1	0.2	0.1	0.2	0.7	0.8	1.0	1.1	1.4

[1]Source: Report of the ICCAT Swordfish Workshop, Madrid, Spain, October 6-13, 1987
[2]Preliminary

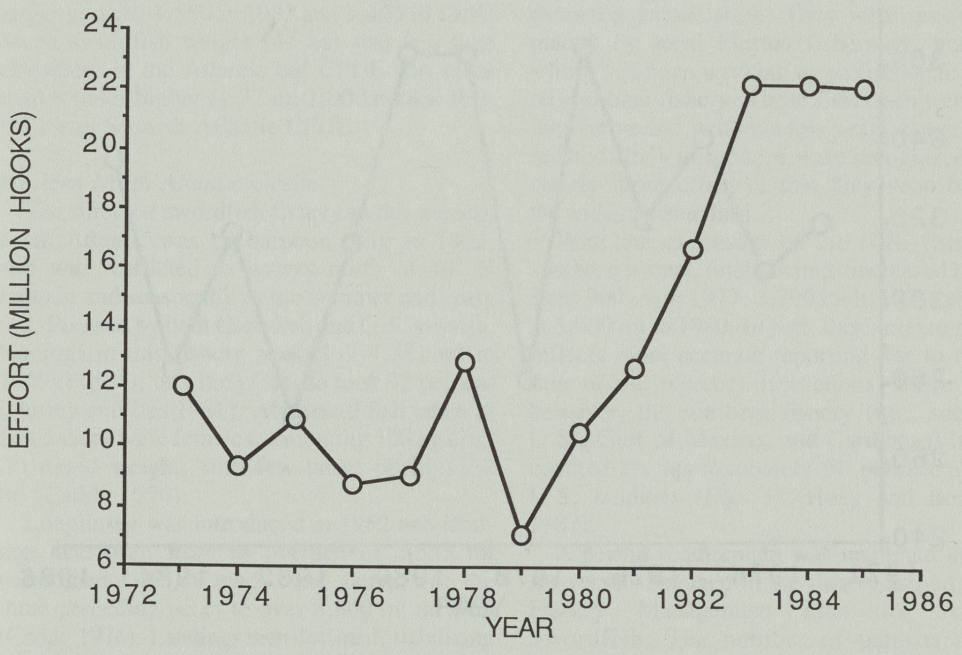

Figure 1. Annual fishing effort, in millions of hooks, in the Spanish Atlantic swordfish longline fishery, 1973-1985.

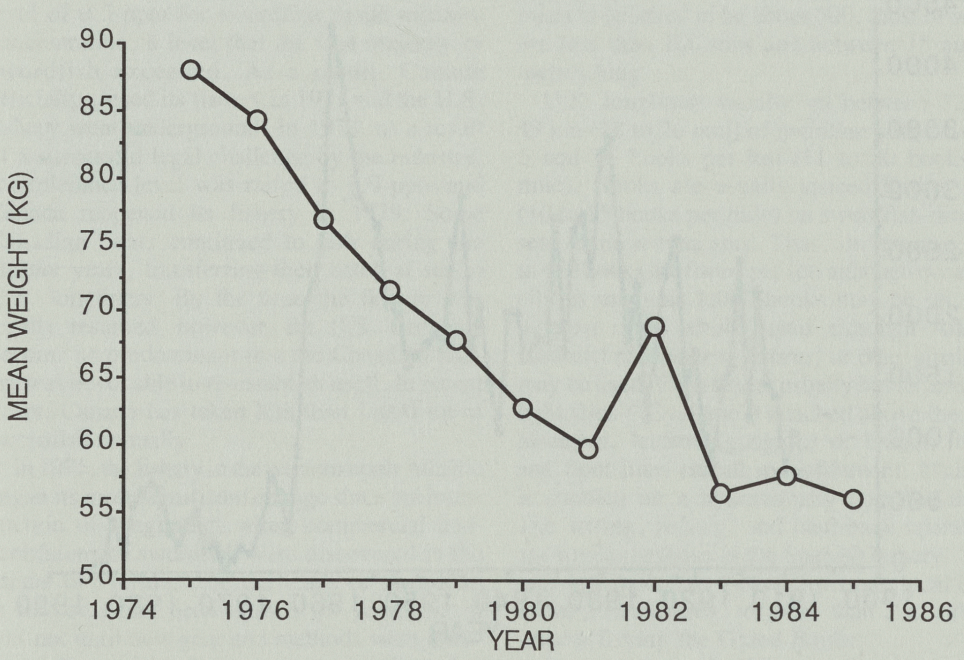

Figure 2. Mean weight of swordfish in the Spanish Atlantic longline fishery, 1975-1985.

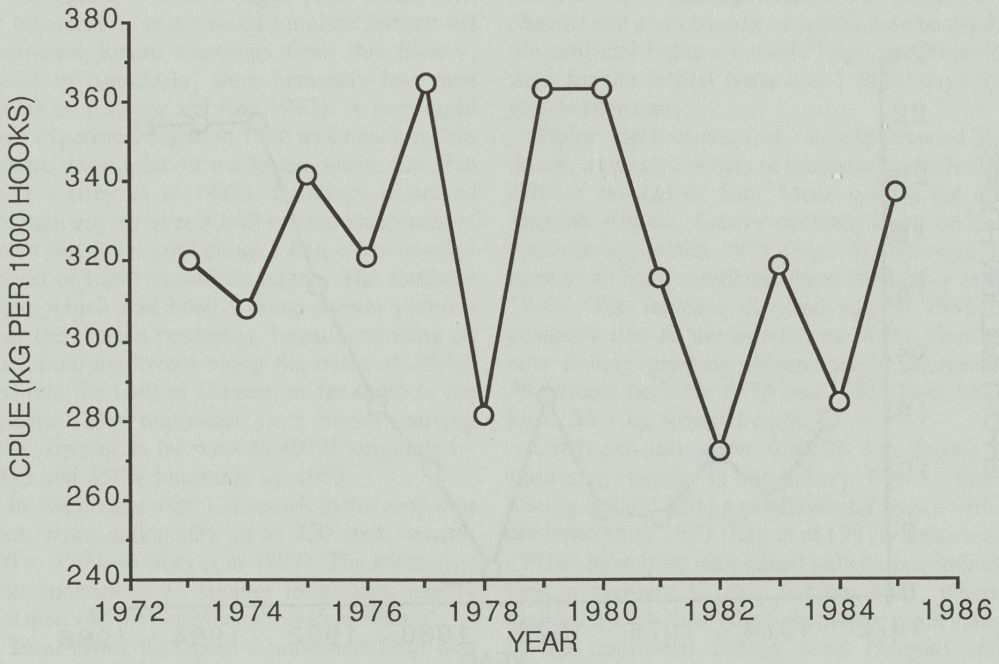

Figure 3. Swordfish catch-per-unit-effort (CPUE) in the Spanish Atlantic longline fishery, 1973-1985.

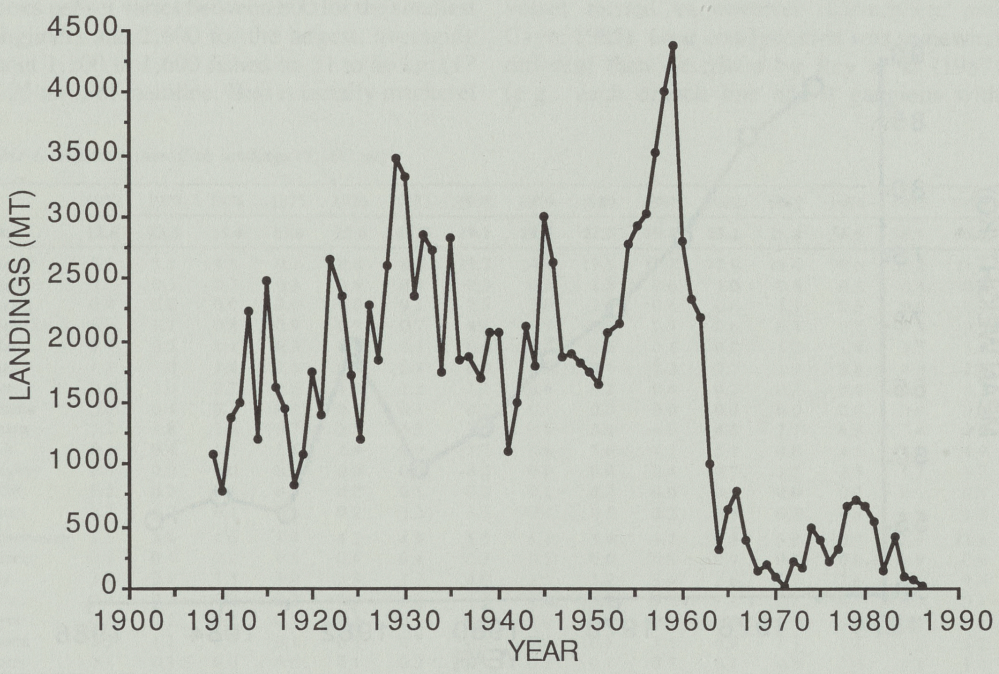

Figure 4. Combined U.S. and Canadian swordfish harpoon landings, 1909-1986.

hooks attached) although the average number of hooks per set was within the range given for larger vessels: 1,580 in 1983 and 1,463 in 1986. Mean swordfish weight (44 kg) was less than elsewhere in the Atlantic but CPUE was more than 4 times higher (1.37 mt/1,000 hooks) than the mean Spanish Atlantic CPUE.

Western North Atlantic Ocean

The directed swordfish fishery in the western north Atlantic was by harpoon prior to 1962, and was restricted to waters north of 40° N latitude and seasonally to the summer and early fall. Pursued by both Canadian and U.S. vessels, landings in this fishery peaked at 4,381 mt in 1959 (Fig. 4), of which Canada took 92 percent (Hurley and Iles 1981). Almost all fish taken in this fishery were females, averaging 120 kg (265 lb) round weight, with few under 60 kg (132 lb) (Caddy 1976).

Longlining was introduced in 1962 and landings increased from an average of 2,533 mt (combined U.S., Canada, and Japan) for the three preceding years to over 8,800 mt in 1963 (Caddy 1976). Landings then declined, stabilizing at about 5,000 mt through 1970. Canada was the major harvester, taking 85 to 95 percent of total landings. In 1971, the U.S. Food and Drug Administration (FDA) established a tolerance level of 0.5 ppm for swordfish tissue mercury concentration, a level that the vast majority of swordfish exceeded. As a result, Canada officially closed its fishery in 1971 and the U.S. fishery went underground. In 1978, as a result of a successful legal challenge by the industry, the tolerance level was raised to 1.0 ppm and Canada reopened its fishery in 1979. Some Canadian boats continued to fish during the closure years, transferring their catch at sea to U.S. longliners. By the time the fishery was legally resumed, however, the U.S. fleet had become so predominant that the Canadian fishery was never able to re-establish itself. In recent years, Canada has taken less than 1,000 mt of swordfish annually.

In 1975, the fishery in the western north Atlantic began its most significant change since the introduction of longlining, when commercial concentrations of swordfish were discovered in the Straits of Florida. The existence of swordfish in this area had been known for years, but it was not until new gear and methods were introduced that a viable fishery developed (Berkeley et al 1981). The fishery was begun by Cuban-American fishermen who were displaced from Bahamian waters when that country declared extended jurisdication. They were quickly replaced by local Florida fishermen, many of whom had been working as professionals in the recreational fishery. These fishermen were very innovative and, within a few years, the gear and methods they introduced were recognized as so clearly more effective that they soon became the industry standard.

With the expansion of the U.S. fishery to southern waters, total landings increased rapidly from 900 mt in 1977, 3,700 mt in 1978, peaking at 5,600 mt in 1980. In part, this increase merely reflects more accurate reporting due to relaxation of the mercury restrictions. Since 1980, however, the southern fishery (i.e., southeast U.S., Gulf of Mexico, and Caribbean) has accounted for approximately 50 percent of total U.S. landings (Fig. 5) (Hoey and Bertolino 1987).

A permit requirement was instituted in 1983 for vessels engaged in the fishery as part of the Fishery Management Plan for Atlantic Swordfish. The number of permits issued (annually, free to anyone requesting one) has increased every year. A total of 625 permits were issued in 1986, not all to longliners. The present fleet of U.S. swordfish/tuna longline boats is believed to be about 500, most of which are less than 100 tons and between 15 and 30 meters long.

U.S. longliners usually set between 32 and 49 km (18 to 26 nmi) of mainline with between 6 and 16 hooks per km (11 to 30 hooks per mile). Hooks are usually spaced farther apart (10 to 15 hooks per mile) on swordfish-directed sets than on tuna sets. Thus, on average, 250 to 450 hooks are fished per set, although occasionally as many as 1,000 hooks may be set. Bait is most often whole squid although Atlantic mackerel *(Scomber scombrus)* or other small fish may be used. Each leader usually has an artificial light stick ("Cyalume") attached above the bait. Mainline, leaders (gangions or branch lines), and float lines are all monofilament. Mainline is spooled on a hydraulically operated drum. The setting, fishing, and haul-back operations are similar to those in the Spanish fishery. Trips may last from 3 to 4 days, for small local boats in the Florida area, to more than a month for vessels fishing the Grand Banks.

In response to declining catches in the Gulf of Mexico and Straits of Florida, in 1984, some

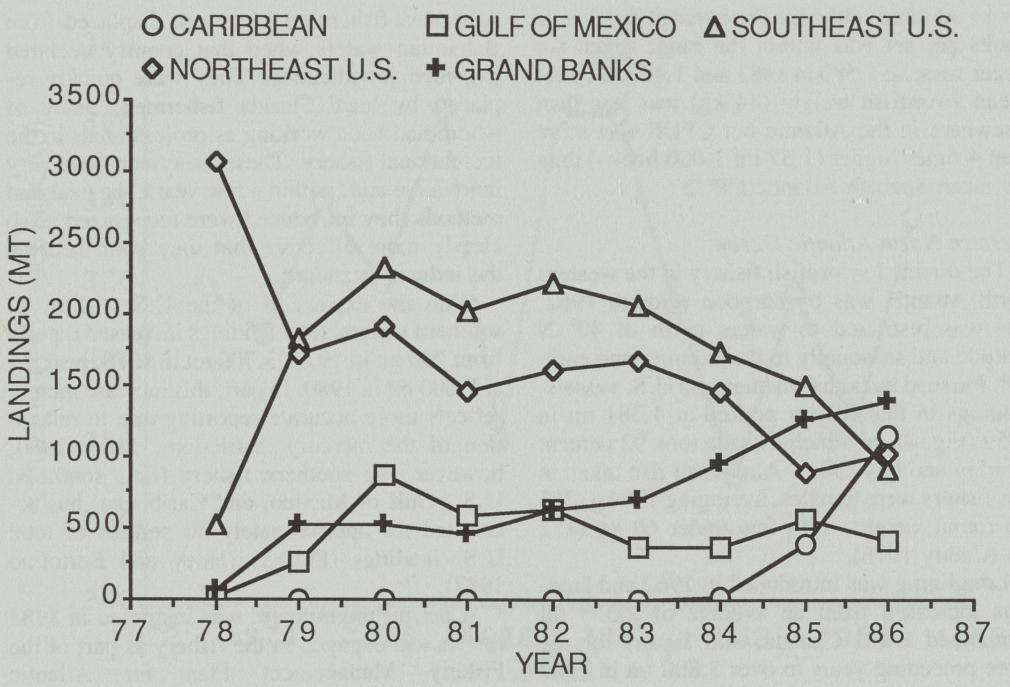

Figure 5. U.S. swordfish landings by major fishing area, 1978-1986.

vessels began fishing in the Caribbean Sea. Relatively high catch rates and larger fish stimulated increased fishing activity here. A total of 1,152 mt of swordfish was landed from this area in 1986, accounting for 24 percent of the total U.S. catch (Fig. 5) (Hoey and Bertolino 1987).

At about this same time and for the same reasons (i.e., declining catches and size), vessels in the northeast began moving farther east, to the Grand Banks and beyond. Almost 1,400 mt of swordfish were taken by the U.S. fleet in this area in 1986 (Fig. 5), accounting for more than 28 percent of total U.S. landings.

An increasing proportion of U.S. landings has been coming from more distant waters where fish tend to be larger. Even so, mean whole weight declined 43 percent, from 69 kg (153 lb) in 1978 to 39 kg (85 lb) in 1987 (Fig. 6; unpublished data, NMFS, Southeast Fisheries Center, Miami, Florida). Mean weight in the Canadian fishery in 1986 was 44 kg (96 lb) whole weight (ICCAT 1987), having declined 60 percent from 109 kg (241 lb) in 1963 (Caddy 1976).

Catch-per-unit-effort trends have been very difficult to quantify in this fishery because of rapid changes in fishing gear and methods (Hoey and Bertolino 1987). Specific changes include use of chemical lights above each hook; long single-stranded monofilament gangions, mainlines, and buoy lines; smaller big-game style hooks; very high-quality squid bait; longer mainlines; wider hook spacing; and ability to vary gangion lengths, depending on oceanographic and atmospheric conditions (primarily moon phase). There is also widespread use of LORAN C and satellite navigation systems; use of weather facsimile machines; ready access to real-time Gulf Stream and sea surface temperature data; use of color depth recorders (Chromoscopes), for locating deep scattering layer, thermocline, bait schools, and bottom topographic features; and — perhaps most important — the accumulated knowledge and experience to utilize effectively this fishing and electronic gear.

Parrack (1986), using catch per trip as an index of abundance, showed an approximate 50 percent decline in CPUE of large fish >130 lb dressed weight) between 1978 and 1981, which then remained level for the next four years. Preliminary results of subsequent size and area-specific CPUE analyses indicate a modest increae in CPUE for the smallest size class (<25

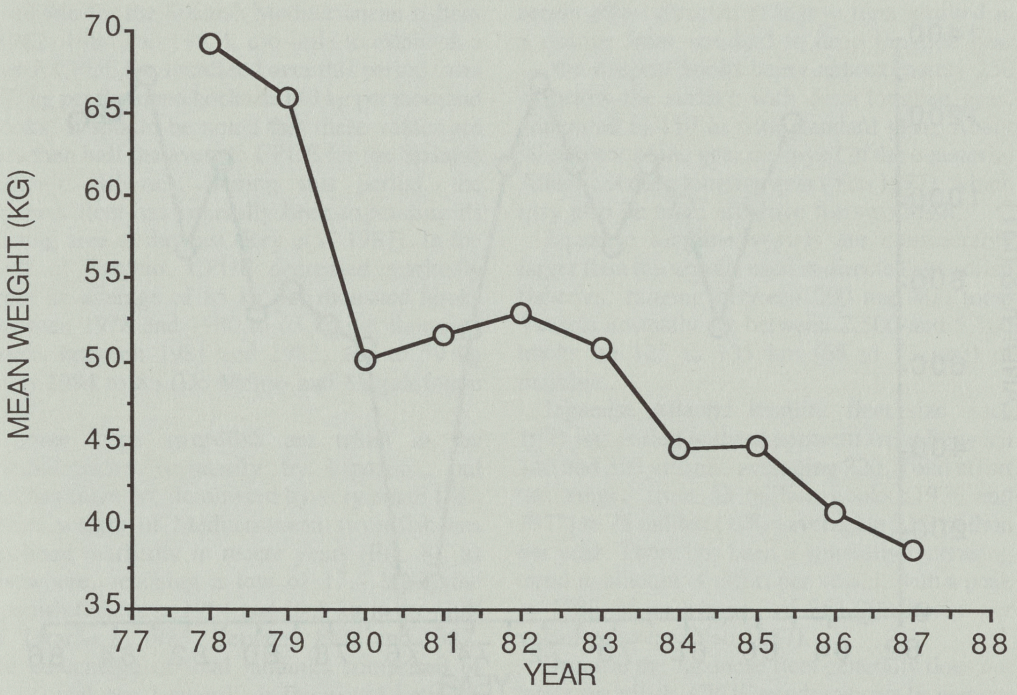

Figure 6. Mean weight of swordfish in the U.S. longline fishery, 1978-1987.

lb dressed weight) and a large decline in CPUE for larger fish between 1981 and 1986 for the fishery within the U.S. EEZ (Hoey and Nelson 1988).

Mediterrean Sea

Although at least 10 countries report swordfish landings from the Mediterranean, Italy is the largest harvester by far, having caught 9,600 mt, representing 72 percent of total landings in 1986 (Table 1). The combined landings of Italy and Spain were 10,800 mt in 1986, or 81 percent of total landings. Since 1984, a comprehensive study of the Italian swordfish fisheries has been ongoing (ICCAT 1987) and, as a result, landings data have been revised upwards. The large increase in reported landings between 1983 and 1984 is probably mostly a reflection of improved statistics. For this reason, the apparent trend in total landings may be largely artifactual.

The swordfish fisheries in the Mediterranean are much more diverse than in the Atlantic. Swordfish are taken here using regular longlines, "small fish" longlines, fish traps, drift entanglement nets, and harpoons. As elsewhere, nevertheless, longlines are the predominant gear.

Longline vessels in the Mediterranean are generally much smaller than in Atlantic fisheries. In the Italian fishery, in the Gulf of Taranto in the Ionian Sea, vessels are 12 to 14 m (40 to 45 ft) long (De Metrio and Megalofonou 1987). The Spanish longline fleet in the Mediterranean, which numbered 145 boats in 1985, consists of vessels generally less than 20 tons (Rey et al 1987).

Total effort (number of hooks per year) has been relatively stable in the Spanish fishery since 1982, varying between 8.5 million and 9.7 million hooks annually. Spanish longliners fished approximately 8.7 million hooks in 1985 (Rey et al 1987). Total effort and fleet size has been increasing steadily in the Italian fishery. De Metrio and Megalofonou (1987) reported that the amount of gear fished per vessel in the Gulf of Taranto has increased from 25 km (13.5 nmi) of mainline with 700 hooks in 1978 to 35 km (19 nmi) and 1,000 hooks in 1987.

Total landings for the Spanish fishery increased somewhat since the mid-1970s (Fig. 7). Although only three years of CPUE data are

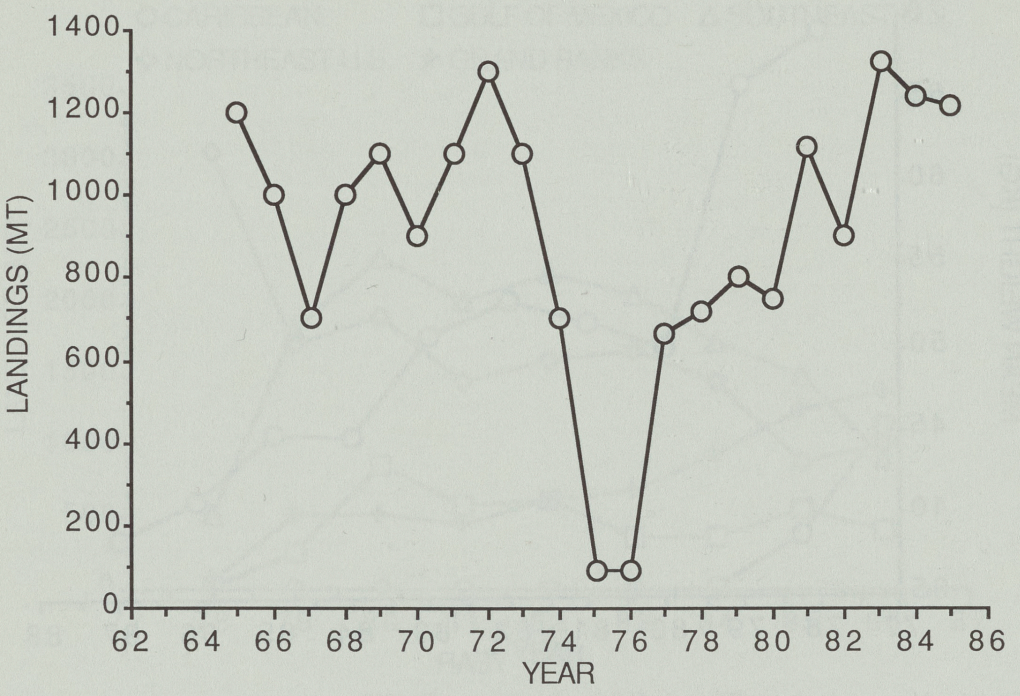

Figure 7. Swordfish landings in the Spanish Mediterranean longline fishery, 1964-1985.

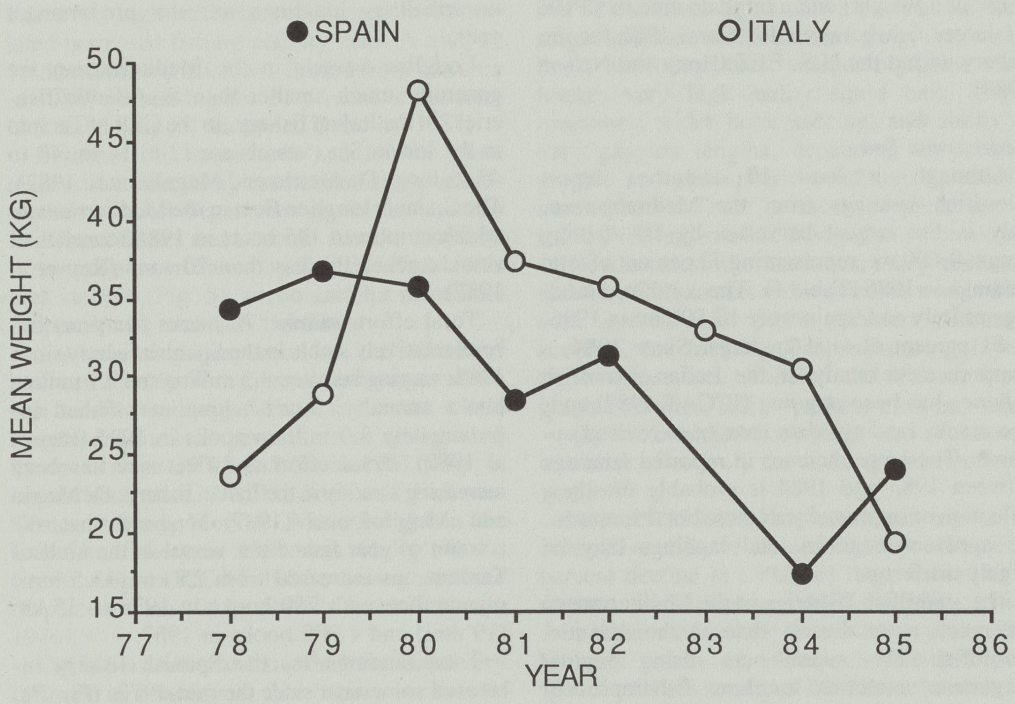

Figure 8. Mean weight of swordfish in the Spanish and Italian Mediterranean longline fisheries, 1978-1985.

available for the Spanish Mediterranean fishery (1982, 1984 and 1985), too little to establish a trend, CPUE has increased over this period from 107 kg per thousand hooks to 140 kg per thousand hooks. It should be noted that these values are less than half the average CPUE for the Spanish Atlantic fisheries. During this period, the Spanish fleet has generally been expanding its fishing area to the east (Rey et al 1987). In the Gulf of Taranto, CPUE decreased markedly from an average of 85 kg per thousand hooks between 1978 and 1980 to 63 kg per thousand hooks between 1981 and 1983, and to 59 kg from 1984 to 86 (De Metrio and Megalofonou 1987).

Some large swordfish are taken in the Mediterranean (primarily by harpoon), but catches there are dominated by very small fish. Mean weight of Mediterranean swordfish has declined markedly in recent years (Fig. 8), as elsewhere, reaching a low of 17.4 kg in the Spanish fishery in 1984 and 19.5 kg in the Gulf of Taranto in 1985. Between 1978 and 1982, the percentage of total landings comprised of age 0 and age I swordfish fluctuated between 48 and 61 percent (by number). These age-groups jumped to 84 percent in 1983 and increased slightly since then (ICCAT 1987).

Japan

The Japanese high-seas longline fleet fishes throughout the Atlantic, taking swordfish as a bycatch in its directed tuna fisheries. Despite the fact that the fishery does not target swordfish, Japan caught 4,600 mt of swordfish in the Atlantic in 1985. Preliminary data indicate a decline to 2,400 mt in 1986 (Table 1). In contrast to the directed fisheries, Japan's catch is taken throughout the north and south Atlantic, from at least 45°S to 45°N latitude. In 1985, approximately 80 percent of the Japanese swordfish catch was taken in the south Atlantic, and most of this was from the eastern south Atlantic (ICCAT 1987).

In the initial period of Japanese longlining in the Atlantic, which began in 1956, the principal target species was yellowfin tuna (Yao 1987). In the 1960s, the Japanese also began targeting albacore. In the 1970s, they again changed their principal target species to bluefin tuna *(Thunnus thynnus)* and bigeye tuna. Concomitantly with these changes in target species came changes in fishing gear, strategy, and temporal and spatial changes in fleet deployment. In particular, the recent effort directed at bigeye tuna resulted in a change from standard to deep longline gear — the deepest hooks being approximately 250 m below the surface with deep longline gear, compared to 150 m with standard gear. About 90 percent of the gear deployed in the equatorial Atlantic is deep longline gear (Yao 1987), which may also be more effective for swordfish.

Japanese longline vessels are considerably larger than the vessels used in directed swordfish fisheries, ranging between 200 and 400 tons. Vessels normally set between 2,500 and 2,700 hooks on 125 to 135 km (68 to 73 nmi) of mainline.

Japanese Atlantic longline fleet size since 1971 has varied without apparent trend between 146 and 320 vessels, averaging 220. Total effort has ranged from 33 million hooks (1976 and 1977) to 75 million (1982) averaging 52.8 million per year. There has been a generally increasing trend in amount of effort per vessel, with a peak in 1985 of an average of 351,000 hooks per vessel per year (Yao 1987).

Because the Japanese fleet generally does not target swordfish, CPUE trends may not be particularly meaningful. Not unexpectedly, analysis of hook rates shows large fluctuations. Despite these fluctuations, it appears that CPUE has generally declined in the western north Atlantic, increased somewhat since the late 1970s in the southeast Atlantic, and fluctuated without obvious trend since the late 1970s in the northeast Atlantic (Yao 1987; Fig. 7).

Discussion

The generally parallel evolution of directed swordfish fisheries in widely disparate areas of the Atlantic Ocean reflects the homogeneous nature of the controlling biological and economic factors. Unlike tunas, swordfish do not form schools, and thus are not especially vulnerable to most types of active fishing gears, especially purse seines or other forms of encircling nets. Further, since they are generally found below the surface and feed at night, they are not vulnerable to other types of surface gear that are so effective on tuna, such as trolling or bait-boat fishing. As a result, directed fisheries exist only in areas where swordfish concentrate for spawning or feeding (Gulf of Mexico, Caribbean Sea, Straits of Messina, Grand Banks), or where they are concentrated by bottlenecks formed by land masses (such as in the Straits of Florida and the Straits of Messina), or by ocean currents (such as the Gulf

Stream). Even in these areas, directed fisheries may not be economically feasible unless there is ready access to a strong market. This factor is undoubtedly the chief reason why there are essentially no directed fisheries in the south Atlantic despite apparent concentrations of swordfish in several areas (e.g., off southern Brazil, Argentina, and in the Gulf of Guinea). With greatly increased value and demand for swordfish, especially in the U.S. and some European countries, increased availability of regular scheduled air freight service, and the relatively small proportion of total value represented by shipping, this situation is likely to change in the near future.

Atlantic swordfish fisheries share many similarities. Interestingly, both eastern and western Atlantic fisheries developed initially as harpoon fisheries and, while remnants of these fisheries still exist in the Mediterranean and in the western north Atlantic, in both areas the longline is, by far, the predominant gear.

All the directed fisheries have experienced significant declines in mean size of catches in recent years, and most have also experienced declining catch rates. Although mean size has remained constant or declined in recent years in the Spanish Atlantic fishery, an increasing proportion of Spanish landings (52% in 1985) is coming from north of 40°N latitude, where fish are of larger average size. Thus, the average size of fish in the northeast Atlantic population had probably declined more than the size in the catch would suggest. The same may be said for the western north Atlantic population as judged by the U.S. catch.

The CPUE index in the Spanish fishery appears to have remained stable but high CPUEs associated with new fishing grounds are, in fact, masking declines in the traditional fishing areas. Fleet movement here, as elsewhere, is almost always motivated by declining CPUE. Thus, despite the inability of the index to detect a decline, it must certainly have occurred. In using CPUE as an indicator of abundance, it is important to recognize that it always has an inherent bias. Fishermen are always gaining experience, gear either stays the same or improves, and marginal fishermen drop out of a fishery as fishing becomes more competitive. Thus, regardless of the unit of effort used, an apparently stable CPUE series often means a decline in abundance since these factors are rarely if ever accounted for.

Despite a similarity in recent trends, actual mean weight and CPUEs are highly variable among Atlantic swordfish fisheries (Table 2). The very high CPUEs in the Azores and off Senegal are undoubtedly due to these areas having been previously unfished. Based on the experience in other areas, the large mean size and high catch rates in the Azores will decline rapidly as exploitation continues and the accumulated biomass of large fish is removed.

Low catch rates and small size of fish in the Mediterranean reflect a long history of intensive exploitation by many countries. Such low catch rates would not sustain most longline fisheries but, in the Mediterranean, the fishery is comprised of a large artisanal fleet having very low operating expenses. The proximity of the fishing grounds to shore also ensures a higher quality, higher value product. While individual catch rates are very low, the large fleet size results in large total landings (38 percent of total Atlantic landings in 1986).

All longline fisheries use somewhat different gear configurations and fishing methods, but only the U.S. fishery is substantively different from the others. Excepting the essentially "virgin" fisheries in the Azores and the exploratory sets off Senegal, CPUE in all other fisheries never exceeds a few hundred kg per thousand hooks, while CPUE in the U.S. fishery averages well over 1,000 kg per thousand hooks.

The U.S. longline fishery is unique in its use of many fewer, but individually much more effective hooks. Unlike other longline fisheries that concentrate on setting large numbers of hooks as quickly and inexpensively as possible, the U.S. fishery developed a different fishing philosophy attempting, instead, to maximize the effectiveness of each hook. The development of this approach can be traced directly to the southern U.S. fishery, which was established by sport fishermen turned commercial longliner. Big-game charter and private boat captains in south Florida have been responsible for many of the major innovations in sport fishing gear and techniques. These fishermen, perhaps more than any others, knew the importance of careful, lifelike bait presentation with well-hidden hooks and the use of terminal tackle and leaders that were as unobtrusive as possible. They recognized that whether fishing with rod and reel or longline, this was still a hook-and-line fishery, and that these techniques would make the difference between occasional success and consistent production. Transferring this approach to the longline fishery, catch rates soared. Those who

did not adopt these methods were soon out of the fishery.

It is estimated that setting 25 (statute) miles of longline with 350 hooks in this fishery, each hook having a chemical light stick and a whole 1 to 2 lb squid bait attached, costs more than $1,000 U.S. per night. Use of this sophisticated gear is economically feasible only because the value of an individual fish is so great. If mean size continues to fall, there may come a point at which such techniques are no longer cost effective.

Understanding the significance of observed trends in Atlantic swordfish fisheries will require a much more detailed understanding of stock structure than we have at present. For example, the recent decline in landings, catch rate, and size of swordfish observed in the U.S. or Spanish Atlantic fisheries are obviously of much greater concern if each fishery is exploiting a discrete stock rather than a small component of a much larger stock.

High catch rates and average size appear to be associated with movement of a fishery into previously unfished areas, even if the new area is close to a heavily exploited one. The very high catch rates and large average size of fish in the recently developed Azorean fishery is a recent example of this phenomenon (Table 2). Swordfish spawning occurs only in tropical and sub-tropical waters (temperatures >22°C), requiring adult fish to migrate from temperate areas to lower latitudes to spawn. Thus, year-round resident populations, which may well exist in tropical areas, are unlikely to occur in temperate ones. A "homing" ability to specific summer feeding grounds, as has been suggested by Beckett (1971), would help explain high initial catch rates that often occur in previously unfished temperate areas.

Table 2. Mean weight and catch-per-unit-effort (CPUE) in kg and number of swordfish per thousand hooks for various Atlantic swordfish fisheries in 1985.

Fishery	Mean Weight (kg)	CPUE (weight)	CPUE (Numbers)
Spain-Atlantic	56.1	337	6.0
Spain-Senegal[1]	44.0	1,370	30.5
Spain-Mediterranean	24.0	140	5.8
U.S.A.	44.9	1,346	30.0
Italy[2]	19.5	59	3.2
Azores	60.5	1,490	25
Brazil	—	165	3.3
Uruguay	—	297	—
Japan-all areas	—	64	<1.0

[1]1983-1984 data
[2]Gulf of Taranto fishery only

On a larger scale, the question of degree of stock separation must be considered before the observed changes in catch, size distribution, and CPUE can be interpreted meaningfully in terms of the status of the resource. Japanese high-seas longline data suggest no obvious discontinuities in swordfish distribution anywhere throughout their range (SEFC 1986). Similarly, swordfish size frequencies of Spanish and U.S. longliners fishing across the north Atlantic, north of 40°N latitude, show striking similarity, also suggesting a continuous distribution of swordfish from east to west (Hoey et al 1987). Even so, tagging results — still the only direct way of establishing stock mixing — suggest stock isolation, at least among broad areas of the Atlantic Ocean. Of 2,540 swordfish tagged in the western north Atlantic, approximately 108 fish had been recaptured as of November 1987. While extensive north-south movement has been documented, no fish have been recaptured in the eastern Atlantic or south Atlantic, or even in the central north Atlantic where there is intensive effort by the Spanish fishery. Similarly, Spanish scientists have tagged 190 swordfish in the eastern north Atlantic (Anon 1987). Only two of those fish have been recaptured, both in the eastern north Altantic.

Despite the lack of any trans-Atlantic tag recaptures, we cannot rule out the possibility that such movement exists. In fact, we can assume that at least some movement across and even between oceans must occur for swordfish to remain a single species world-wide. However, if the amount of movement between areas (or mixing rate) is small enough, then the population may be considered a separate stock whose abundance and size or age composition will not be signficantly affected by the status or abundance of swordfish in other areas (i.e., other stocks).

To estimate possible mixing rates, I used both the Spanish and U.S./Canadian tag-recapture data. From these data I calculated the probability of getting the observed recapture results (i.e., no recaptures in either direction between the eastern and western north Atlantic) for several different hypothetical mixing rates. These results and their derivation are shown in Table 3. As an example of how to read this table, using the first row (probability = 0.05), we would get the observed results (i.e, no recaptures out-

side their respective areas of release) no more than 5 percent of the time if there were as many as 660 western north Atlantic-tagged fish in the eastern north Atlantic and 71 eastern north Atlantic-tagged fish in the western north Atlantic. If 660 western north Atlantic-tagged fish actually were in the eastern north Atlantic, then 660 out of 2540 fish moved from west to east, implying a mixing rate of 26 percent from west to east. Likewise, if 71 out of 190 eastern north Atlantic-tagged fish were in the western north Atlantic population, then the mixing rate from east to west would be 37 percent. If these were the actual mixing rates, then 95 percent of the time we should have gotten at least one trans-Atlantic tag recapture in each direction. At a more realistic probability level of 50 percent, maximum mixing rates in both directions are considerably less than 10 percent, implying that the U.S. and Spanish fisheries are each exploiting relatively discrete stocks of fish. Considering this, and the potential risk to the resource of assuming a single stock, if multiple stocks actually exist, it would be prudent to assume separate stocks for assessment and management purposes.

Table 3. Swordfish mixing rates derived from tag recapture data[1].

	Maximum Mixing Rate West to East		Maximum Mixing Rate East to West	
Probability	Max. No. W. Atl. Tags in Population	Implied Mixing Rate W. to E.	Max. No. E. Atl. Tags in Population	Implied Mixing Rate E. to W.
0.05	660	0.2598	71	0.3737
0.10	411	0.1618	55	0.2895
0.25	190	0.0748	33	0.1737
0.50	79	0.0311	16	0.0842
0.75	29	0.0114	7	0.0368
0.90	10	0.0039	2	0.0105
0.95	5	0.0020	1	0.0053

[1]Derived as follows:

Given: 190 Eastern Atl. tagged fish of which 2 have been recaptured
2,540 Western Atl. tagged fish of which 108 have been recaptured
All recaptures have been in their respective areas of release

For mixing rate west to east at probability level of 0.05:

$X_E^a = 0.05$

where X_E = proportion of all tagged fish in E. Atl. population that are E. Atl. tagged fish

a = number of E. Atl. tags recaptured (= 2)

$X_E^2 = 0.05$; $X_E = 0.2236$

$1\text{-}X_E = Y_E$; $Y_E = 0.7764$

where Y_E = proportion of W. Atl. tags in E. Atl. population

$\frac{190}{Z_E} = 0.2236$; $Z_E = 850$

where Z_E = total number of tags in E. Atl. population

850-190 = 660 = number of W. Atl. tags in E. Atl. population

$\frac{660}{2540} = .2598$ = implied mixing rate

For mixing rate east to west at probability level of 0.05:

$X_W^b = 0.05$

where X_W = proportion of all tagged fish in W. Atl. population that are W. Atl. tagged fish

b = number of W. Atl. tags recaptured (= 108)

$X_W^{108} = 0.05$; $X_W = 0.9726$

$1\text{-}X_W = Y_W$; $Y_W = 0.0274$

where Y_W = proportion of E. Atl. tags in W. Atl. population

$\frac{2540}{Z_W} = 0.9726$; $Z_W = 2611$

where Z_W = total number of tags in W. Atl. population

2611-2540 = 71 = number of E. Atl. tags in W. Atl. population

$\frac{71}{190} = 0.3760$ = implied mixing rate

Future Trends

The following predictions of future trends in Atlantic swordfish fisheries, partly conjectural, are derived largely from extrapolation of recent trends discussed above.

Eastern North Atlantic Ocean

The Spanish fishery, perhaps joined by other longlining nations, will continue to move southward along the African coast. Swordfish in many of these areas have been only lightly exploited and, unless exploitation of these more distant areas is precluded for economic reasons (declining price or increased operating expenses), relatively high catch rates should be realized for several years as the fishery moves into new areas. Landings from the eastern equatorial Atlantic should thus increase. Landings from the more traditional areas may stabilize, but CPUE and average size will continue to decline. The movement of Spanish vessels west towards the U.S./Canada coast will soon reverse itself in response to decreasing catch rates, as it will no longer be cost effective to spend such a high proportion of a fishing trip to transit to and from the grounds. Vessels will return to more nearby areas where catch rates will be lower but where more time can be spent fishing. For the same reasons, the movement of U.S. vessels eastward will also reverse itself.

Western North Atlantic Ocean

The fishery in the western north Atlantic has probably expanded as far as it can. The U.S. fishery will almost certainly become a mixed tuna/swordfish longline fishery, a trend that is already well established. As the fresh tuna market expands, and demand and price for tuna increase, swordfish will become increasingly a

bycatch of directed tuna fishing. Directed swordfish effort will continue in ever narrower time-area strata, which will likely be limited to the Straits of Florida in spring, the Caribbean in winter, and the Grand Banks in late summer and fall.

Mediterranean Sea

A long history of intensive fishing appears to have restructured the size and age composition of the population in the Mediterranean. Continued high fishing effort despite very low catch rates is possible because of the accessibility of the fishing grounds to small boats having very low operating expenses. This situation is unique to this area.

The fishery here is dependent almost entirely on the first one or two age classes. Thus, landings will be determined largely by the strength of the incoming year class. Adult biomass appears to be very small and recruitment failure would seem a real possibility. Without effective regulations, landings will increase only in the event of a fortuitously large year class. Recent high landings may reflect such large year classes, in which case landings will not be maintained at present levels. Should a year-class failure occur, landings will drop precipitously and without warning.

South Atlantic Ocean

Landings in the south Atlantic are presently rather small. With increased availability of air freight and increased price and demand, directed swordfish fisheries should develop here in the next several years. Both the eastern and western south Atlantic areas almost certainly have the available stocks to support considerably increased fishing effort and landings. The price and demand for fresh tuna in North America and perhaps in Japan, however, will play a large role in determining if and when such directed swordfish fisheries develop.

Summary

In the Atlantic Ocean, swordfish are caught in directed longline and harpoon fisheries, and incidentally by tuna longliners. In contrast to other billfishes, there is no longer a recreational fishery for this species.

Nominal landings increased dramatically from about 13,000 mt in the mid-1970s to an all time high of just over 35,000 mt in 1985 (Atlantic and Mediterranean). In part, this increase merely reflects revisions to the data base for the most recent years as a result of increased interest in and scrutiny of swordfish fisheries. Nevertheless, much of the increase is real and results from a number of interacting factors, e.g., increased demand (and value); increased effort in the directed fisheries; increased bycatch in tuna-directed fisheries (due to shift in target species from yellowfin to bigeye; geographic expansion of various fishing fleets; and significant improvements in gear, fishing methods, electronics, and navigational equipment.

Major swordfish harvesting nations in the Atlantic are Spain, Italy, United States of America, and Japan, which collectively accounted for over 75 percent of the swordfish landed in 1986. Fishing methods, areas, and catch rates vary widely among these fisheries. Japan lands swordfish as a bycatch of its tuna fisheries. Recent increases in Japan's swordfish landings (4,300 mt in 1985) are probably due to a change in principal target species from yellowfin to bigeye, and a concomitant change in fishing gear from shallow (to 150 m depth) to deep (to 250 m depth) longline.

While landings by Italy, Spain, and the United States have remained either constant or have increased in recent years, in all cases one or more of the following factors have applied: increased fishing effort; fleet movement to new, more distant fishing grounds; deployment of increasingly more effective fishing gear. Despite these changes, mean size and area-specific CPUEs have declined in all these fisheries.

Although there are no obvious discontinuities in swordfish distribution, increases in catch rate and mean size observed whenever a fishery moves into a new area, in conjunction with tagging data, suggest that Atlantic swordfish do not mix freely throughout their range. A method for estimating mixing rates from tag-recapture data is presented which suggests that eastern and western north Atlantic populations probably comprise discrete stocks. Understanding the significance of changes in landings, mean size, and CPUE will require a much more critical analysis and detailed understanding of stock structure.

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Steven A. Berkeley received the M.S. degree from the University of Miami's Rosenstiel School of Marine and Atmospheric Sciences in 1972. He was employed as a research associate at the University of Miami until 1984 when he became staff fishery biologist with the South Atlantic Fishery Management Council in Charleston, South Carolina. While at the University of Miami, his principal research activities included: studies on age, growth, mortality, and population dynamics of various species of fish including halfbeaks, clupeids, swordfish, and pelagic sharks; resource assessment from ichthyoplankton surveys; effects of juvenile fish on water column ecology (CEPEX); and various aspects of fishery assessment and management of Biscayne Bay, Florida. He began research on the fishery and biology of swordfish in 1978, shortly after the fishery began off the southeastern U.S. Since then, he has published on various aspects of the biology, age and growth, population dynamics, and fishery for Atlantic swordfish, and participated in numerous national and international meetings concerned with stock assessment, biology, and management of species. His primary responsibility on staff of the South Atlantic Council has been the development of fishery management plans for swordfish and billfish for the eastern U.S., including the Gulf of Mexico and Caribbean Sea. During this time, both a swordfish plan and a billfish plan were submitted to and approved by the Secretary of Commerce.

Trends in Fisheries for Swordfish in the Pacific Ocean

Gary T. Sakagawa

The broadbill swordfish, *Xiphias gladius* (Fig. 1), is largely distinguishable from other billfishes by the absence of pelvic fins. It is a large pelagic species that attains a maximum size of 540 kg (1,190 lb) and is found in tropical, subtropical and temperate waters of the world's oceans and adjacent seas (Nakamura 1985, Palko et al 1981). It has been a favorite food fish in many countries since antiquity, esteemed for its white firm flesh, mild flavor, and high flesh-to-bone ratio.

Beside being esteemed as a food fish, the swordfish is a prized game fish. It is a difficult game fish to catch with rod and reel, so is pursued by only the most dedicated anglers. Trolling is the traditional method used, although this is done only after the swordfish is visually sighted basking at the surface.

In 1976, drift fishing for swordfish with baited lines and light sticks at night proved successful off Florida. This method quickly spread to other places along the Atlantic and Gulf of Mexico coasts of the United States (Palko et al *op. cit.)*. The nominal sport catch, however, has remained small, amounting to no more than a few hundred swordfish per year.

The commercial fisheries produce more than 50,000 mt annually and are by far the major producers of swordfish. They are the focus of this chapter, which begins with a discussion of the markets, or forces that directly influence the level of commercial fishing for swordfish. This is followed by a review of the world catch and a description of the major fisheries in the Pacific Ocean, and concludes with a discussion of trends and outlook for the Pacific fisheries.

Global Markets

Commodity markets for swordfish are forces behind production. As a food fish having a high market value and ability to hold quality when frozen for long-distance shipment, swordfish is produced and traded on an international scale. It is sold fresh or frozen as steaks, fillets, and for raw consumption. The major markets are western Europe, Japan, and the U.S. Collectively, they account for an estimated 87% of the annual consumption.

Europe

The western European market is the largest, estimated to consume about 35% of the annual world supply of swordfish, principally for steaks and fillets. Consumption is concentrated in the Mediterranean countries, particularly Italy and Spain. This market depends largely on swordfish caught by the Spanish, Italian, and Greek fleets fishing on stocks in the Atlantic Ocean and Mediterranean Sea (ICCAT 1988).

Japan

The second largest market for swordfish is Japan. Consumption is estimated to be about 30% of the annual world supply. This market is primarily for high-quality fish, eaten raw as "sashmi" and "sushi." The product must be fresh or, if frozen, kept at low temperatures ($-50°$ to $-60°$C, or $-58°$ to $-76°$F) for retention of desired qualities. Average ex-vessel price was approximately \$4.70/kg (\$2.13/lb) in 1986 (Yao 1988).

A world-wide Japanese fleet of longliners is largely the source of fish for this market. About 70% to 80% of the supply is from swordfish stocks in the Pacific Ocean and the remainder is evenly divided from stocks in the Atlantic and Indian oceans.

United States

The U.S. market currently consumes about

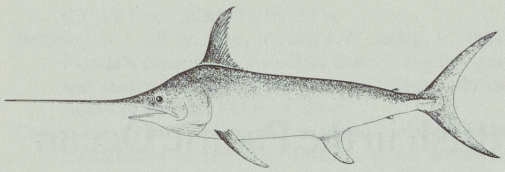

Figure 1. Broadbill swordfish with distinguishing characteristics, including absence of pelvic fins (from Nakamura 1985).

12,000 mt annually, or 22% of the world supply of swordfish. Products are in the form of fresh and frozen steaks and fillets. This market is growing at an estimated annual rate of 5% to 7% (Lipton 1986).

About half of the U.S. supply comes from the U.S. fleet and half from foreign fleets operating in the Atlantic and Pacific oceans. Canada, Spain, and Taiwan currently are the major sources for U.S. imports. In 1986, the average ex-vessel price for U.S.-caught swordfish was $6.95/kg ($3.15/lb); for foreign-caught fish, it was $5.65/kg ($2.56/lb).

The U.S. market has evolved in phases. Before 1971, the market was almost completely dependent on imports, mainly from Canada and Japan (Fig. 2). The discovery in 1970 of high levels of mercury residue in swordfish steaks (Peterson et al 1973), in excess of established health safety margins, reversed this picture.

In 1971, the U.S. strictly enforced a regulation on the permissible level (0.5 ppm) of mercury in imported fish. Consumers stopped buying swordfish, supplies quickly dried up and the market collapsed (Lipton *op. cit.*). A slow recovery began in 1973, with U.S. consumers cautiously returning to the market as fears of mercury poisoning faded. U.S. fishermen increased their efforts to fill the supply lines since they were largely exempt from the mercury regulation that had virtually stopped the entry of imports. They captured over 90% of the market and began establishing new fisheries to meet the increasing demand. Production increased slowly at first, and grew. By 1978, it had grown sufficiently to attain the levels that were consumed before the mercury scare of 1971, and was increasing in line with renewed market growth. In 1985, however, domestic production showed signs of leveling off at 7,500 mt (Fig. 2).

In 1979 the mercury regulation was revised to allow a higher level of 1.0 ppm. In combination with rising value of the dollar relative to foreign currencies and, foremost, exponential growth in U.S. consumption of swordfish, this revision allowed imports to be more competitive (Lipton *op. cit.*). Significant amounts of foreign-caught swordfish began reappearing in 1981. Imports captured 10% of the market share that year and grew in subsequent years. The largest increase occurred in 1985, when domestic production leveled off while consumption continued upwards. Imports captured 35% of the market in 1985, increasing further to 44% in 1986.

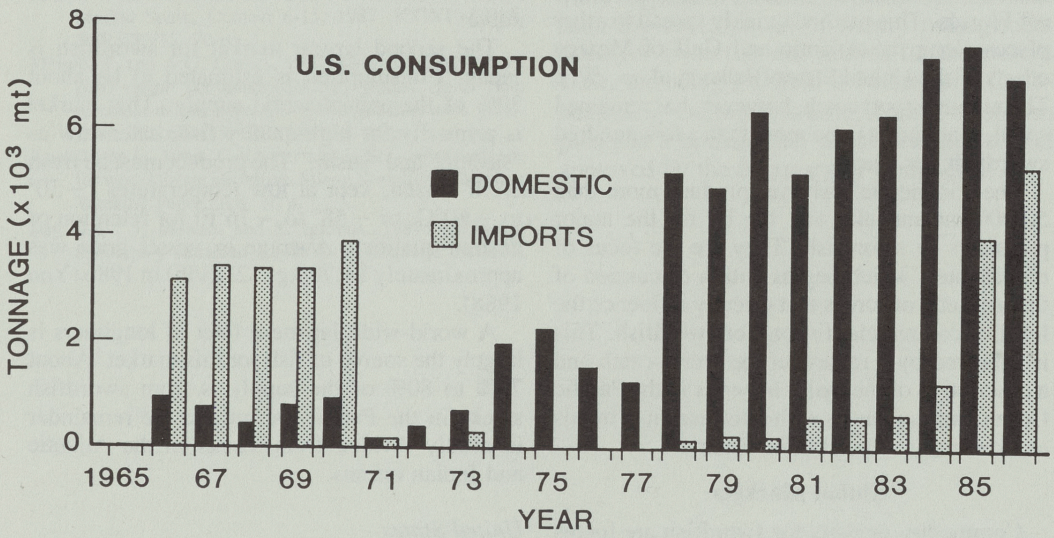

Figure 2. Tonnage of swordfish consumed by U.S. consumers, 1966-1986. (Source: Lipton 1986 and NMFS.)

Global Production

Identifying trends in the catch of swordfish on a world-wide basis is difficult, owing to changes in data gathering and reporting procedures over time, inaccurate reporting of some statistics, and non-reporting for some fisheries. Nonetheless, by piecing together recent estimates from several sources, particularly from ICCAT *(op. cit.)* and FAO (ms), the global catch appears to be increasing — from a low of about 27,000 mt in 1972 to a high of approximately 56,000 mt in 1986.

The major increases have been in the Atlantic Ocean and Mediterranean Sea although the trend has also been upward in the Pacific Ocean. In 1972, the Pacific catch was 12,600 mt or about 47% of the total global catch; in 1986, it was about 21,000 mt and only 37% of the global catch (Fig. 3).

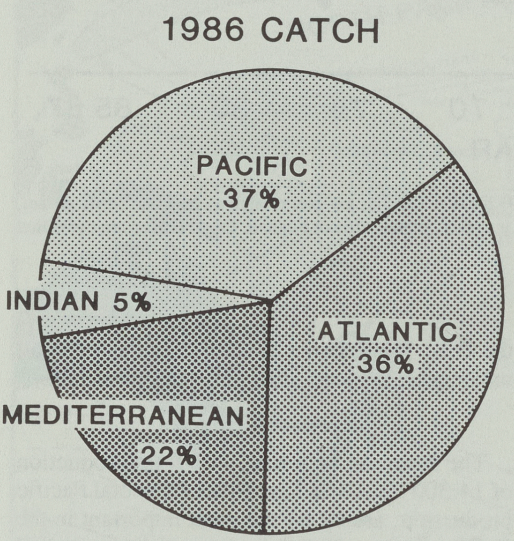

Figure 3. Proportion of swordfish catch by ocean, 1986.

The Pacific catch has shown an increasing trend since 1972, although remaining below the peak of 24,300 mt recorded in 1961 (Fig. 4). The stocks are considered to be in good condition (Bartoo and Coan 1989) and able to sustain increased catches. Comparison of Pacific catches with those of the Atlantic or Mediterranean, and relative sizes of the areas where they are made, suggest that there is considerable opportunity for increased production of swordfish from the Pacific Ocean.

Nations participating in the Pacific fisheries include: United States (harpoon and drift gillnet fisheries off California); Chile, Mexico, and Peru (coastal handline, gillnet and longline fisheries); Japan (Pacific-wide longline fishery and a coastal, mainly drift gillnet fishery off Honshu); the Philippines (coastal handline fisheries); Taiwan (Pacific-wide longline fishery and coastal, primarily longline and harpoon fisheries); and Republic of Korea (Pacific-wide longline fishery).

Pacific Fisheries

The geographic distribution of swordfish varies with seasonal changes in water temperature, but can extend from 50°N lat to 50°S lat. Preferred water temperature for swordfish is 18° to 22°C (64° to 72°F) (Nakamura *op. cit.)* and varies with size of the animal. Juveniles prefer warm water and are found only in the tropical region. Adults have a wider temperature tolerance and occupy the full distributional range, spawning in the tropics and feeding in the temperate regions. Females reach a larger maximum size than males, and can tolerate colder water and occupy the highest latitudes. The smaller adult males generally remain in warmer water close to the equator.

Adult swordfish are found throughout the year in most parts of their distributional range, except in the extreme sub-polar latitudes during the winter. They concentrate in areas where food is abundant, commonly along frontal zones where ocean currents or water masses intersect to create turbulence and sharp gradients of temperature and salinity. The fisheries for swordfish occur in these regions of frontal zones.

In the Pacific Ocean, there are five frontal zones (Sverdrup et al 1942) where swordfish are found in fishable concentrations (Fig. 5): (1) in the northwestern Pacific (Huang 1974, Sakagawa and Bell 1980), where the warm Kuroshiro Current meets the coastal waters of Taiwan and Japan, and where the Kuroshiro Extension Current meets the Oyashio Current to the north; (2) off southeastern Australia (Sakagawa and Bell *op. cit.*), where the warm East Australian Current meets intrusions of the cold Southern West Wind Drift Current; (3) off northern New Zealand (Bailey and Ross 1987), where the warm South Equatorial Current intersects with intrusions of the cold Southern West Wind Drift Current; (4) in the eastern tropical Pacific (Squire and Au 1989), where the warm

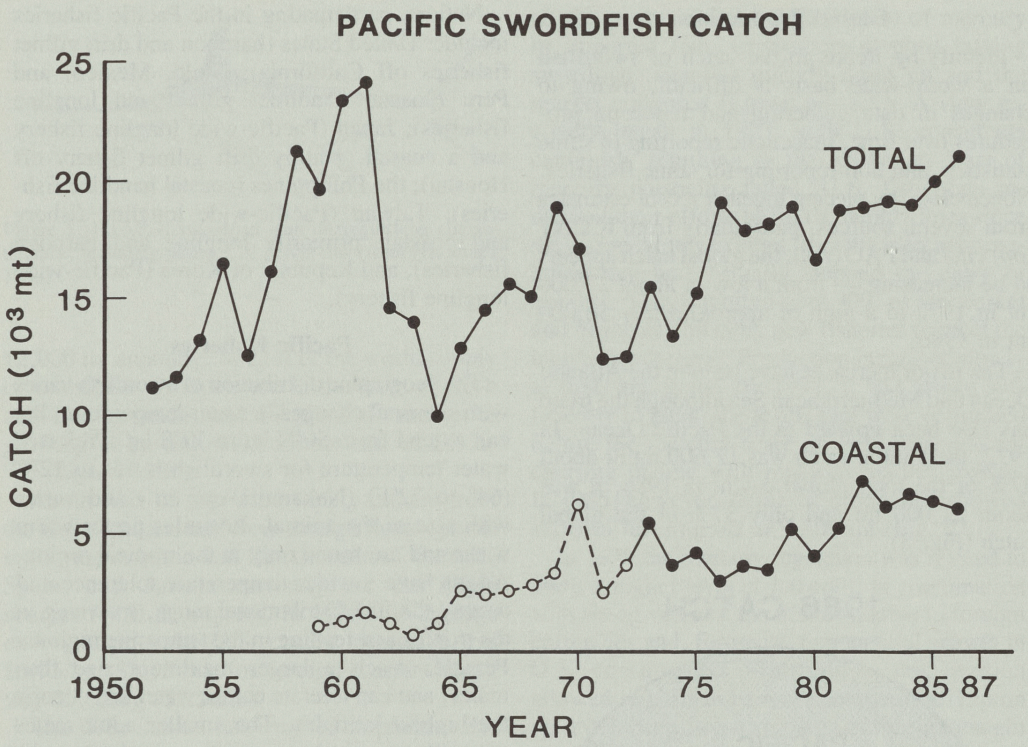

Figure 4. Total catch of swordfish from the Pacific Ocean, 1952-1987. Catches by gears, such as harpoon, drift gillnet, and longlines in coastal waters are labeled "coastal". High seas longline catches are not labeled. Open circles are estimated catches. (Source: FAO ms.)

Equatorial Counter Current intersects with the colder Peru Current; and (5) along Baja California, Mexico, and California, U.S.A. (Bedford and Hagerman 1983, Squire and Au 1989), where the cool offshore California Current intersects with intrusions along the coast of warmer water from the south.

Swordfish are caught in artisanal and other small-scale fisheries but mostly by fisheries that are large-scale commercial operations. Because swordfish forage in the surface waters during the night, inhabiting deeper depths during the day (Carey ms), catches are made principally during the night. Most of the Pacific catch of swordfish is taken incidental to fishing for other species, such as tunas, which are fished during the day. Typically, fisheries that catch significant quantities of swordfish, even incidentally as a complex of target species, are arbitrarily designated as swordfish fisheries.

This review, employed this procedure and applied it to the fisheries of Japan, Taiwan, and the U.S. The fisheries were further separated by major gear: longline, drift gillnet, and harpoon.

Japanese Fisheries

The Japanese fisheries, with total production of 14,300 mt in 1986, or 68% of the total Pacific production, are by far the most important in the Pacific Ocean. The fisheries can be separated into longline, drift gillnet, and harpoon. Each is actively managed by the Japanese government through a complex system of vessel licenses, gear limitations, and area-time regulations to reduce gear conflicts and to enhance economic viability of the fisheries. Over the years 1972 and 1985, the contribution of each fishery to the total catch has changed, with the drift gillnet fishery contributing a greater proportion, and the longline and harpoon fisheries contributing smaller proportions (Fig. 6).

Longline Fishery

The Japanese longline fishery is conducted

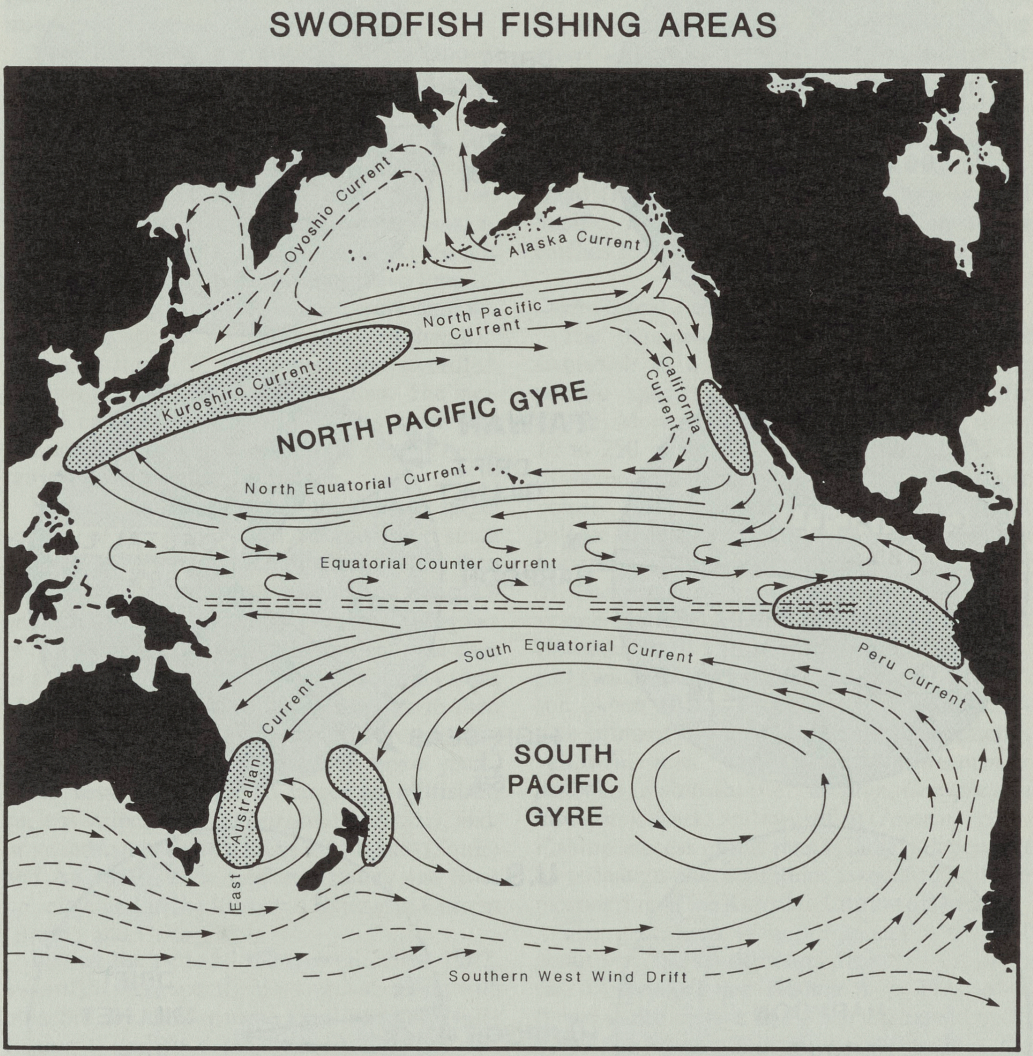

Figure 5. Location of major swordfish areas (stippled) in the Pacific Ocean. The areas correspond to zones of high production of food organisms and where major ocean currents meet.

on the high-seas using vessels of 50+ gross tons and in near-shore and coastal waters of Japan using vessels of less than 50 gross tons. The fleet consists of approximately 1,200 vessels of which about 600 may be deployed in the Pacific during a single fishing season.

The gear used by the vessels is the longline, consisting basically of a main line with float lines and branch lines with baited hooks. For the large high-seas vessels, the main line is set over a distance of 25-75 km (14-40 nmi) and fishes about 2,000 hooks during a single set.

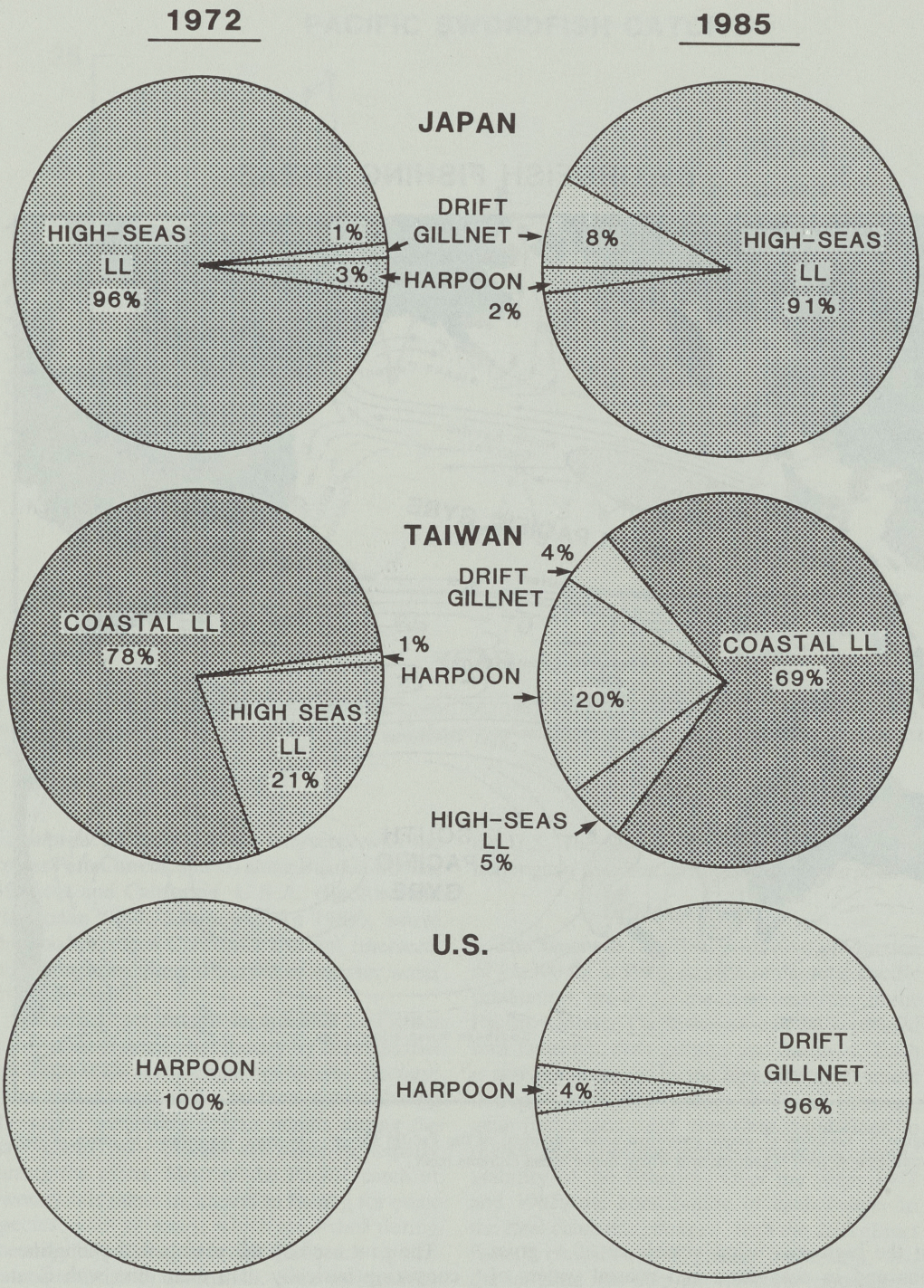

Figure 6. Comparison of percent swordfish catch by fisheries for 1972 and 1985.

Float lines are attached to the main line to regulate fishing depth, a maximum of 170 m (557 ft) for standard sets and about 300 m (984 ft) for deep sets (deep longlining). A set is normally deployed early in the morning and retrieved beginning around noon, frequently ending after midnight (Ueyanagi 1974).

Deep longlining is a relatively recent innovation that was introduced to catch the deep-swimming bigeye tuna, *(Thunnus obesus)*. Deployment started by the Japanese in about 1974 in the equatorial regions of the Pacific and Indian oceans (Suzuki et al 1977, Suzuki and Kume 1982). It spread gradually to all oceans and to other longline fleets, i.e., those of Korea and Taiwan. Because it fishes deeper, deep longlining is less efficient in catching the more shallow-swimming species — albacore *(T. alalunga)*, yellowfin tuna, *(T. albacares)*, and swordfish — than is the standard longline gear. The incidental catches of swordfish by this latter gear are probably largely made as the gear is being retrieved during the night hours.

Swordfish is not currently the primary target species of this fishery and the catch is a small proportion of the total longline catch (less than 5%). Tunas are the target species and the catch amounted to about 190,000 mt in 1986 (Sakagawa et al 1987). In past years, this was not the case as swordfish was a target species in certain areas of the Pacific Ocean and made up more than 50% of the catch in some 5×5 degree fishing areas (Bartoo and Coan 1989). In recent years, some vessels continue to target on billfishes, such as striped marlin *(Tetrapturus audax)*, and/or swordfish in limited areas off Mexico (Squire and Au 1989), New Zealand (Bailey and Ross *op. cit.)*, and in the Kuroshio Extension Current (Bartoo and Coan 1989).

During the period 1952 through about 1962, swordfish were specifically targeted, along with albacore, by the Japanese longline fleet. Night fishing at shallow depths with squid as bait was used in certain areas (Ueyanagi *op. cit.)*. The longline catch during that period reached a record high of 22,000 mt of swordfish in 1961 (Fig. 7). Since then the fishery changed to primarily day operations, using a mixture of bait types and emphasizing catching tunas for the sashimi market; swordfish catches slipped to a lower level, averaging 12,300 mt (1966-1969). In 1971, catches decreased again owing to the mercury scare and collapse of the U.S. market. Since 1975, catches have rebounded to an average of about 11,000 mt (Fig. 7).

The areal distribution of the swordfish catches for 1976 shows that swordfish were taken mostly in the northwestern region, along the edge of the Kuroshio and Kuroshio Extension Currents, off the Mexican coast, and off southeastern Australia (Fig. 8, panel B). In 1980, fishing effort was more widely distributed and for the most part targeted for bigeye tuna (Fig. 8, panel A). Significant amounts of swordfish continue to be taken in the northwestern region and in other areas where major frontal systems are located (Fig. 8, panel C). The eastern tropical Pacific, in particular, shows significant recent catches by this fishery.

Drift Gillnet Fishery

The Japanese drift gillnet fishery lands swordfish as a by-catch of fishing for other pelagic species in the northwestern Pacific Ocean. More than 1,600 vessels of varied sizes, 10 to 250 gross tons, participate in this fishery (Yonemori and Honma ms). Generally, the larger vessels operate on the high-seas and target pelagic species such as squid *(Ommastrephes bartrami)*, salmon *(Oncorhynchus* sp.), pomfret *(Brama japonica)*, and albacore. The smaller vessels operate closer to the coast off northern Honshu Island, primarily from July to October, and switch to other fisheries during the off-season (Anon 1978). This coastal component targets primarily striped marlin but also catches yellowfin tuna, skipjack tuna *(Katsuwonus pelamis)*, mahimahi (i.e., dolphin, *Coryphaena hippurus)*, sharks and swordfish (Anon *op. cit.)*. Fishing success of this fleet is largely dependent on oceanographic conditions associated with the meandering of the Kuroshio Current off Japan.

The gear used is multifilament netting of about 9 m (30 ft) deep and 18 cm (7 in) mesh size (Yonemori and Honma ms). The net is fished at the surface and a set can extend up to 12 km (6.5 nmi). Sets are usually made in the afternoon, allowed to drift during the night, and retrieved beginning before dawn.

This fishery began recording significant catches of swordfish in the mid-1970s (Fig. 7). Catches increased sharply to a peak of 3,500 mt in 1976, declined to 1,000 mt in 1979 and remained fairly level since then.

Harpoon Fishery

The Japanese harpoon fishery targets striped marlin and takes blue marlin *(Makaira nigri-*

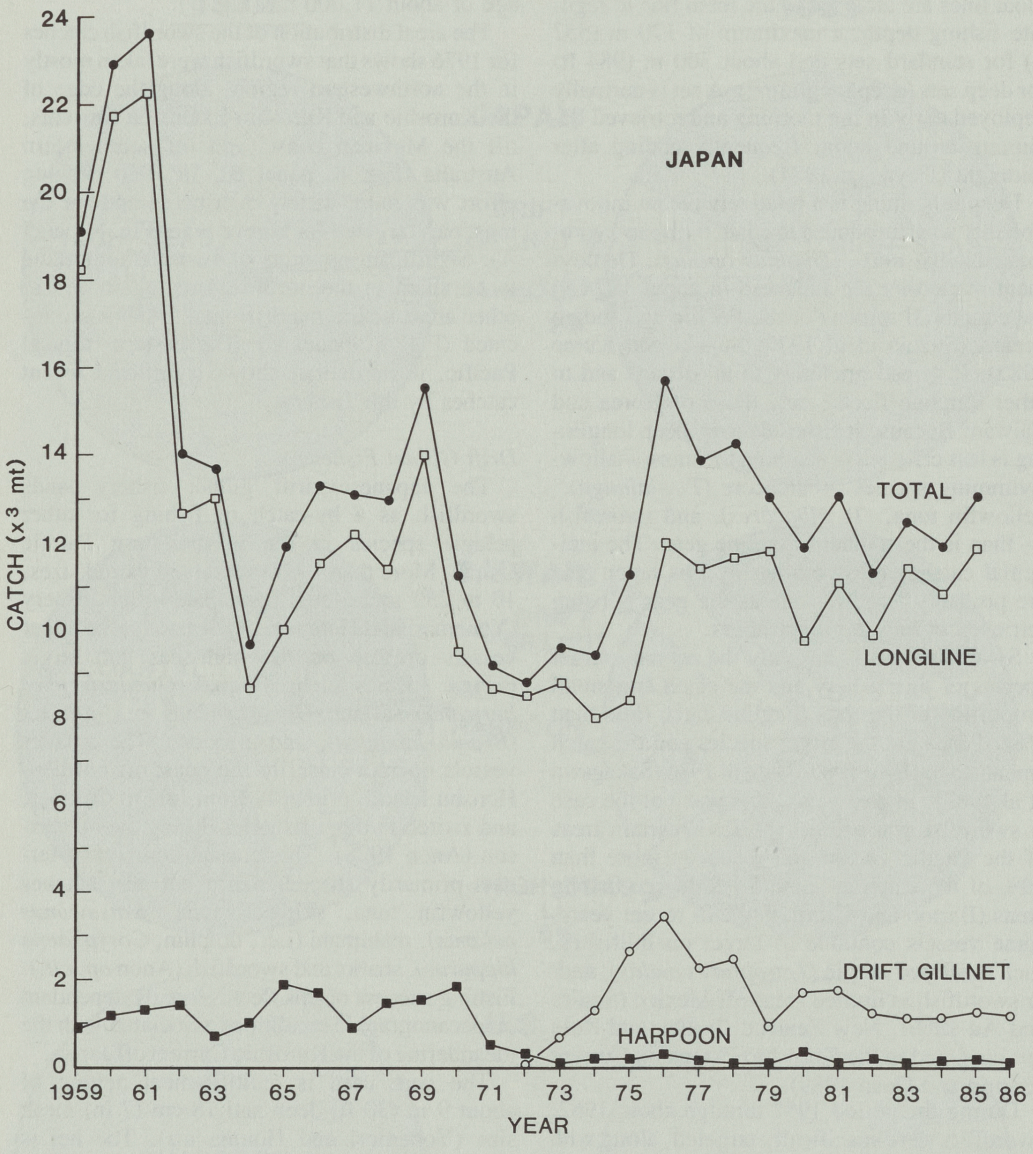

Figure 7. Catch of swordfish by gear for the Japaneses fisheries, 1959-1986. (Sources: FAO ms, Y. Watanabe pers. comm.)

cans), and swordfish incidentally. Because fishing with harpoons requires calm seas for visually sighting the basking fish, and for positioning the vessel within striking distance of the fish, oceanographic conditions, particularly associated with the Kuroshio Current, dictate the fishing season (Sawadaishi 1985). Typically, this fishery is active from December to May. The fishing areas are in the Bonin and Izu Islands (south of Tokyo) and off the northern coast of Honshu Island (off Miyako).

About 100 boats of less than 20 gross tons (mainly 3 to 15 gross tons) participate in this fishery. Most boats are active in harpooning only during December to May, squid jig fishing during the rest of the year (Y. Watanabe pers. comm.).

The gear used is a three-prong electric-dart

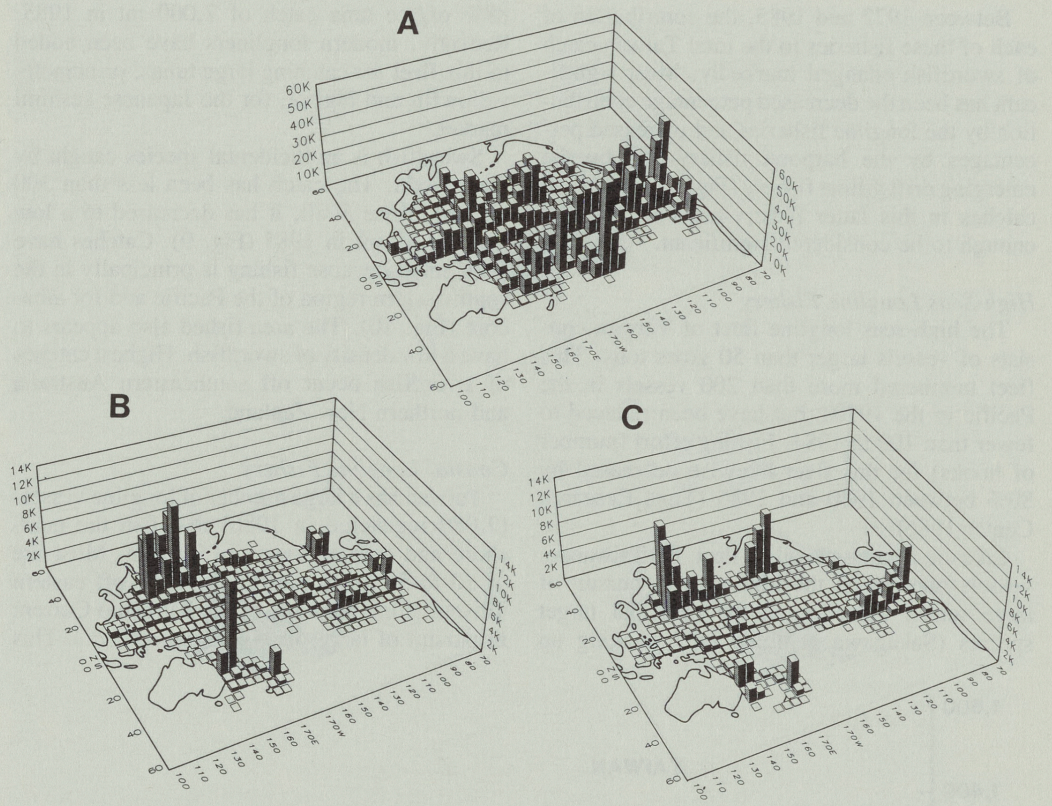

Figure 8. Areal distribution of catches (in numbers) for the Japanese longline fishery in the Pacific Ocean. Panel A is catches of bigeye tuna, the principal target species for 1980. Panel B is catches of swordfish for 1976, a year of exceptional high catches. Panel C is catches of swordfish for 1980, a recent year.

harpoon (Sawadaishi *op. cit.*). The pole is 5 m (16 ft) long and 4 cm (1.6 in) in diameter, of oak or reinforced plastic. Fastened to the tip of the pole is a steel attachment with three prongs, each holding a removable dart. The dart is 8 to 12 cm (3.1 to 4.7 in) long, arrow shaped and made of steel. Holes in the shank of the dart allow attachment of electrical wiring and the main line of 4 to 5 mm (0.16 to 0.2 in) diameter rope. The opposite end of the electrical wire is attached to a storage battery located in the engine room of the vessel.

Operationally, fish are sighted from the crow's nest. The vessel maneuvers to the target, and the harpooner on the bow plank is positioned. The harpooner throws the harpoon by hand. The harpoon tips embed in the fish and separate from the pole while the main line, with electrical wire, is played out as the fish tries to escape. The electrical shock is administered and the dead fish is retrieved.

The swordfish catch of this fishery ranged from a high of 1,700 mt in 1970 to a low of about 100 mt in 1986 (Fig. 7). In 1971, the catch fell substantially (−71%) and has not recovered. Because this low catch corresponds to the period of increased activity of the drift gillnet fishery, the harpoon fishery appears to compete directly with the drift gillnet fishery for available swordfish in the coastal waters.

Taiwanese Fisheries

Taiwanese fisheries contributed an estimated 700 mt, or 3% to the total Pacific swordfish catch in 1986. They are not major fisheries, but are reviewed here because Taiwan is a major exporter of swordfish to the U.S. market and Taiwan has a major world-wide longline fleet. Taiwanese fisheries that catch significant amounts of swordfish are the high-seas longline, coastal longline, and harpoon fisheries.

Between 1972 and 1985, the contribution of each of these fisheries to the total Taiwan catch of swordfish changed markedly. Most significant has been the decreased percentage contribution by the longline fisheries and increased percentages by the harpoon fishery and by the emerging drift gillnet fishery (Fig. 6). Swordfish catches in this latter fishery are not yet large enough to be considered significant.

High-Seas Longline Fishery

The high-seas longline fleet of Taiwan consists of vessels larger than 50 gross tons. This fleet numbered more than 200 vessels in the Pacific in the 1970s, but have been reduced to fewer than 100 in 1984. Fishing effort (number of hooks) for this fleet likewise decreased by 80% between 1980 and 1985 (Tuna Research Center 1986).

Like the Japanese longline fleet, the Taiwanese vessels operate on the high-seas in pursuit of large tunas. Albacore is the principal target species (Sakagawa et al *op cit.),* making up 88% of the tuna catch of 7,000 mt in 1985. Recently, modern longliners have been added to this fleet for catching large tunas, principally yellowfin and bigeye, for the Japanese sashimi market.

Swordfish is an incidental species caught by the vessels. The catch has been less than 300 mt and, since 1980, it has decreased to a low level of 40 mt in 1985 (Fig. 9). Catches have been small because fishing is principally in the southwestern region of the Pacific and for albacore (Fig. 10). The area fished also appears to have a low density of swordfish. Highest catches of swordfish occur off southeastern Australia and northern New Zealand.

Coastal Longline Fishery

Taiwan has a large number of longline vessels (2,080 registered in 1986) that fish the nearshore and coastal waters of Taiwan. Most are of 20 to 50 gross tons and operate off eastern Taiwan along the edge of the Kuroshio Current in pursuit of large tunas (Huang *op. cit.).* This

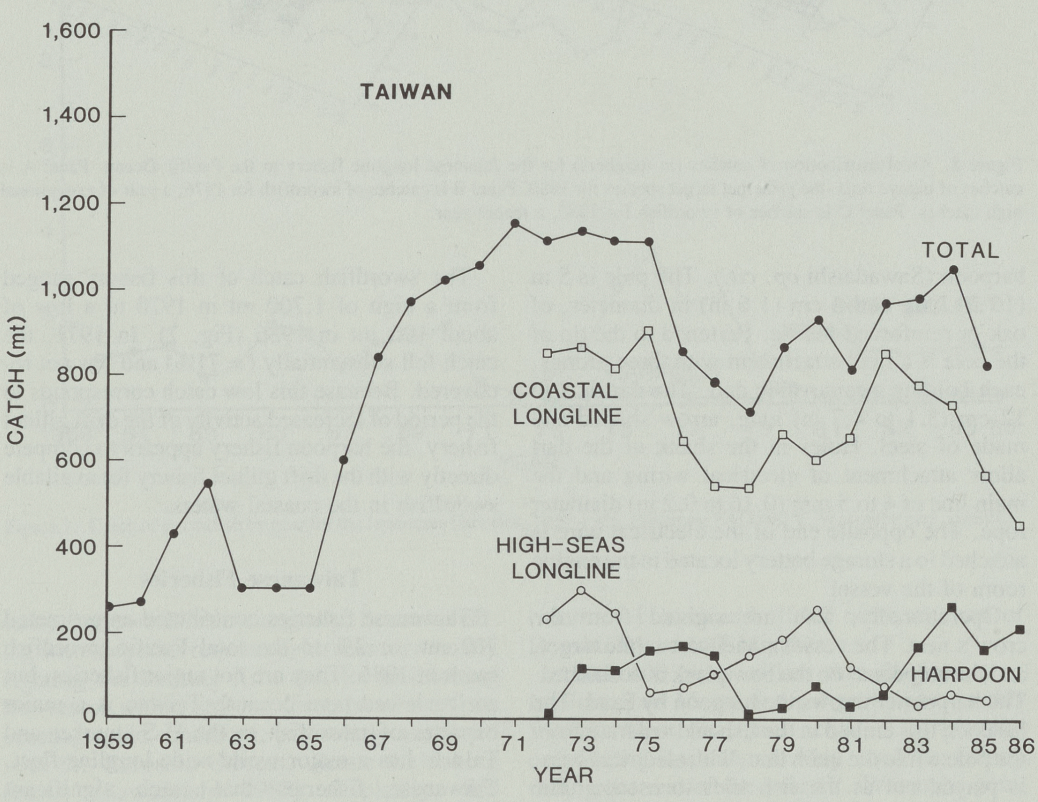

Figure 9. Catch of swordfish by gear for the Taiwanese fisheries, 1959-1986. (Sources: Tuna Research Center 1986, FAO ms, H.C. Liu, pers. comm.)

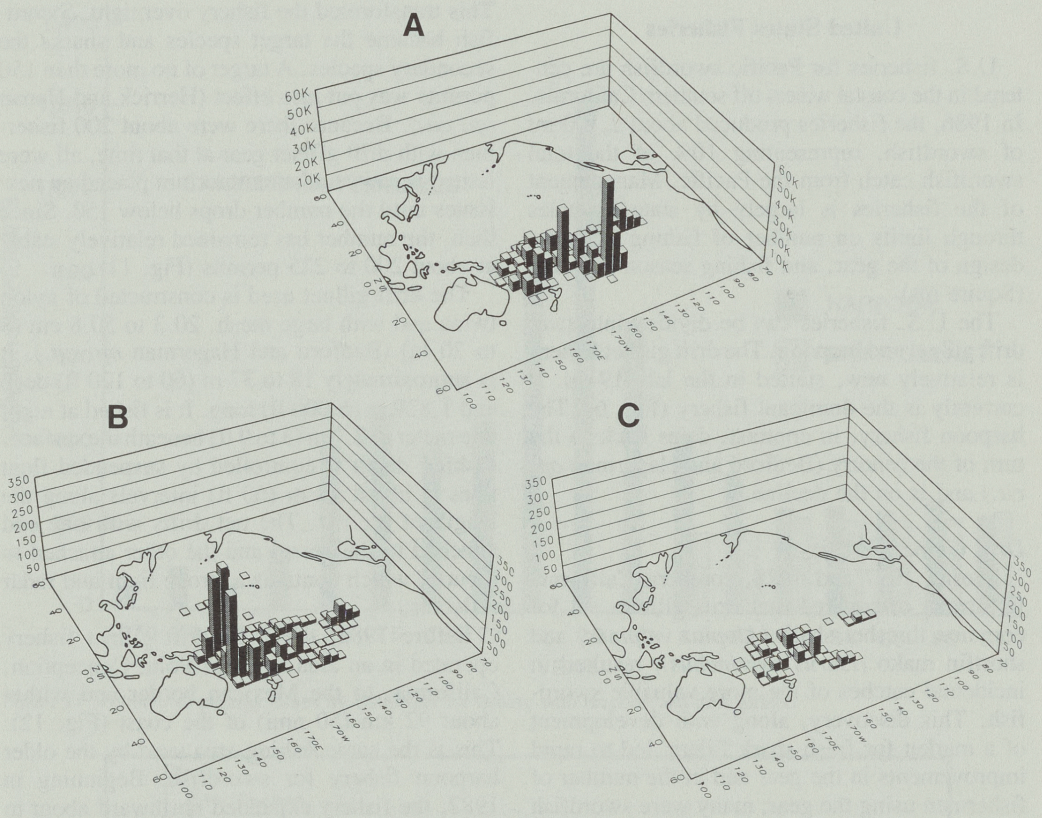

Figure 10. Areal distribution of catches (in numbers) for the Taiwanese longline fishery in the Pacific Ocean. Panel A is catches of albacore, the principal target species for 1985. Panel B is catches of swordfish for 1977, a year of exceptionally high catches. Panel C is catches of swordfish for 1985, a recent year.

fleet catches significant amounts of billfishes, including swordfish, and other large pelagic species as a by-catch.

The swordfish catch of this coastal longline fishery has fluctuated between 500 mt and 900 mt (Fig. 9). Since 1982, the trend has been downward, with the catch reaching a record low of 500 mt in 1986. Among the billfishes caught in this fishery, swordfish ranks low at 14%, behind blue marlin at 35%, and sailfish *(Istiophorus platypterus)* at 24% (Table 1).

Harpoon Fishery

Harpoon fishing for billfishes was introduced into Taiwan by the Japanese in 1913 (Huang *op. cit.)*. In 1986, a total of 390 vessels participated in this fishery. They operated primarily in the eastern region of Taiwan, from the southern ports of Kaohsiung and Taitung and from the northern port of Keelung.

Unlike the Japanese harpoon fishery, this fishery appears to target a complex of billfishes, with swordfish ranking low (Table 1). Blue marlin, sailfish, and black marlin *(Makaira indica)* are principal target species. Catches of swordfish were low during 1978-1982, at less than 100 mt annually (Fig. 9). Since then, it appears to have stabilized at the 200 mt level.

Table 1. Average (1980-1985) catches of billfishes by species in the billfish catch of Taiwanese fisheries. (Source: H.C. Liu pers. comm.)

	Billfish species					
Fishery	Swordfish	Striped marlin	Blue marlin	Black marlin	Sailfish (others)	Total
High-seas longline						
Catch (mt)	94	145	236	19	15	509
Percentage	18	29	46	4	3	100
Coastal longline						
Catch (mt)	699	524	1,695	773	1,144	4,835
Percentage	14	11	35	16	24	100
Harpoon						
Catch (mt)	120	147	585	524	554	1,930
Percentage	6	8	30	27	29	100
Total						
Catch (mt)	913	816	2,516	1,316	1,713	7,274
Percentage	12	11	35	18	24	100

United States Fisheries

U.S. fisheries for Pacific swordfish are centered in the coastal waters off southern California. In 1986, the fisheries produced about 2,100 mt of swordfish, representing 10% of the total swordfish catch from the Pacific. Management of the fisheries is largely by state agencies through limits on number of fishing licenses, design of the gear, and fishing season and area (Squire ms).

The U.S. fisheries can be divided into two: drift gillnet and harpoon. The drift gillnet fishery is relatively new, started in the late 1970s. It currently is the dominant fishery (Fig. 6). The harpoon fishery, in contrast, dates back to the turn of the century (Bedford and Hagerman *op. cit.)* and is on the decline.

Drift Gillnet Fishery

During 1977 and 1978, southern California fishermen discovered that drift gillnets set for common thresher shark *(Alopias vulpinus)* and shortfin mako *(Isurus oxyrinchus),* resulted in incidental catches of the more valuable swordfish. This discovery, along with development of a market for fresh shark fillets, led to rapid improvements in the gear and in the number of fishermen using the gear; many were swordfish harpoon fishermen, as well. By 1980, a full-fledged modern drift gillnet fishery targeting sharks, with significant catches of swordfish, was in operation.

Opposition mounted to this new fishery (Herrick and Hanan 1988). Opposition forces were concerned with the adverse effects on other commercial and recreational fisheries as well as protection of marine mammals and seabirds that get entangled in the gear. As a result, a series of laws was enacted by California to control the drift gillnet and other similar net fisheries.

Most significant of the new laws was one requiring revocable, nontransferable permits for all drift gillnet fishermen, and which specified qualifications for obtaining them. It also required permit holders to submit logbooks and to allow observers on fishing trips.

Another significant piece of legislation was passed in 1982 in recognition of the significant amounts of swordfish taken in drift gillnets and concern over excessive effort on the shark resource (Herrick and Hanan *op. cit.).* The legislation allowed for targeting swordfish with drift gillnets and placed a limit on number of licenses. This transformed the fishery overnight. Swordfish became the target species and sharks the secondary species. A target of no more than 150 permits was put into effect (Herrick and Hanan *op. cit.).* Because there were about 200 fishermen with drift gillnet gear at that time, all were issued permits and a moratorium placed on new issues until the number drops below 150. Since then, the number has remained relatively stable at about 200 to 225 permits (Fig. 11).

The drift gillnet used is constructed of nylon twine and with large mesh, 20.3 to 50.8 cm (8 to 20 in) (Bedford and Hagerman *op. cit.).* It is approximately 18 to 37 m (60 to 120 ft) deep and 1,829 m (6,000 ft) long. It is fished at night one meter to 2.7 m (3 to 9 ft) beneath the surface. Fishing depth is controlled by suspended float lines at about 18 m (60 ft) intervals along the length of the net. The net drifts with one end attached to the vessel and the other attached to a buoy, which contains a strobe light and radar reflector.

Before 1982, the U.S. drift gillnet fishery operated in an area south of Point Conception, California, to the Mexican border and within about 92 km (50 nmi) of the coast (Fig. 12). This is the same fishing area used by the older harpoon fishery for swordfish. Beginning in 1982, the fishery expanded northward about to San Francisco and, in some years, even farther northward to waters off Oregon and Washington (Fig. 13). Fishing in the most northern part is almost exclusively for sharks and only rarely results in swordfish catches; hence, swordfish fishing by the fleet can be considered limited to waters off California.

The fishing season is regulated and extends from May to February. Within this season, the distribution of fishing effort is bimodal, May and October (Fig. 14). Approximately 80% of the fishing takes place, however, during August through January, when 99% of the catch is made.

Most of the catch (75%) is made in the area south of Point Conception, with exceptional catches made off San Diego, between Catalina Island and the mainland (off Los Angeles), and southeast of Anacapa Island in the Santa Barbara Channel Islands (Fig. 15). North of Point Conception, the catch is relatively small (about 6,000 fish in the 1984-1985 season) and there is only one exceptionally high catch area, off San Francisco. Fishing effort is also reduced in this northern area owing to poor ocean condi-

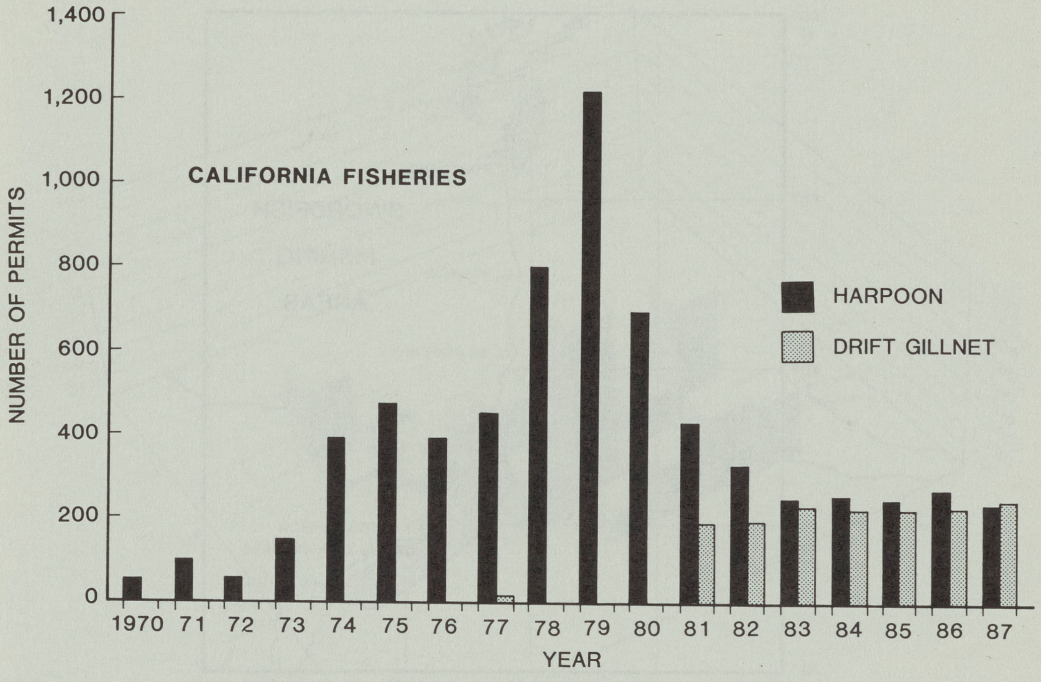

Figure 11. Number of permits issued by California for fishing with harpoon and drift gillnet.

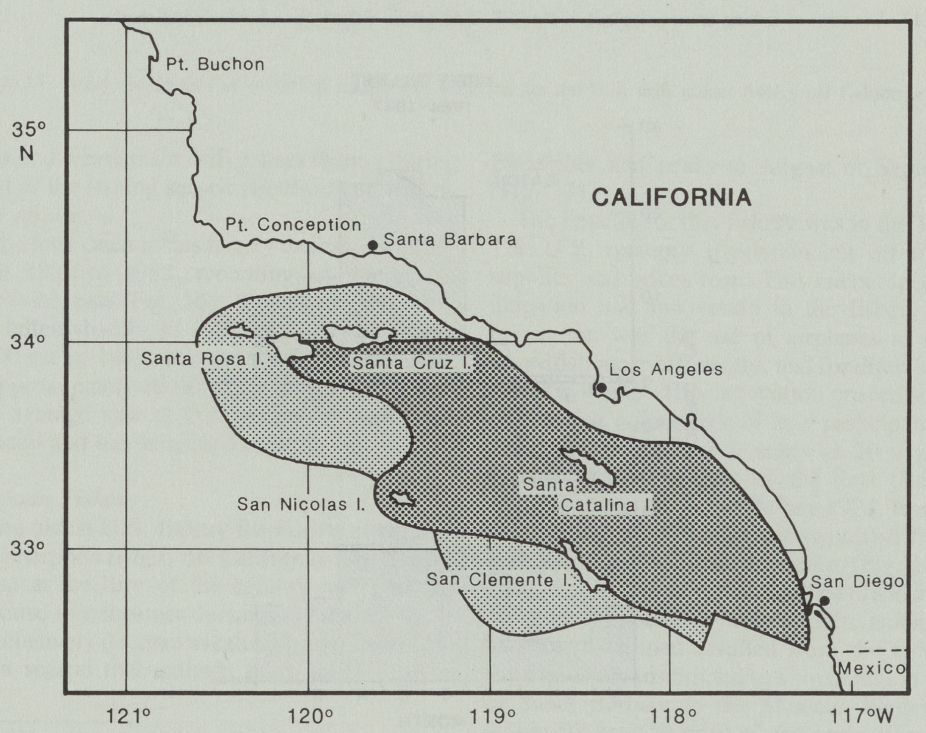

Figure 12. Location of fishing areas of the U.S. harpoon fishery (dark stipple) and drift gillnet fishery (light stipple) for swordfish off California.

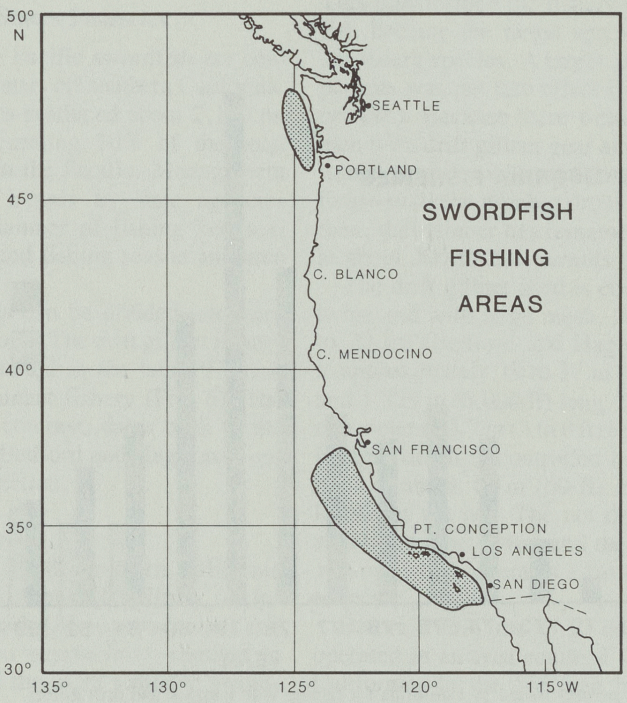

Figure 13. Location of fishing areas (stippled) of the U.S. drift gillnet fishery for swordfish and sharks.

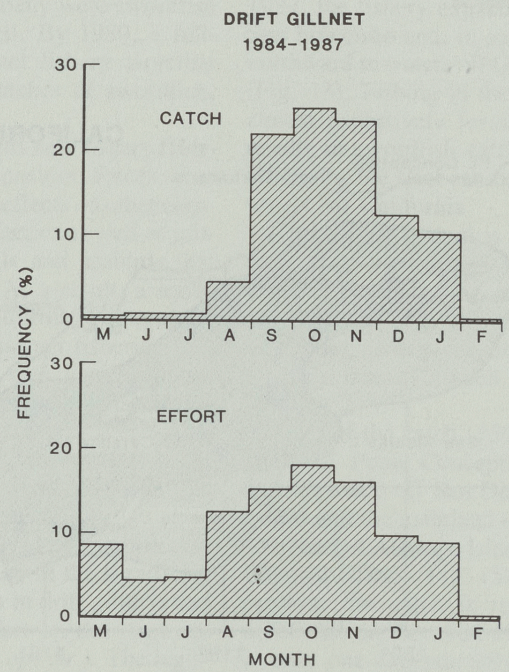

Figure 14. Seasonal distribution of swordfish catch and fishing effort for the U.S. drift gillnet fishery. (Source: D. Bedford pers. comm.)

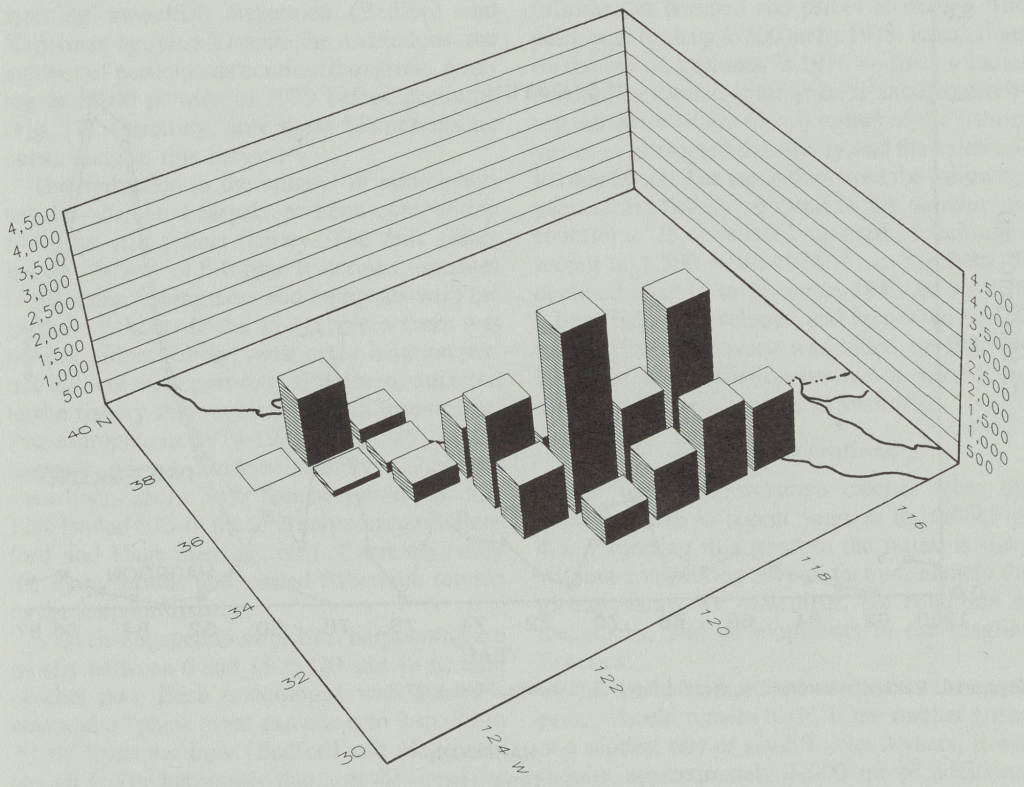

Figure 15. Areal distribution of swordfish catches (in numbers) for the U.S. drift gillnet fishery off California, 1985.

tions and weather for drift gillnet fishing during most of the fishing season (Bedford and Hagerman *op. cit.)*.

The total catch in this fishery increased steadily from 1980 to 1985, recording an impressive 890% increase (Fig. 16). Since then, the catch has fallen sharply to 1,900 mt in 1986 and to 1,400 mt in 1987, despite stable fishing effort of approximately 10,000 days fished per season. The average size of fish caught has not been affected and has remained stable[1].

Harpoon Fishery

The oldest U.S. fishery for Pacific swordfish is the harpoon fishery off California. The fishery began at the turn of the century and grew in response to consumer demand for swordfish. It is exclusively devoted to catching swordfish during a season that extends from about June to December and peaks in August or September (Fig. 17).

The heyday for this fishery was in the 1970s. The U.S. mercury regulation cut off foreign supplies and prices rose. This encouraged participation and innovation in the fishery. One innovation was the use of airplanes to locate swordfish more efficiently, and for directing the harpoon vessel. This innovation proved so successful that a flood tide of new participants entered the fishery and as many as 20 airplanes were engaged full time by the fleet (Bedford and Hagerman *op. cit.)*. Before 1974, less than 150 persons held permits for swordfish fishing with harpoons in California waters (Fig. 11). In 1974, the number more than doubled to about 400.

Fierce competition and conflicts among the harpoon fishermen resulted from the fact that the fishing area is limited to a small region south of Santa Barbara to the Mexican border and within 92 km (50 nmi) of the coast (Fig. 12). To reduce the conflict, beginning in 1976, restrictions were placed on the use of aircraft for

[1] Available data on dressed length of swordfish average about 1.5 m (5 ft) annually in 1984 to 1988 (D. Bedford pers. comm.).

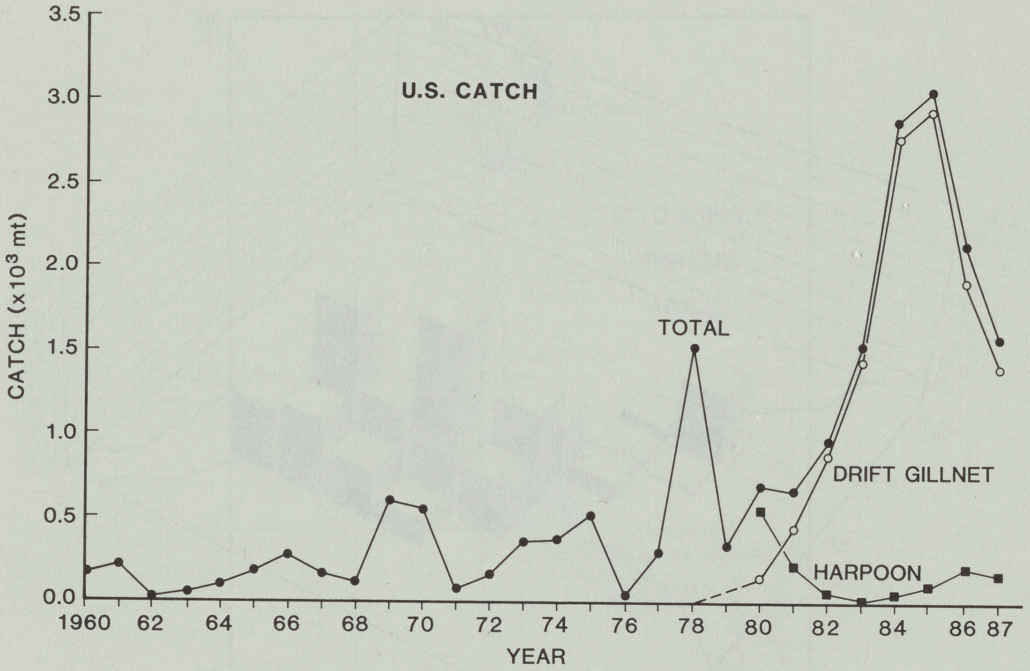

Figure 16. Catch of swordfish by gear for the U.S. fisheries, 1960-1987.

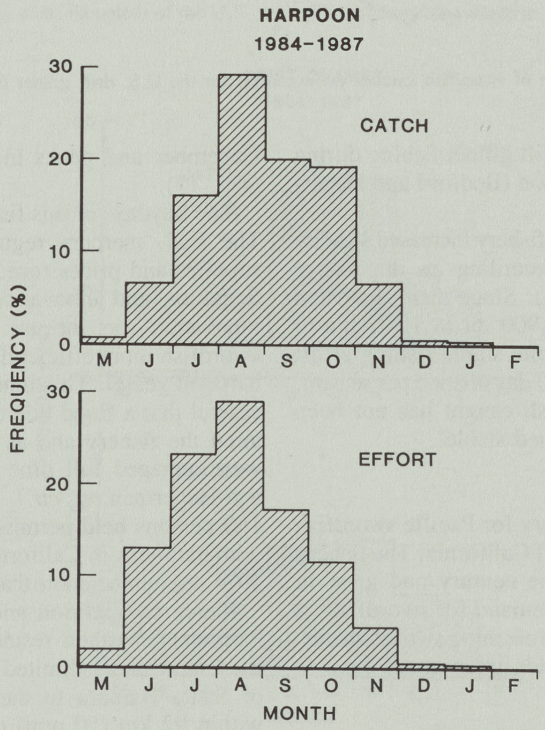

Figure 17. Seasonal distribution of swordfish catch and fishing effort in the U.S. harpoon fishery. (Source: D. Bedford pers. comm.)

assisting swordfish fishermen (Bedford and Hagerman *op. cit.)*. Despite the restrictions, the number of participants continued to grow, peaking at 1,200 permits in 1979 before declining (Fig. 11). Currently, only about 225 permits are outstanding in this fishery.

This reduction in the number of participants can be attributed largely to keen competition from the drift gillnet fishery. The drift gillnet fishery, largely of full-time fishermen, operates in the same fishing area and competes with the harpoon fishery. In the 1970s, when there was no drift gillnet fishery, most of the harpoon permit holders were part-time fishermen, attracted to the fishery that required modest investment. For example, in 1974-1978, only 52% of the harpoon permit holders actually fished for swordfish, about 34% caught swordfish, and 12% landed 50% of the total harpoon catch (Bedford and Hagerman *op. cit.)*. Currently, only the more serious and skilled fishermen remain in the harpoon fishery.

Vessels engaged in swordfish harpooning are mostly between 6 and 15 m (20 and 49 ft) long (Weber ms). Each is equipped with a crow's nest and a "plank" that extends 6 to 9 m (20 to 30 ft) from the bow (Bedford and Hagerman *op. cit.)*. The harpooner stands at the tip of the plank in a "pulpit" and throws the harpoon by hand at the target.

The harpoon consists of a pole of tubular steel construction with an attachment at one end for holding a removable brass or bronze arrow-shaped dart of about 10 cm (4 in.). Holes in the shank of the dart allow attachment of the main line of nylon rope. About 91 m (300 ft) of main line are used, with several neoprene floats or solid PVC balls and a marker-flag attached at the end.

When a fish is harpooned, the main line, floats, and marker-flag are thrown overboard. The fish is allowed to tire from dragging the line, floats, and marker flag, while the vessel pursues other targets. After about 2 to 3 hours, the vessel returns to retrieve the line and fish (Weber ms). The catch is dressed — gutted, head removed back of the cleithrum, and fins trimmed — and stored on ice at sea. Similar dressing of the catch at sea is done by the drift gillnet fishermen.

The catch of the harpoon fishery was at a high point of 600 mt in 1969 and 1970 just before the mercury scare (Fig. 16). The catch collapsed to less than 100 mt in 1971. Recovery followed as demand and prices increased. The catch built back up to 500 mt by 1975. Restrictions on the use of airplanes in 1976 — first as a total ban but, by the end of the year, relaxed to searching outside of 8 km (5 mi) radius of the fishing vessel — disrupted the fishery and the catch fell to only 50 mt. The catch improved the following year as the fishery adjusted to the airplane restrictions. It continued upward, reaching a record of 1,500 mt in 1978. From this peak, it declined sharply to 30 mt in 1983 as the drift gillnet fishery developed and recovered to 160 mt in 1987. Recovery was aided in 1985 by lifting of the restriction on use of aircraft for directing harpoon vessels to swordfish.

Trends and Outlook

The trend of swordfish catches from the Pacific Ocean in recent years is upward (Fig. 4.). Projecting this trend to the future is risky without considering several factors, namely the global market for swordfish, the condition of the stocks, and developments in the longline fisheries.

The world market for swordfish is strong, so prices should remain high. If the market grows at a modest rate of say 5% over 3 years, it will require approximately 1,000 mt of additional swordfish per year, above the 56,000 mt caught worldwide in 1986, to meet the demand.

The Pacific Ocean stocks are in sufficiently good condition (Bartoo and Coan *op. cit.)* to contribute to such an increase. Other major stocks, such as those in the Atlantic Ocean and Mediterranean Sea, are not as healthy. They are showing signs of overfishing, with large numbers of small fish making up the catch (ICCAT *op. cit.)*. These stocks, therefore are not likely to contribute substantially to future increased world supply. In fact, total yield from them could decrease in the long run if stock conditions worsen and the fleets remove smaller fish. Such a decrease will exert pressure on the Pacific fisheries to make up the shortfall.

Except for some coastal fisheries, such as the U.S. fisheries, the Pacific fisheries generally do not target swordfish. Most of these fisheries target tunas and take swordfish as a by-catch; consequently, the markets for tuna will dictate how these fisheries operate and the level of by-catch. The U.S. fisheries target swordfish, and production and catch per unit of effort are declining owing largely to the limited area for suitable operation of the gears and fishing restrictions.

The outlook for coastal fisheries for swordfish is not good, judging from experiences with similar coastal fisheries in the Atlantic Ocean (Caddy 1976). Production is likely to decrease or stall at current levels unless the fisheries expand and exploit additional segments of the stock outside the traditional fishing areas. This will be difficult to do because the fishable areas where the gears are most effective are limited.

In contrast, the longline fisheries of the Pacific have the greatest potential for improved catches of swordfish. Longline fishing effort currently targets the more abundant tunas for the high-value markets, particularly the Japanese sashimi market. This Japanese sashimi market is limited and undergoing strains because of oversupply and instability of prices (Yamashita ms). Discussions among the major suppliers, i.e., Japan, Korea, and Taiwan, are being held to bring stability to the market. If successful, longline fishing effort on tunas could be cut back and the excess effort directed towards other species such as swordfish. Targeting longline effort to swordfish can be easily done by night fishing in certain areas.

As for the outlook of U.S. production of Pacific swordfish, the trend is downward or leveling off. Production is severely limited because the current gears, drift gillnets and harpoon, are effective only in a limited coastal area. Although current state laws allow for experimental gear permits, the restrictions on them and on use of alternative gears, including longlines, and on incidental catches, discourage innovation in catching and landing swordfish (Squire ms). Lacking modification of these restrictions, there is little incentive for investment in new ways to expand the fisheries and increase U.S. production of swordfish from the Pacific Ocean.

Summary

Swordfish are caught in significant amounts only by commercial fishermen. In the Pacific, the catch peaked at 24,300 mt in 1961. The discovery in 1970 of high levels of mercury in swordfish steaks resulted in reduced consumer demand and the catch declining to 11,000 mt in 1971. This decline was short lived, however, as demand returned and production increased to 21,000 mt in 1986.

Approximately 70% of the Pacific swordfish catch is taken with longline gear that is directed at catching tunas, while 30% is taken by surface fishing gears, such as harpoon, drift gillnets, and handlines, directed at catching large pelagic species. Hence, there is little directed fishing for swordfish except for the U.S. fisheries. Both drift gillnets and harpoons are used in the U.S. fisheries off southern California to target swordfish. The total catch for these fisheries was 2,600 mt in 1986 and 1,600 mt in 1987. About 96% of this catch is made by the drift gillnet fishery.

The outlook for the Pacific fisheries is mixed. The world market for swordfish is strong, so prices should remain high. Greater yields appear to be available from the Pacific swordfish stocks as they are in good condition. Increased production by coastal fisheries operating in traditional areas, however, appears unlikely owing to limitations of the gears and suitable fishing areas. In contrast, longline fisheries have considerable potential for increased catches of swordfish. The current fisheries are largely day-fishing operations and directed at catching tunas. They can be redirected to night-fishing operations in certain regions to target swordfish.

For the U.S., the outlook is not good. Pacific swordfish production is severely limited because the gears used are effective only in a limited coastal area. Furthermore, government restrictions on use of alternative gears and on incidental catches discourage efforts to expand the fisheries and increase production.

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Trends in the Fisheries for Billfishes in the Indian Ocean

Eric G. Silas

The First International Billfish Symposium, held in 1972, made hardly a passing reference to the billfishes from the Indian Ocean. Billfishes though non-target species, are closely linked with the vagaries of the commercial tuna longline fishery. They are also landed in the coastal artisanal fisheries by gillnetting, trolling, and longlining. A newly emerging area is ocean sport fishing which, in some countries such as Kenya, Mauritius, and Seychelles, is linked with the tourism industry. Since 1982, there has been a sea change in the pattern of tuna fishing with the explosive development of purse seining in the western Indian Ocean. As a result, the skipjack tuna *(Katsuwonus pelamis)* catch of 30,000 mt in 1979 had increased to 140,000 mt in 1985. Similarly the yellowfin tuna *(Thunnus albacares)* catch, which up to 1980 varied from 25,000 to 50,000 mt, shot up to 104,000 mt in 1985. This new development can cause changes in the trend of longline fishing in some of the geographical areas of the Indian Ocean, initiated in 1952 by Japan. Taiwan and the Republic of Korea (ROK) entered the longline fishery in the Indian Ocean in 1962 and 1967, respectively.

The increase in longline fishing effort from 1952 stablized after two decades. Suda (1973) deliniated three phases in the Indian Ocean longline fishery, the first from 1952 to 1958, when Japanese longliners extended operations to cover most of the tropical waters and the western Indian Ocean. Phase II, from 1959 to 1966, witnessed a shift in the effort of Japanese fleets toward the southern Indian Ocean, along with a slow increase in fishing effort. Phase III, from 1967 to 1970, saw a rapid rise in fishing effort without any substantial increase in the catch, and an expansion of longline fishing activity by Taiwan and ROK. It is not wrong to say that this phase had continued on to 1975, whereafter a number of coastal and island States declared their EEZs. Thenceforth, to 1981, constitutes a phase when the distant-water fishing nations had to make joint ventures and other bilateral arrangements with some of the Indian Ocean countries for continuing or further expanding their operations, mainly for longline fishing. The next phase, 1982 to 1987, involved the significant development of purse seining for tuna, especially in the western Indian Ocean. By 1985, the catch of yellowfin tuna by purse seine exceeded the catch of the species by longline fishing. The likely interactions of this spectacular development with the non-targeted billfish catch is discussed later.

Trends of Exploitation of Billfish Stocks

The status of the stocks of billfishes in the Indian Ocean for the period up to 1979 has been summarized by Silas and Pillai (1982). Significant contributions are by Ueyanagi (1974), Sharp (1979), Weatherall et al (1979), and Yoshida (1981). The five-yearly average ('000 mt) of estimated catch of billfishes by longline from the Indian Ocean, based on annual catch statistics reported by FAO for 1965-1979, and the Indo-Pacific Tuna Program (IPTP) for 1985, are as follows:

Year	Striped marlin (MLS)	Blue marlin (BUM)	Black marlin (BLM)	Swordfish (SWO)	Sailfish (SAI)
1965-69	4.2	5.1	1.0	2.1	1.5
1970-74	1.7	1.2	1.0	1.5	0.9
1975-79	2.0	1.6	0.5	1.7	0.7
1985 (annual)	1.3	1.5	0.4	2.9	0.1

A decline in the catches from the late sixties is clearly evident. It is also necessary to look at the trend in production of species of billfishes (% contribution) in the light of shifting national

priorities of the longline fleets of the distant-water nations, also resulting partly from the establishment of EEZs by some of the coastal and island States. (Source FAO 1980 a):

Species	Country	Years			
		1966	1971	1976	1979
Sailfish	Japan	92.6%	59.3%	32.2%	81.5%
(Istiophorus	Taiwan	7.3	26.6	43.4	9.5
platypterus)	ROK	0.2	14.1	23.3	8.9
Black marlin	Japan	86.3	48.8	42.0	49.1
(Makaira indica)	Taiwan	13.5	33.5	16.3	50.9
	ROK	0.3	17.7	22.6	—
Blue marlin	Japan	87.9	39.5	29.8	16.2
(M. nigricans)	Taiwan	11.9	29.5	22.6	0.1
	ROK	0.2	21.0	48.6	83.7
Striped marlin	Japan	93.7	47.8	20.8	68.0
(Tetrapturus	Taiwan	6.3	34.1	34.1	9.4
audax)	ROK	0.1	18.1	45.1	22.6
Swordfish	Japan	86.3	50.5	28.1	18.6
(Xiphias gladius)	Taiwan	13.5	32.3	34.7	52.0
	ROK	0.2	17.1	37.2	29.4

The total annual catch of billfishes in the longline fishery during 1965-1979 fluctuated between 6,000 mt (1973) and 17,700 mt (1967). From the minimum in 1973, it had revived to 11,550 mt in 1979. The 1985 longline catch (IPTP 1986) reflected a decline to 8,439 mt. Between 1980 and 1986, the total annual production of billfishes from all gears, inclusive of the artisanal sector, ranged from about 9,800 mt (1980) to about 15,900 mt (1986) averaging 12,000 mt annually. Since only 14 countries are reporting catch details to IPTP, there is bound to be some inadequacy of data (Tables 1 and 2).

Species-wise Fluctuations

The striped marlin catch fluctuated between 1,100 mt in 1973 and 4,700 mt in 1969. A shift of effort by Japanese longline fleets toward the southern Indian Ocean, where striped marlin are scarce, could be a contributing cause for the decline in MLS catches during the late sixties and early seventies. With the ROK fleet filling in this gap, however, by 1979, the production of MLS had recovered to about 3,150 mt. The 1985 catch was 2,297 mt.

The annual production of blue marlin varied between 1,500 mt (1976) and 4,074 mt (1967), the 1979 and 1985 catch, being only 1,640 and 1,500 mt, respectively.

The total catch of black marlin ranged between 343 mt (1977) and 2,460 mt (1968), paralleling the trend seen for blue marlin, the 1979 and 1985 productions being 367 and 365 mt, respectively.

The sailfish catch fluctuated between 334 mt (1979) and 1,972 mt (1967). Due to a lumping of this species with the shortbill spearfish *(Tetrapturus angustirostris)* by Japanese fishermen, the longline catch data for sailfish will be biased. The 1979 and 1985 productions were estimated at 1,174 mt and 115 mt, respectively.

The total catch of swordfish in the longline catch fluctuated between 1,220 mt (1977) and 2,315 mt (1978). It was 2,200 mt and 2,090 mt in 1979 and 1985, respectively.

Status of Billfish Stocks

Howard and Starck II (1975), Pillai and Ueyanagi (1977), and Honma and Ueyanagi (1979) have discussed the status of the billfish stocks taken by longline from the Indian Ocean. One fact emerging out of this is that reliable stock assessments of these fishes were difficult on account of the mixed reporting of landings of BUM and BLM, and SAI and shortbill spear-

Table 1. Billfish landings (tonnes) from the Indian Ocean (1980-1986).*

	1980	1981	1982	1983	1984	1985	1986	Average
Blue marlin	2440	2692	2416	3146	3410	3397	2613	2873
(%)	24.9	25.2	22.3	31.2	30.8	21.8	16.5	
Black marlin	180	147	123	297	334	438	1410	418
(%)	1.8	1.4	1.1	2.9	3.0	2.8	8.9	
Striped marlin	3025	3121	1559	1891	2148	4150	3213	2729
(%)	30.8	29.2	14.4	18.8	19.4	26.8	20.2	
Sailfish	312	172	163	149	126	1220	1228	481
(%)	3.2	1.6	2.6	1.5	1.1	7.8	7.7	
Swordfish	1197	1395	1597	1952	1807	2943	2511	1915
(%)	12.2	13.0	14.7	19.4	16.4	18.9	14.8	
Reported as billfishes	2663	3165	4978	2648	3257	3407	4907	3575
(%)	27.1	29.6	44.9	26.3	29.4	21.9	30.9	
Total	9817	10692	10836	10083	11082	15555	15882	11992

*(Source: IPTP 1987)

fish. Detailed effort statistics were wanting for some areas. Based on available information, the situations are as follows:

Striped marlin. There is a suggestion that different stocks of striped marlin may exist in the Indian Ocean, but data are not available to support this contention. Honma and Ueyanagi (1979) estimated the MSY of the species to be 3,000 to 3,500 mt, produced by an optimum effort of about 100 million hooks. Weatheral et al (1979) estimated the MSY as 3,500 mt, opining that the present level of fishing effort amounted to only about half the level of the optimum effort. There is a possibility of increasing the catch, which was estimated at 2,297 mt in 1985.

Blue marlin. According to Yoshida (1981), the production model analyses for this species indicated an MSY of 3,400 to 3,600 mt, achievable with less effort than has been expended. A marginal increase in catch through increasing effort is suggested by Honma and Ueyanagi (1979).

Black marlin. No information on stock structure of this species is available. Weatheral et al (1979) have estimated the MSY of this species as 1,400 to 1,550 mt. Considerable variation about the equilibrium yield curve at an effort level of 40 to 60 million hooks has been reported by Yoshida (1981). Information on areas of concentration of this species in the eastern Indian Ocean and off southeast Africa and the Oman Coast of Saudi Arabia are available.

Swordfish. The potential yield of swordfish is estimated to be much higher than the catch from this area. It is felt that the present level of effort by the longline fishery has not affected the stocks of swordfish.

Sailfish. Previous longline data have been biased by the mix of species (sailfish and shortbill spearfish); nevertheless, the stock of sailfish appears to have been least affected by the longline fishing effort. The potential yield of the species is expected to be much higher than the 1979 yield of 1,174 mt. The decline of catch to about 115 mt in Japanese and Taiwanese longline fishing may be due to operations being conducted outside the EEZs of many of the littoral states. Besides, the ROK catches are not available species-wise, being grouped under the general heading of 'Billfish'. About 2,041 mt have been landed by them, in this category, part of which may have been sailfish.

Table 2. Gear-wise landings of billfishes in the Indian Ocean (1980-1986).*

	1980	1981	1982	1983	1984	1985	1986
Longline							
BUM	2440	2687	2416	3143	338	3066	1558
BAM	180	147	123	294	334	300	549
SRM	3025	3129	1559	1891	2148	2311	3104
SLF	312	156	163	148	126	153	220
SWF	1197	1392	1597	1955	1801	2572	1967
BF	1616	1688	1936	1871	1700	2049	2678
% =	89.3	86.6	71.9	92.2	85.7	67.2	63.4
Drift Gillnet							
BUM	—	—	—	—	—	—	853
BAM	—	—	—	—	—	—	705
SRM	—	—	—	—	—	—	90
SLF	—	16	—	—	—	978	833
SWF	—	—	—	—	—	352	530
BF	—	—	—	520	144	210	266
% =	—	0.1	—	5.2	1.3	9.9	20.7
Gear not specified							
BUM	—	—	—	3	27	331	202
BAM	—	—	—	—	—	138	164
SRM	—	—	—	—	—	1839	19
SLF	—	—	—	—	—	89	167
SWF	—	—	—	—	6	9	14
BF	1047	1477	3042	257	1413	1148	1963
% =	10.7	13.9	28.1	2.6	13.0	22.9	15.9

*BUM = Blue marlin, BAM = Black marlin, SRM = Striped marlin, SLF = Sailfish, SWF = Swordfish and BF = Reported as billfishes by different countries (unclear). (Source: IPTP 1987).

Country-wise Catch Details

One or more species of billfishes occur in the waters of over 25 coastal and island States in the Indian Ocean area, as is evident from ichthyofaunal and fishery survey records. Catch statistics or even species identifications from the artisanal fisheries sectors are not available for most countries. The post-1980 information generated through correspondance, combined with IPTP data from Colombo, particularly for distant-water fishing operations (longline and purse seining) by Japan, Taiwan, Republic of Korea, France, and Spain, are briefly dealt with here.

Tanzania. Dr. P.K. Chisara, Senior Fishery Officer, Dar es salaam, has kindly made available the following catch data for his country for billfish, swordfish, and sailfish (combined).

Year	Catch (mt)	Year	Catch (mt)	Year	Catch (mt)
1976	138	1980	106	1984	233
1977	283	1981	172	1985	210
1978	242	1982	582	1986	476
1979	312	1983	257	—	—

Maldives. Mr. N.T. Hasen Didi, Senior Under Secretary, Ministry of Fisheries, Republic of Maldives, has been good enough to send me some information. Species-wise landings are not recorded, but sailfish is the most common

species caught by vadhu dhonis trolling just outside the atolls. They are also taken by rowing boats using droplines with live fish bait. Sailfish landed are generally in the length range 180 to 230 cms, the maximum size measured being 265 cm (FL). Smaller sized swordfish and marlin (BUM, BLM, and MLS) are also caught outside the atolls by trolling from masdhonis. Klawe (1980) estimated that an annual average of 106 mt of billfishes were caught between 1972 and 1977 by longliners operating in what is today the EEZ of Maldives. The catch comprised BUM 37%, SWO 19%, SAI 19%, MLS 18%, and BLM 7%.

Sri Lanka. Through the courtsey of Dr. Hiran W. Jayewardene the following information is available. The total billfish productions (combined) for the years 1984, 1985, and 1986 were 4,188, 3,754, and 3,260 mt, respectively. Maximum catches occur from April to October. Marlin make up 69% of the gillnet catch and sailfish 25%. Marlin and swordfish dominate the longline catch, operated from 9-m (3.5 GT) and 12-m (11 GT) class boats. Monitoring of the fishery, initiated in 1982, has been strengthened since 1987 by a joint programme set up with IPTP, Colombo. Joseph and Amarasiri (1987) have reported on the billfish landings in the multi-species, multi-gear, small-scale fisheries sectors of Sri Lanka.

India. Most of the billfish catches are from the west coast gillnet fishery. Sailfish is the main catch in surface trolling. A recent longline survey for tuna caught in the EEZ has shown that almost 19% of the catch from the Bay of Bengal, 10.6% of the catch in the Andaman Sea, and 8% of the catch in the eastern Arabian Sea are billfishes, recent annual landings of billfishes (India)* being as follows:

	1983-84	**1984-85**
East Coast	283	553
West Coast	396	731
Andamans	42	156
Lakshadweep	37	41
TOTAL	758 Mt	1,481 Mt

*(Source: CMFRI, 1986)

Malaysia (West Coast). The Fisheries Research Institute, Malaysia, has supplied the following details of billfish (marlins and sailfish) landings along the west coast of peninsular Malaysia for the years 1979-1986, based on the Annual Fisheries Statistics collected by the Department of Fisheries, Ministry of Agriculture, Malaysia:

Year	*Landings (mt)*	*Year*	*Landings (mt)*
1979	44.22	1983	120.25
1980	69.63	1984	73.42
1981	49.00	1985	138.41
1982	75.86	1986	93.00

Species-wise break up is not available.

Ocean Sport Fishing

The Indian Ocean offers excellent opportunities for ocean sport fishing. In fact, Malindi on the Kenya coast has been well recognized as one of the world's best sport fishing grounds for sailfish. The coming decade may see an expansion in ocean recreational activities linked with sport fishing of the different nations. Information available on the present status of ocean sport fishing for some of the countries is discussed here.

Mauritius. Data on sport fishing is available over a ten-year period (1976-1987). Over 80% of the fish caught between 1978 and 1987 find entry in the logbooks. Black marlin and blue marlin can be caught throughout the year (July 1 to 30 June). The maximum effort is normally expended during mid-summer (January-February). Blue marlin are generally in the weight range of 49.9 to 90.7 kg, but fish up to 304.8 kg have been taken by rod and reel.

Black marlin, although occurring in the same weight range as blue marlin (49-304 kg), are caught most frequently in the weight range 90.7 to 158.7 kg. Peak catches occur during November-December. Based on size frequency, Dean et al (1986) opine that males are scarce. Fully mature fish have not been encountered.

The sport fishing programme in Mauritius has a research component linked with it. The University of South Carolina, U.S.A., collects data on weight of fish, length of fish (lower jaw fork length and back of jaw fork length), pectoral girth, sex, reproduction condition of fish, gonad weight (samples preserved for ova diameter analysis), and otolith studies for age determination. In mid-December 1985, otolith samples from 136 fish (72 M and 35 F blue marlin, and 2 M and 27 F black marlin) were collected for age studies. This tie-up, which receives significant support from the private sector of the Mauritius tourism industry, should result in generating more information on the biology, behaviour, and habits of billfishes.

Kenya. The sport fishing season commences on 1st August and generally ends on 31st March, the dates varying slightly at different sectors along the coast. Mr. S.C. Hemphill, one of the directors of Pemba Channel Fishing Club, has been good enough to inform me that the area is well known for striped marlin, and Malindi, further north, for sailfish. According to him, tagging has increased in popularity. Over the last few years, increasing numbers of small-size sailfish and striped marlin have been tagged and released. Widespread tagging, especially of larger fish, may have limitations on account of the food value of the catch. The P.C.F.C. records, kindly made available by Mr. Hemphill, show that the catch per unit of effort (Kg/boat day × 100) for the ten-year period, 1978-1979 to 1987-1988, is as follows:

	Black marlin		Blue marlin		Striped marlin		Sailfish	
Season	Cpue	No.	Cpue	No.	Cpue	No.	Cpue	No.
1978/79	293	14	399	12	1064	78	188	23
1979/80	176	7	55	2	2414	182	192	23
1980/81	147	5	232	5	2135	144	116	13
1981/82	334	14	400	11	2622	193	179	23
1982/83	212	13	258	10	1090	88	252	36
1983/84	463	26	175	10	1305	108	407	56
1984/85	290	11	214	6	1444	108	702	95
1985/86	40	3	132	5	1399	130	310	50
1986/87	185	9	147	4	1392	112	1111	166
1987/88	207	7	40	1	1552	129	778	130

Around Pemba Island, unlike in Mauritius, it is the striped marlin that predominates.

From the data received through the courtsey of the Honarary Secretary of the Kenya Association of Sea Angling Clubs it has been possible to estimate the average weight of the fish caught, based on catch statistics from eight affiliated sport fishing clubs, as given below:

	1983/84		1984/85		1985/86		1986/87	
Species	(No.)	Kg	(No.)	Kg	(No.)	Kg	(No.)	Kg
Black marlin	81	76.6	84	83.0	70	78.3	95	57.7
Blue marlin	19	60.1	10	121.5	14	90.5	22	99.8
Striped marlin	132	51.5	155	53.14	213	50.6	343	37.9
Sailfish	1016	23.2	740	28.4	2146	23.7	2335	27.4
Swordfish	1	40.0	—	—	—	—	—	—

The numbers given above do not include the fish caught, tagged and released. For instance, during the year ending 30 June 1987, the Kenya Association of Sea Angling Clubs tagged and released 66 billfishes as follows:

Type of Tags	Sailfish	Black marlin	Blue marlin	Striped marlin	Total
Australian tags	27	3	3	17	50
N.A.O.O. Snark tags	6	—	—	—	6
N.A.O.O. Tina tags	10	—	—	—	10

As at Mauritius, the swordfish is extremely rare, only 7 in the weight range 13.6 kg to 89.4 kg having been caught during the period 1979-1983. The bulk of the sailfish caught are taken around Malindi. The club catch statistics combined with the voluntary tagging undertaken, portends the major supportive role that ocean sport fishing can play in generating data valuable for research on the billfish stocks and interactions with other fisheries.

India. All the species of billfishes except the shortbill spearfish occur in the Indian seas. Ocean sport fishing has great possibilities and, on the basis of catches from the small-scale fishing in the shelf waters and the Bay islands, Silas (1985) identified the following areas for development of sport fishing, particularly for the billfishes, seerfishes (*Scomberomorus* spp.), and tunas:

Andaman Sea (between Port Blair and Diglipur) — excellent area for tunas, seerfish, sailfish, marlin, and barracudas.

Gulf of Mannar (along Tuticorin - Cape Comorin Coast) — excellent area for sailfish, marlin, tuna, and seerfish.

Cochin - Mangalore Coast — good area for tunas, sailfish, and seerfish.

Lakshadweep (Agathi, Minicoy, and other islands) — good areas for marlin, swordfish, sailfish, tunas, and pelagic sharks.

Other countries. The information on sport fishing given here is incomplete inasmuch as it lacks data from countries such as Seychelles, Madagascar, Reunion, Mozambique, and western Australia.

With the rapid growth of the tourism industry in many of the coastal and island States, a major development in ocean sport fishing is envisaged. How best this can also be harnessed for scientific data acquisition to help monitor the stocks of billfishes needs serious consideration.

Tuna Fisheries Interaction

Until recently, interactions between related oceanic fisheries activities were not a matter of serious concern in the Indian Ocean area. It had become quite evident by 1985, however, that, unless interactions between the rapidly developing purse-seine fishery in the western Indian Ocean and the by now "traditional" longline fishery for specific resources are properly evaluated and monitored, serious imbalances could develop with adverse effects on the longline fisheries. The question is whether the yield per recruit (Y/R) would suffer a major or minor reduction or remain stable in spite of an intensive juvenile fisheries for the yellowfin tuna. A secondary question concerns the effect

any such reduction would have in a fisheries based on adult fish of the target species and other non-target associated species such as the billfishes. The gravity of the situation is such that this question was made almost the focal theme at the Expert Consultation on Stock Assessment of Tunas in the Indian Ocean, held in Colombo, Sri Lanka, from 4 to 8 December, 1986. Some of the papers presented at that consultation were of a preliminary nature as sufficient data were not available. Parallels from the eastern Atlantic and Pacific longline and purse-seine fisheries involving yellowfin tuna were discussed, which threw more light on similar interactions.

It is now felt that yellowfin tuna, which occur in both the longline fishery (large adults) and the purse-seine fishery (juveniles and adults), could be a good "indicator" species. The highly migratory behavior of the species is also to be reckoned with. The pattern of movements of this highly migratory species may differ in the Indian Ocean, which is landlocked in the north. The moot point is whether any disequilibrium resulting from an overexploitation of the juveniles by purse seining could affect recruitment to the large adult yellowfin taken in the longline fishery, and the consequent reduction in effort in the latter fishery, or phasing out of operations if the fishery is not economical. Reduction or phasing out could adversely affect the production of non-targeted species such as billfishes largely taken in the longline fishery in the Indian Ocean. It could be opined that the longline fishery could be kept going economically even at a reduced level if it is possible to exploit the large adult yellowfin. The fact that the latter category of fish may also be caught in purse seines should be a matter of concern. This could force reduction in effort expended in the longline fishery.

Though a theoretical speculation at present, a great deal of work is going to be centered around this problem until sustained productions for the different fisheries (purse seining and longlining) are stablized. Stabilization is vitally necessary in view of the large capital investments involved in tuna purse seining and longlining. It is hoped that the IPTP expert consultation in June, 1988, at Mauritius, will add more information on these aspects to think of regulations in fishing effort for different types of oceanic palagic fisheries.

Tuna and billfish production has also shown considerable increase in the artisanal sector, and it is also necessary to look at interactions between this sector versus purse seining and longlining. One reason is that species such as the sailfish breed in coastal waters, and juveniles are caught close to the coast in the gillnet fishery. Abundance of adults in the high-seas fishery (longline) may depend upon uninterrupted recruitment.

If purse seining is left unregulated, as is happening today in the western Indian Ocean, there could be eventual conflicts with the artisanal sector which also shares such a combination of species resource.

In very specific areas, sport fishing could have interaction with production in longline or even purse-seine artisanal fisheries for a common resource. Fortunately, we are nowhere near such a situation now.

Therefore, the importance of interactions between fisheries and exploited resources needs more attention. Simulation models may be designed even to look at the processes of interaction, to help suggest correction courses if necessary for sustained production in the various sectors.

Conclusion

From the foregoing it is evident that:

1. Billfishes form an important component of the Indian Ocean.
2. While the artisanal sector has shown marked improvement in production, the major source of production is the effort by the distant-water fishing nations in longline fishing and purse seining, the latter especially from Seychelles.
3. Ocean sport fishing activity is an important new area of development and its interaction with the artisanal sector needs careful study.
4. Any disequilibrium, leading to reduction or phasing out of the longline fisheries due to an overemphasis of purse seining for juveniles and adults of the epipelagic tunas, especially yellowfin, is bound to affect adversely the fishery for billfishes from the high seas and deeper neritic waters.
5. No reliable assessments of stocks are possible without proper catch statistics. A system of data acquisition, storage, and dissemination of information on billfishes is vitally necessary. What agency or organization in the Indian Ocean will undertake this, through an involvement of

all coastal and island States, will have to be decided.

6. There should be an international center in the Indian Ocean for the collection, collation, analysis, and dissemination of data on oceanic sport fishing activities.

Summary

The first international billfish symposium (1972) made hardly a passing reference to the billfishes from the Indian Ocean. Historical data on billfish catches have been very meager and are summarized.

Country-wise and year-wise landings of billfishes from the Indian Ocean from 1979 to 1986 are discussed in the context of commercial tuna longline fishery from the high seas and by the artisanal sector.

Longline fishery: The changing pattern of fishing and the shifting effort in the fishing grounds from 1952 to 1986 are described. The annual production of billfishes from 1980 to 1986 has shown an increase from about 9,800 t to about 15,900 t (av. 12,000 t). The blue marlin catch has fluctuated between 2,400 and 3,400 t; the black marlin between 123 and 1410 t; the striped marlin between 1,000 and 3,000 t; the sailfish around 1,200 t and swordfish around 2,500 t.

Gillnet fishery: Sri Lanka and India have shown substantial increase in their small-scale gillnet fisheries for billfishes (3,659 and 1,486 t for 1986, respectively) and other scombrids.

Purse seining: The significance of the explosive development of tuna purse seining from practically nil in 1982 to over 130,000 t in 1987, and the likely repercussions on the longline fishery in the Indian Ocean, are discussed.

Sport fishing for billfishes is an emerging area which can contribute significantly to billfish catches in the Indian Ocean. The status of the sport fishery is examined.

The need for a proper data acquisition system for billfishes, to enable management and judicious utilization of the resources, is stressed. In this context, the establishment of an International Commission for the Conservation and Management of Indian Ocean Tuna and Billfish Resources is suggested.

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fishes of the Indian Ocean, and has participated in several national and international expeditions studying tunas and billfishes. From 1975 to 1985, he was director of the Central Marine Fisheries Research Institute, Cochin, India, and is currently vice-chancellor of the Kerala (India) Agricultural University. In 1982, he published his compendium, "Resources of tunas and related species and their fisheries in the Indian Ocean."

Economic Trends Affecting Commercial Billfish Fisheries

Dennis M. King

This symposium focuses on trends and events that are affecting the health of the world's billfish resources, and on trends and events that are affecting global billfish fisheries. Despite wishful thinking, the forces operating in each case are not pushing in the same direction.

We may hope, for example, that when billfish populations are stressed, catch rates and profits in commercial fisheries will decline, causing fishermen to direct fishing pressure away from billfish and towards other species. Unfortunately, there are three good reasons why this kind of self-regulating phenomenon, which does provide natural protection for some fisheries, does not apply in the case of modern billfish fisheries. First, the extraordinary growth in billfish markets and dramatic increases in billfish prices in Japan, the U.S.A., and Europe, coupled with fairly stable fishing costs, keep fishing profits up despite declining catch rates in some important billfish fisheries. Second, regulations and limited-entry programs imposed in coastal fisheries are pushing fishermen offshore to open-access tuna and billfish fisheries. Third, 90% of the commercial billfish harvest is taken by fishermen who are targeting on other species, especially tuna, and the fishing strategies of these fishermen do not respond to declines in billfish catches.

Under these conditions, the economic incentives to continue billfish fishing will remain strong despite any decline in catch rates. This is why recent trends in coastal and high-seas fisheries and billfish markets portend billfish management problems in the future, regardless of what we conclude at this symposium about the need to manage billfish today.

The chapters that follow will establish the condition of various billfish resources and evaluate important trends in billfish fisheries. With a few exceptions, scientific arguments made there will be based on analyses and comparisons of catch-and-effort data using the conventional premise that fishermen, in one way or another, are engaged in "sampling" what lives below the surface of the sea. In order to distinguish changes in fishermen's "sampling" techniques from changes in billfish populations, there will be discussion about subtle shifts and trends taking place in high-seas fishing operations.

With this in mind, and because the market forces that drive many important trends in commercial billfish fisheries are often overlooked, I will emphasize recent changes in billfish markets rather than recent changes in fishing operations. The tripling of the Atlantic swordfish *(Xiphias gladius)* harvest during the past ten years (1976-1985), for example, was most certainly a direct result of shifts in the strategies and target species selected by U.S. and other fishermen. These shifts, however, were influenced to a large extent by a doubling in U.S. swordfish prices and a five-fold increase in the size of the U.S. swordfish market during the same period. The discussion here will focus on such market changes, which usually precipitate shifts in the level and distribution of commercial fishing, and corresponding changes in the size and composition of the billfish harvest. By considering the driving economic forces behind commercial billfish harvesting, we may be better able to identify important trends and anticipate when and how we should plan the future of billfish.

Commercial Billfish Fisheries

Billfish have been harvested in directed fisheries by the Japanese since ancient times and were caught as part of multispecies fisheries around the ancient world wherever fishermen had the means and inclination to venture "outside the reef." Originally, individual billfish were taken using handlines or harpoon and, later, small entanglement nets; until this century, the collective billfish harvest was very small. In the early 20th century, however, the Japanese developed the tuna longline fishery and the incidental take of billfish from this fishery drastically increased the world harvest of billfish. By World War II, the incidental billfish harvest by Japan's growing fleet of tuna longliners accounted for most of the 20,000 to 30,000 mt of billfish harvested globally. Billfish markets in Japan, which historically had been small, were already starting to expand by the time of World War II.

The impact of World War II on commercial fisheries around the world, including global billfish fisheries, was dramatic. Offshore fishing was a dominant industry in Japan before the war, but it relied on shore support-bases scattered throughout the western Pacific. During the war years, Japan's network of Pacific Island fishery bases was completely destroyed. At the same time, however, the war effort on all sides introduced new synthetics, new hull designs and boat building materials, and new electronic and refrigeration systems to the world's fishing industries. Each of these factors influenced the post-war development of Japanese distant-water fisheries.

The reconstruction of the Japanese economy after the war focused on traditional Japanese fisheries, but Japan took full advantage of the new materials and technologies developed during the war. With modern vessels and improved refrigeration and electronics, tuna longline fishermen could venture farther away from Japan even without access to traditional island support bases. In the early 1950s, as they moved further away from home fisheries in search of migrating tuna, they encountered increasing numbers of oceanic species like marlins, swordfish, and sailfish *(Istiophorus platypterus)*. Japanese markets for these species were still very small but, once they were caught, it was usually worthwhile to deliver billfish to port regardless of the price received.

The growing post-war Japanese economy fueled demand for sashimi-quality tuna, and with high catch rates and high tuna prices, Japan's distant-water longline fleets flourished. Following U.S. nuclear tests on Bikini Island in 1954, however, tuna taken from Japan's traditional central Pacific fishing grounds were found to be contaminated with radiation. In Japan, where the population was still experiencing the devastation of radioactive poisoning from Hiroshima and Nagasaki, the news of tuna contamination caused the tuna market to collapse.

The Japanese tuna industry reacted to the market crisis by attempting to stimulate tuna demand. They introduced new tuna products, including sausages and hams, and mixed tuna dishes, which eventually became popular. Black marlin *(Makaira indica)* and blue marlin *(M. nigricans)* which were being taken in significant quantities by longline fishermen at that time, were perfectly suitable as ingredients in these products, and became near-perfect substitutes for tuna in most intermediate seafood markets. When the fresh/frozen tuna markets in Japan recovered in the early 1960s, marlin and swordfish were viewed by Japanese consumers as a type of tuna, and billfish markets began to mature.

Beginning in the late 1960s, some Japanese longliners were equipped to deep freeze catches to −55 degrees centigrade and hold catches at temperatures as low as −40 degrees centigrade. This technique allowed high-quality sashimi-grade tuna and billfish to reach Japan even from very distant fishing areas, and pushed down the price of sashimi-grade fish in Japan. Lower prices stimulated markets for sashimi-grade fish, and consumption of tuna and billfish began to increase. It was also discovered at this time that billfish experienced less discoloring and maintained its quality better than most tuna when frozen and shipped long distances. Billfish became a very popular species for sashimi and sushi and developed an image of quality and freshness.

By the mid-1970s, striped marlin *(Tetrapturus audax)* commanded higher prices in Japan than all species of tuna except highly prized bluefin *(Thunnus thynnus)*. With the exception of small spearfish *(Tetrapturus* spp.), species of billfish went to high-end sashimi markets and not into processed products. Increasing supplies of low-cost tuna since that time have not affected the demand for billfish in Japan, and the various species of billfish now have established markets

in Japan that can be distinguished from tuna markets.

New Entrants

Distant-water tuna longlining is fuel intensive and labor intensive and requires long hours of hard work on trips that take fishermen away from home for months. Changes in fuel costs and shore-based employment opportunities in Japan, during the late 1970s, had a significant impact on Japan's ability to continue operating in this fishery. Industrial growth in Japan was surging ahead during the 1970s, generating new job opportunities for existing and potential distant-water fishermen. At the same time, catches of large deep-swimming tuna, the mainstay of tuna longline fisheries, were declining and the size of the international longline fleet competing in the longline fishery was growing. This combination put downward pressure on vessel profits and fishermen's earnings in Japan's high-seas tuna longline fisheries. As a result, Japanese tuna companies in the late 1970s began to move away from tuna long-lining and into tuna purse-seine fishing, which is less labor intensive, targets on more abundant surface-swimming tunas, and takes very few billfish as an incidental catch. Fishermen from Korea, Taiwan, Cuba, and other nations having limited shore-based employment and business opportunities, immediately replaced the Japanese in the tuna longline fisheries. As a result, the incidental take of billfish in the global tuna longline fisheries has not declined. In 1976, the Japanese longline fleet accounted for over 50% of the 87,400 mt global billfish harvest and only a few other nations were involved in tuna longline fishing. By 1985, Japan accounted for less than 40% of the 110,200 mt global billfish harvest, and many developing nations had become active in billfish fisheries.

Another noteworthy development in terms of new entrants involves U.S. participation in Atlantic and Pacific swordfish fisheries. Small-scale harpoon fisheries have existed on both U.S. coasts for years but, since 1980, two new U.S. fisheries have developed which do not target specifically on swordfish but take significant quantities of swordfish nonetheless. The first is the California drift gillnet fishery which targets on sharks, but takes marlins and swordfish as well. Because of this new fishery, the U.S. catch of Pacific swordfish increased ten-fold during 1976-1985. The second is the coastal tuna longline fishery off the Gulf and Atlantic coasts which targets on yellowfin tuna *(Thunnus albacares),* but takes significant quantities of swordfish and some marlin as well; the U.S. swordfish catch in this fishery doubled during 1976-1985. Combined, U.S. commercial fishermen in 1985 landed 5,854 metric tons of swordfish or about 10% of the global harvest. The incidential take of marlin by U.S. gillnet and longline fishermen is still small, but marlin does appear on restaurant menus in some parts of the U.S., and some U.S. fishing companies are increasing their exports of fresh and frozen marlin to Japan.

Circumstances and economic forces differ from nation to nation, but the trends in the U.S. summarize what seems to be taking place worldwide. Billfish prices are rising faster than the price of most other kinds of finfish (Fig. 1), and in recent years have been rising faster than the major components of fishing costs (Fig. 2). As long as such market trends continue, interest in commercial billfish fishing will continue even if billfish become more scarce.

The rapid development of offshore fisheries in the U.S. and the surge in U.S. swordfish landings have also been the result of a few special factors including:

- The overbuilding of U.S. commercial fleets during the early 1970s in anticipation of the "200 Mile Bill," and the subsequent reallocation of excess capacity away from heavily regulated nearshore fisheries.
- The decline of the gulf shrimp and mackerel fisheries and the Pacific tuna industry which forced many idle fishing vessels and fishermen to look to other fisheries for a livelihood.
- The increase in Asian immigrants to the U.S. who have a strong seagoing tradition and a willingness to work long hours off shore.
- Depressed vessel prices and low cost monofilament line and nets which have reduced the cost of entering commercial fishing in recent years.
- U.S. tax laws which encourage fishing on a commercial basis, even by fishermen who fish for pleasure and earn their livelihoods elsewhere.

Recent Trends in the Supply of Billfish

Species Composition

Billfish are usually taken incidentally in tuna

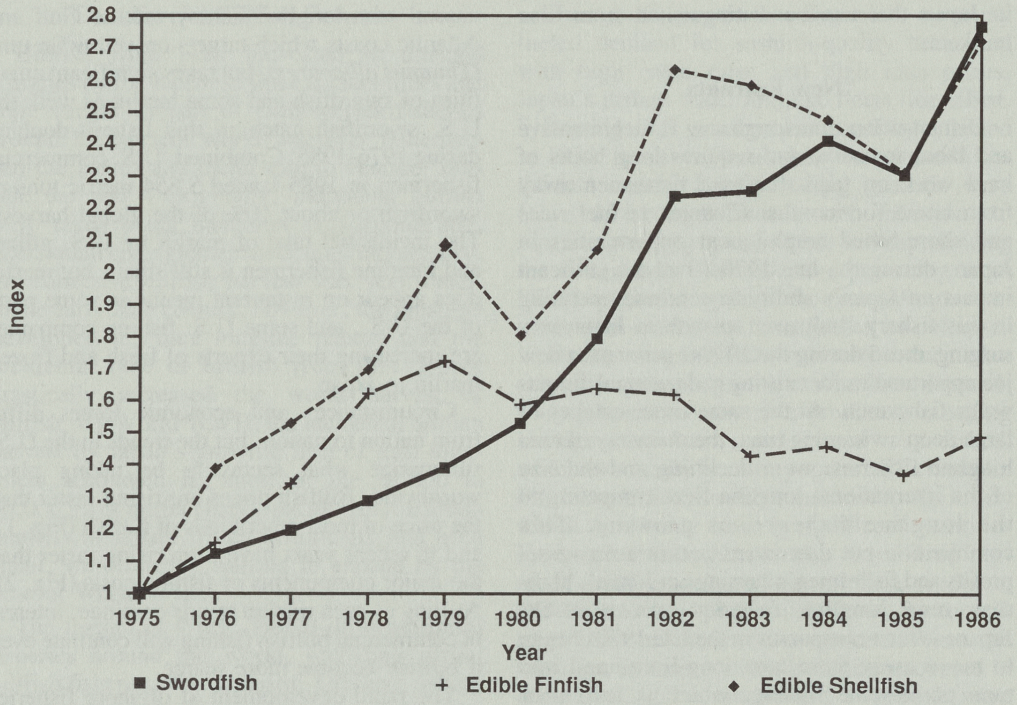


Figure 1. Index of exvessel prices (1975 = 1.0). Source: National Marine Fisheries Service data.

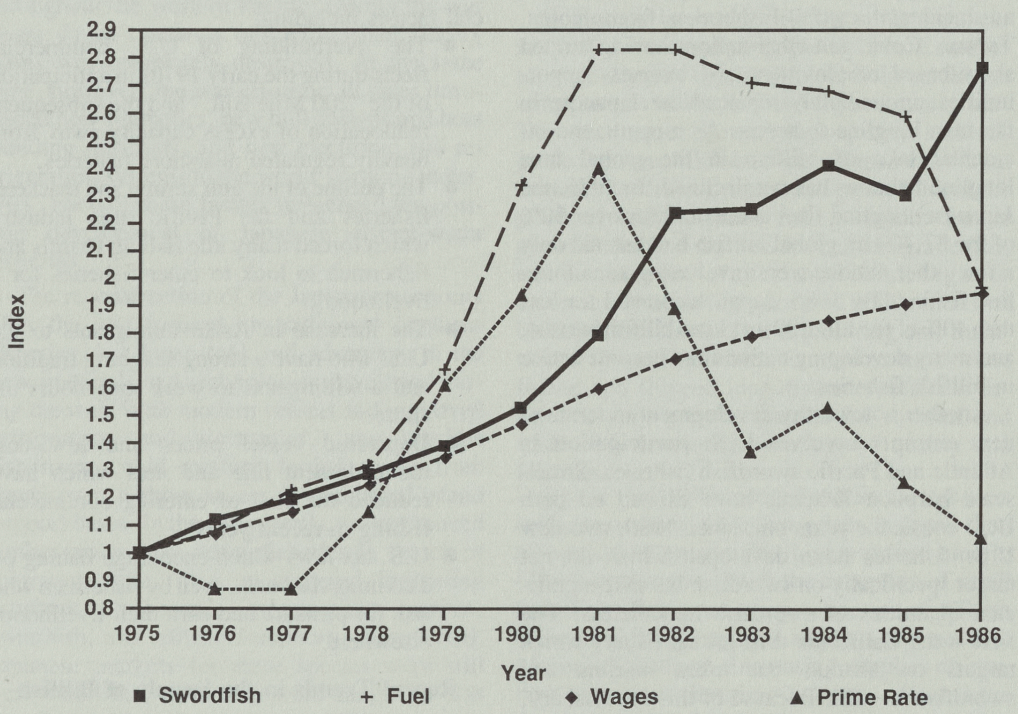
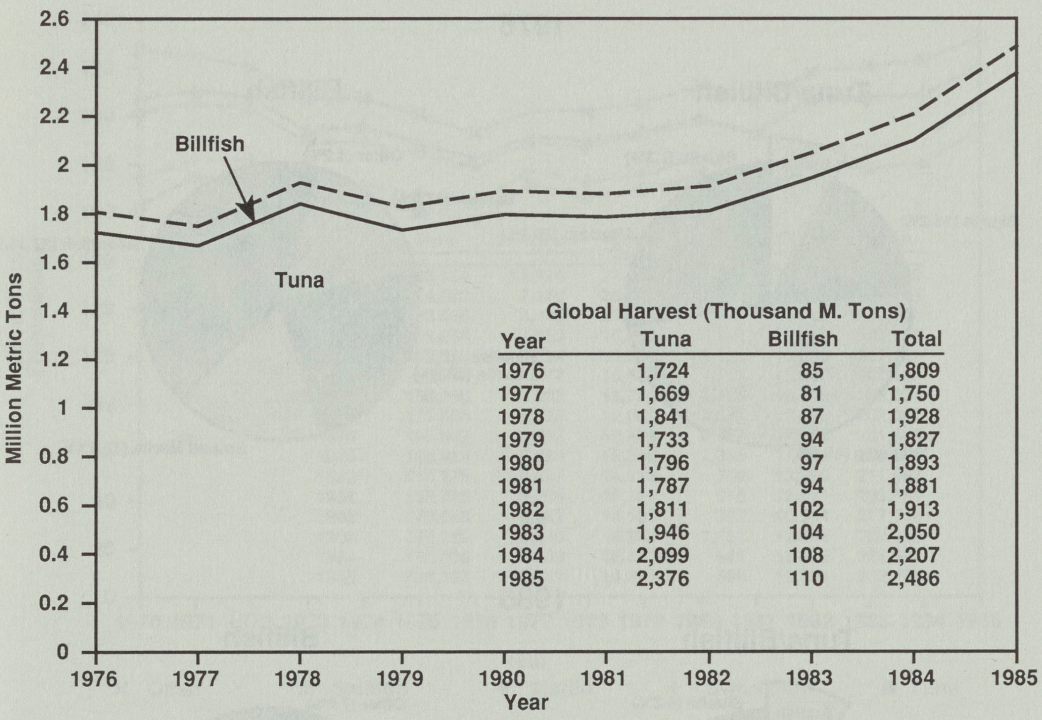


Figure 2. Index of U.S. prices and costs (1975 = 1.0). Sources: National Marine Fisheries Service and Bureau of Labor Statistics data.



Global Harvest (Thousand M. Tons)

Year	Tuna	Billfish	Total
1976	1,724	85	1,809
1977	1,669	81	1,750
1978	1,841	87	1,928
1979	1,733	94	1,827
1980	1,796	97	1,893
1981	1,787	94	1,881
1982	1,811	102	1,913
1983	1,946	104	2,050
1984	2,099	108	2,207
1985	2,376	110	2,486

Figure 3. Global tuna/billfish harvest, 1976-1985. Source: U.N. Food and Agriculture Organization; Fishery Statistics, 1976-1985.

fisheries but even in directed billfish fisheries tuna and billfish are frequently taken together. For this reason it is useful to consider trends in relative tuna/billfish harvests and why they may be changing. Figure 3 shows that, while the annual global billfish harvest has increased by nearly 30 percent over the recent ten-year period, the global tuna harvest has increased by nearly 40 percent. As a percentage of the overall tuna harvest, global billfish landings decreased slightly from 4.9% in 1976 to 4.6% in 1985. More revealing, however, is the fact that, in relation to those tuna species typically taken with billfish, the relative billfish harvest has increased from 7.4 percent in 1976 to 8.3 percent in 1985 (Fig. 4).

Since over 90 percent of the commercial billfish harvest is taken by the longliners, a closer look at relative trends in the longline fishery is also useful. Reliable statistics for all international longline fleets are not available but Figure 5 summarizes reported landings by the Japanese distant-water longline fleet. The harvest of billfish as a percentage of the total longline harvest decreased from 19.3 percent in 1970, to 13.3 percent in 1976, and to 11.3 percent in 1985. Because of the growth in billfish prices and sluggishness of tuna prices during this period, billfish landings have accounted for a growing share of vessel revenues for the longline fleet despite declining relative catches. Relatively high billfish prices during the period and sluggish tuna markets also suggest that the decline in relative billfish catches by the Japanese longline fleet was not the result of market forces. Other chapters in this book, dealing with biological, oceanographic, and political factors influencing world billfish stocks, will attempt to explain these relative trends in tuna/billfish catches.

Figure 6 shows that the international billfish harvest has been increasing steadily since 1976. Note, however, that the harvest of swordfish has accounted for most of the increase while catches of other billfish species have been steady or declining. Again, market forces do not seem to be playing an important role; the relative decline in catches of marlin in the face of increasing prices and growing markets will need to be explained elsewhere.

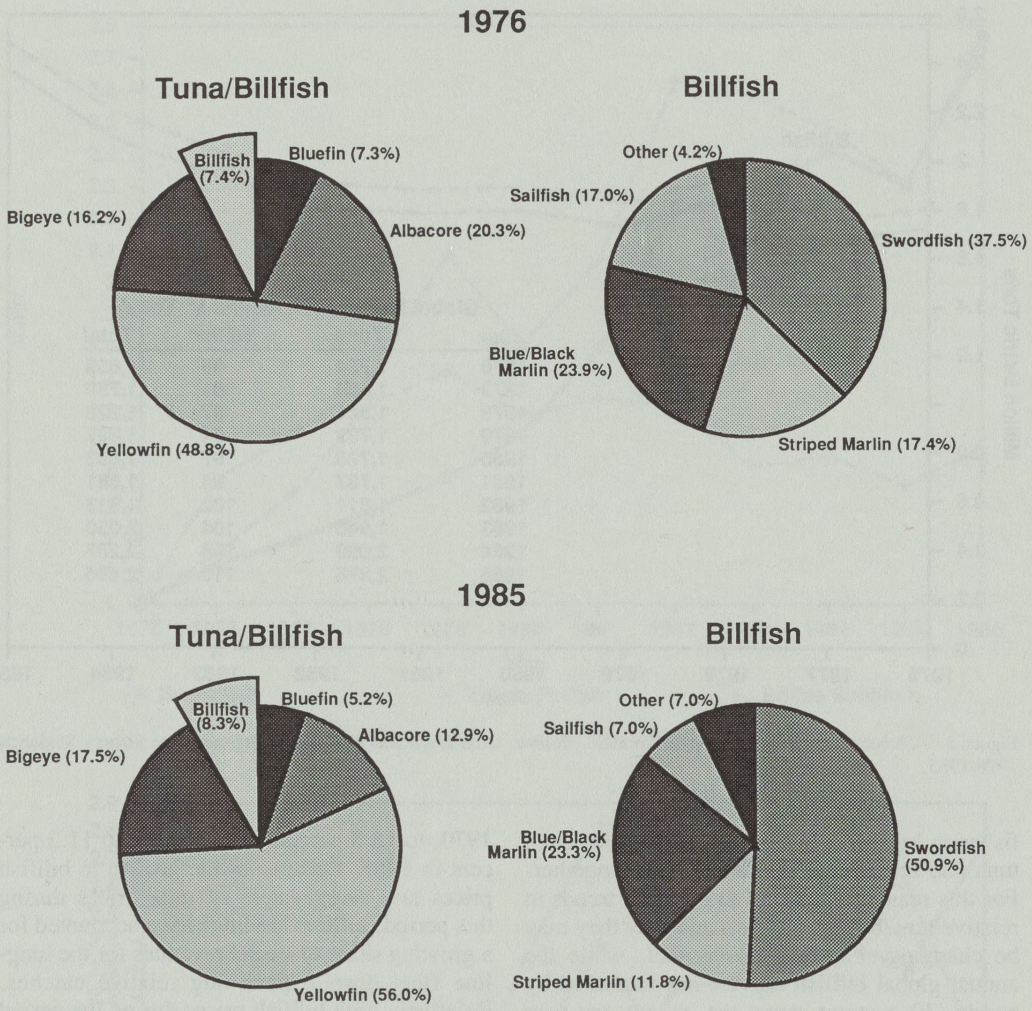


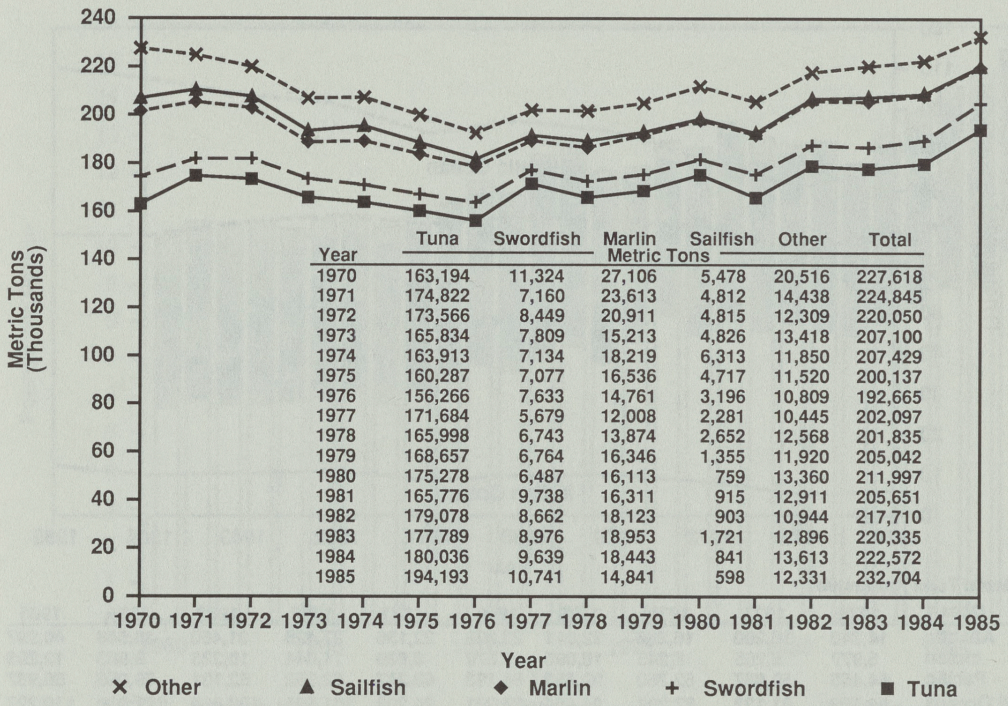
Figure 4. Global tuna and billfish harvests. Source: U.N. Food and Agriculture Organization; Yearbook of Fishery Statistics, 1976; 1985.

Ocean Areas

Billfish landings by ocean have also changed significantly over the past ten years, with a 12% decline in billfish landings from the Pacific and a nearly three-fold increase of billfish landings from the Atlantic (Fig. 7). These changes reflect a new mix of purse-seiners, pole-and-line vessels, and longliners in the global tuna fleet, and a redistribution of longline fishing effort from traditional fishing areas in the Pacific to new fishing areas in the Atlantic and Indian oceans. The steady decline in Pacific marlin catches in recent years and the dramatic increase in the Atlantic swordfish catch account for most of the important trends in overall billfish catches by ocean area.

Billfish Markets

Billfish catches by local fishermen are sold at many small regional markets, but most commercial landings eventually reach Japan — where there are established markets for all kinds of billfish, or the U.S. — where the market is limited primarily to swordfish. Using 1986 prices at major world markets, the 1.1 million tons of billfish taken annually by the international fleet had a dockside value of between US $1 and 2 billion. By the time this catch was



Year	Tuna	Swordfish	Marlin	Sailfish	Other	Total
	Metric Tons					
1970	163,194	11,324	27,106	5,478	20,516	227,618
1971	174,822	7,160	23,613	4,812	14,438	224,845
1972	173,566	8,449	20,911	4,815	12,309	220,050
1973	165,834	7,809	15,213	4,826	13,418	207,100
1974	163,913	7,134	18,219	6,313	11,850	207,429
1975	160,287	7,077	16,536	4,717	11,520	200,137
1976	156,266	7,633	14,761	3,196	10,809	192,665
1977	171,684	5,679	12,008	2,281	10,445	202,097
1978	165,998	6,743	13,874	2,652	12,568	201,835
1979	168,657	6,764	16,346	1,355	11,920	205,042
1980	175,278	6,487	16,113	759	13,360	211,997
1981	165,776	9,738	16,311	915	12,911	205,651
1982	179,078	8,662	18,123	903	10,944	217,710
1983	177,789	8,976	18,953	1,721	12,896	220,335
1984	180,036	9,639	18,443	841	13,613	222,572
1985	194,193	10,741	14,841	598	12,331	232,704

Figure 5. Japanese longline harvests, 1970-1985. Source: Fisheries Agency of Japan.

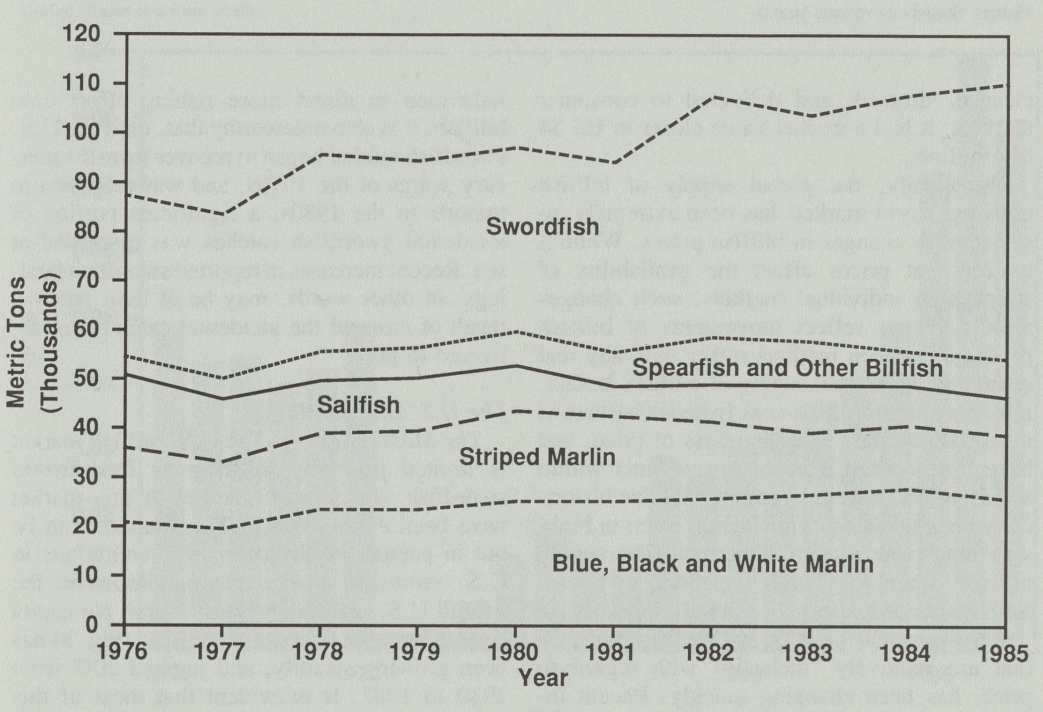
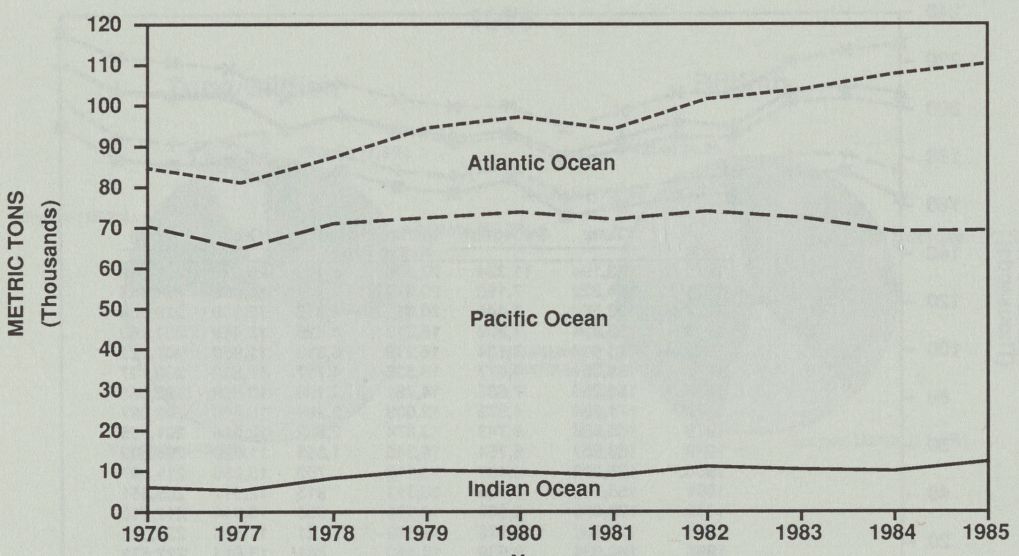


Figure 6. Global billfish harvests by species, 1976-1985. Source: U.N. Food and Agriculture Organization, Yearbook of Fishery Statistics (various years).



Metric Tons Harvested

Ocean	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Atlantic	14,340	16,200	16,286	22,011	23,329	22,136	27,495	31,460	38,648	40,997
Indian	5,977	5,265	8,245	10,093	9,679	8,820	11,044	10,323	9,983	12,293
Pacific	64,455	59,667	62,760	62,350	64,193	63,247	62,962	62,101	59,053	56,937
All Oceans	84,772	81,132	87,291	94,454	97,201	94,203	101,501	103,884	107,684	110,227

Figure 7. Global billfish harvests by ocean, 1976-1985. Source: U.N. Food and Agriculture Organization; Yearbook of Fishery Statistics (various years).

cleaned, dressed, and delivered to consumer markets, it had a market value closer to US $4 to 6 billion.

Historically, the global supply of billfish reaching world markets has been extremely insensitive to changes in billfish prices. While it is true that prices affect the availability of supplies in individual markets, such changes almost always reflect movements of billfish products between markets rather than any real change in the overall supply of billfish. In fact, fishermen in most high-seas fisheries harvest as much fish as they can regardless of price, and have little control over the species mix within a season. Moreover, since billfish have historically been taken as an incidental catch in high-seas tuna fisheries, the fishermen who supply billfish, when they have responded to prices, have responded primarily to tuna prices.

This historical situation with billfish supplies that are relatively "inelastic" with regard to price, has been changing quickly. Recent increases in world billfish prices and several years of stagnant tuna markets have enticed offshore fishermen to direct more fishing effort onto billfish. It is also noteworthy that, until the U.S. swordfish market began to recover from the mercury scares of the 1970s, and was reopened to imports in the 1980s, a significant portion of incidental swordfish catches was discarded at sea. Recent increases in reported swordfish landings, in other words, may be at least partly a result of more of the incidental catch being delivered to port.

The U.S. Billfish Market

The Market Setting. The U.S. billfish market is limited primarily to fresh or fresh/frozen swordfish, and recent changes in this market have been extraordinary. The situation can be put in perspective by comparing conditions in U.S. swordfish markets to conditions in the overall U.S. seafood market. Overall per capita consumption of seafood in the U.S. (Fig. 8) has been growing steadily, and jumped 20% from 1980 to 1987. It is evident that most of this increase was the result of increases in U.S. consumption of fresh and fresh/frozen seafood (fillets

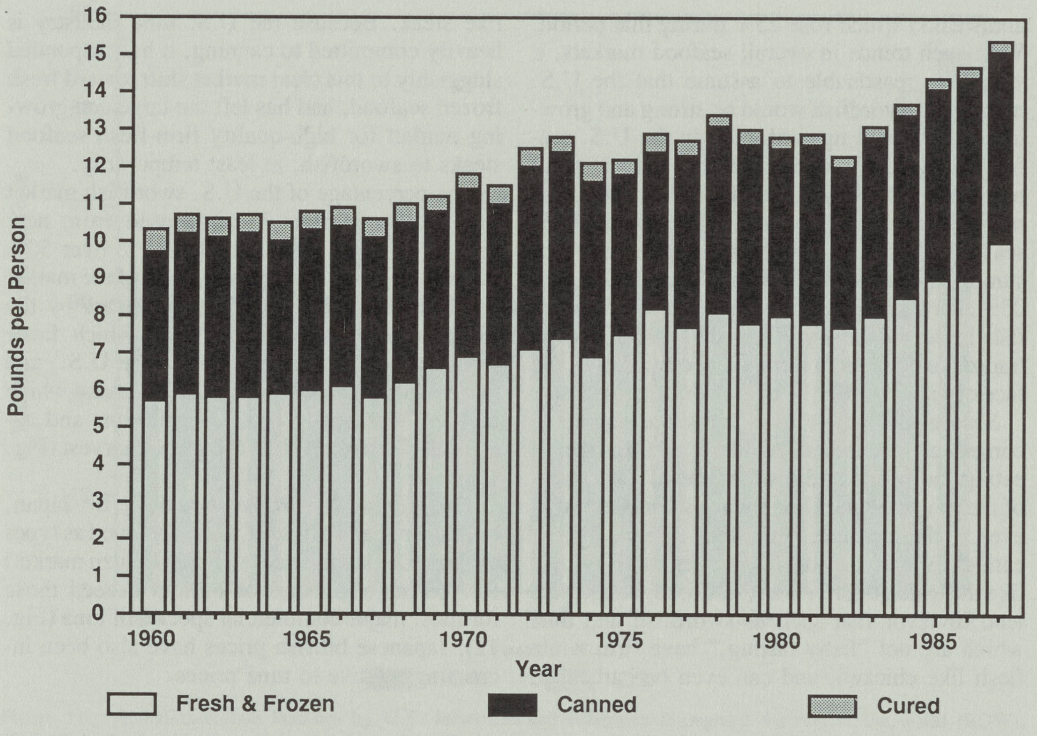


Figure 8. U.S. per capita seafood consumption, 1960-1987. Source. National Marine Fisheries Service, Fisheries of the United States (various years).

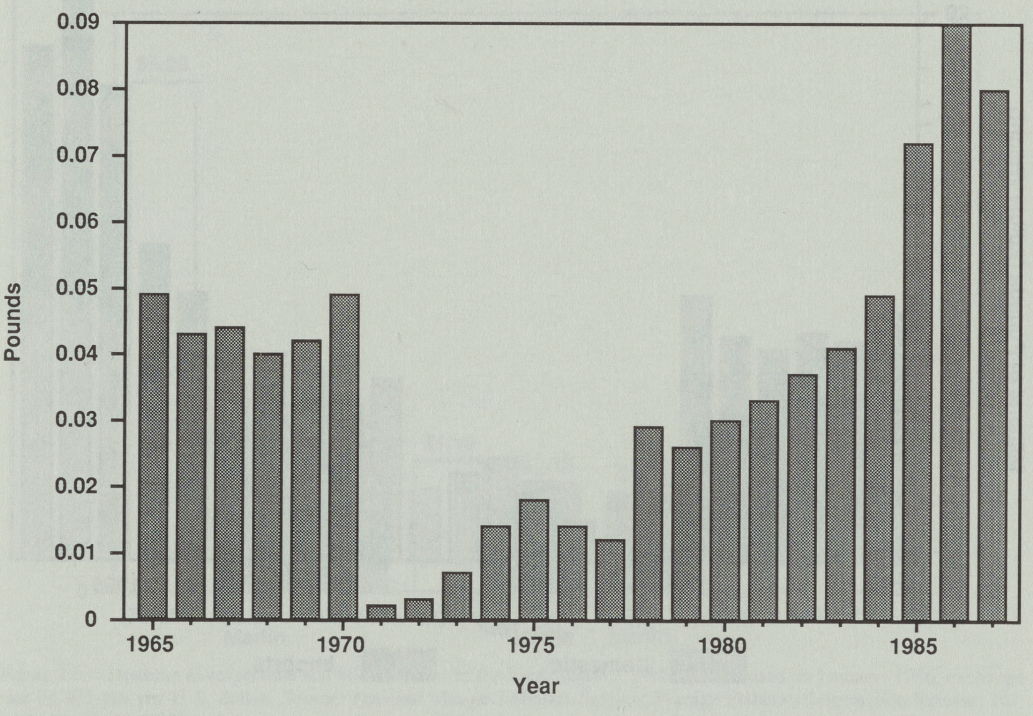


Figure 9. U.S. per capita consumption of swordfish, 1965-1987. Source: National Marine Fisheries Service data.

and steaks) which rose 25% during that period. With such trends in overall seafood markets, it would be reasonable to assume that the U.S. market for swordfish would be strong and growing. The overall upward trend in the U.S. seafood market, however, explains only a small part of what has happened in the U.S. swordfish market. During this period, when overall U.S. seafood consumption increased 20% and consumption of fresh and frozen seafood increased 25%, the U.S. per capita consumption of swordfish increased nearly 300% (Fig. 9.) This extraordinary surge in demand took place in the face of a near tripling of U.S. swordfish prices.

Sources of Change. U.S. consumers have become health conscious and they like the idea of eating more fish and less red meat. The secret of the growth in the U.S. swordfish market, however, is the fact that, while they like the idea of eating fish, U.S. consumers generally do not like the taste of fish. As a result, U.S. consumers tend to favor fish such as swordfish and tuna which are not "fishy tasting," have firm white flesh like chicken, and can even be barbecued like steak. Because the U.S. tuna industry is heavily committed to canning, it has responded sluggishly to this clear market shift toward fresh frozen seafood, and has left the large and growing market for high-quality firm-flesh seafood steaks to swordfish, at least temporarily.

The percentage of the U.S. swordfish market supplied by imports has increased from near zero in 1975 to 10% in 1980 and to over 50% in 1985 (Fig. 10). The import share of the market has been limited in the past few years by the weak dollar and the strong Yen which favor shipment to Japan rather than to the U.S., and the growth in the U.S. swordfish harvest which in 1985 was nearly 6,000 metric tons and accounted for over 10% of the global harvest (Fig. 11).

The Japanese Billfish Market. In Japan, billfish are handled, sold, and consumed as types of tuna. Dockside prices in Japan (Yaizu market) for the major species of billfish exceed those for most major commercial species of tuna (Fig. 12). Japanese billfish prices have also been increasing relative to tuna prices.

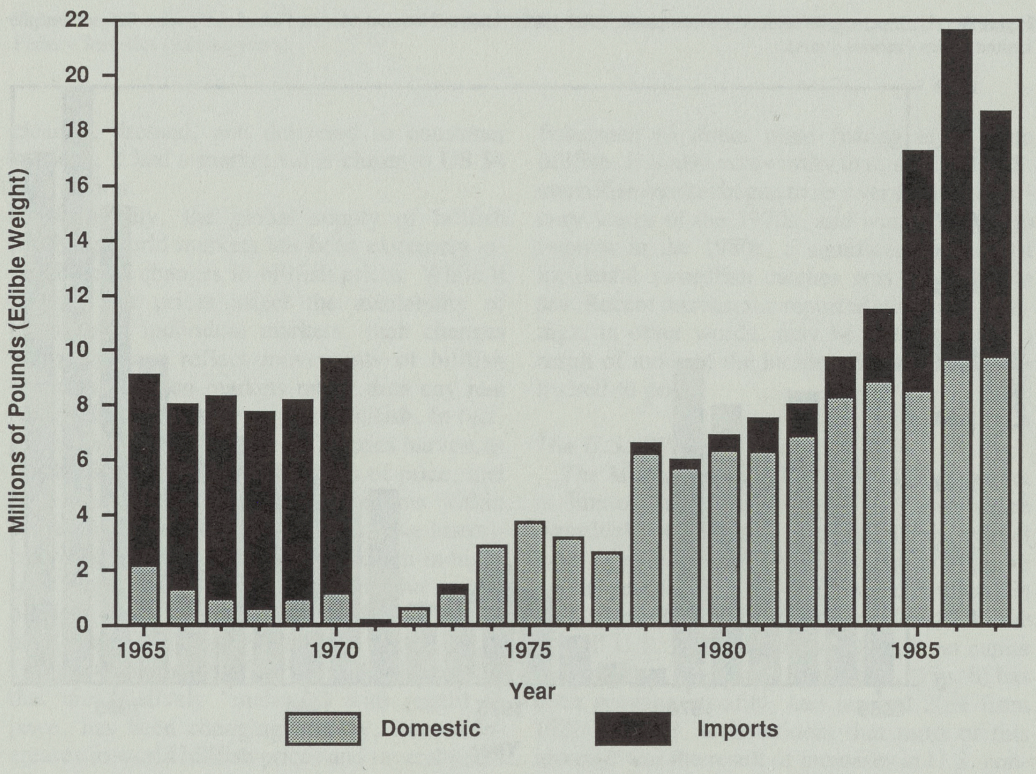


Figure 10. U.S. consumption of swordfish by origin, 1965-1987. Source: National Marine Fisheries Service data.

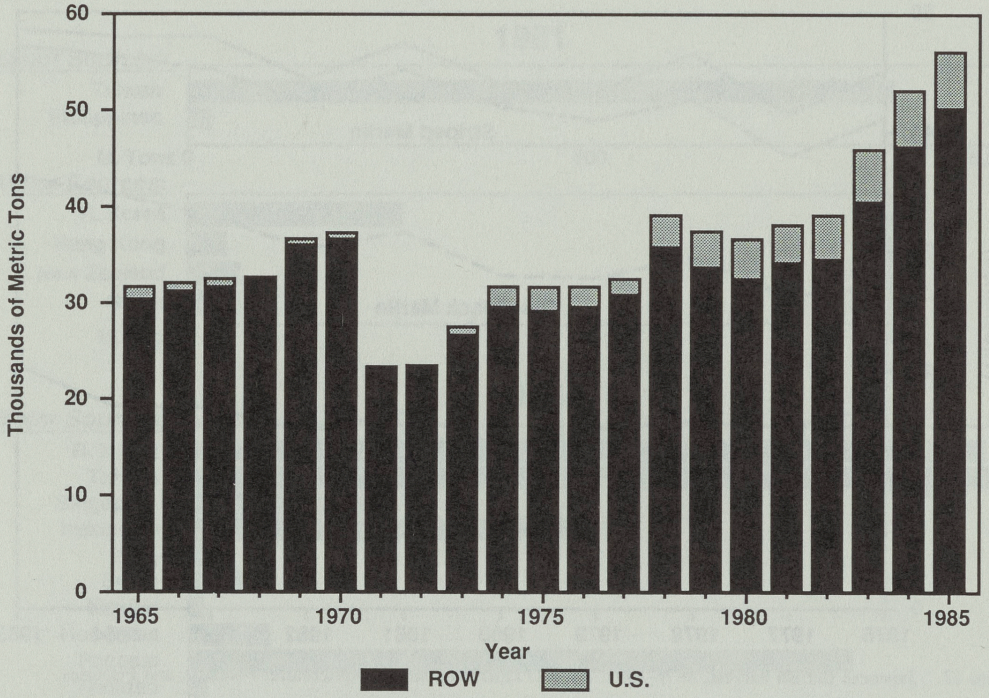


Figure 11. Global swordfish landings by U.S. fishermen and fishermen throughout the rest of the world (ROW), 1965-1985. Source: National Marine Fisheries Service data.

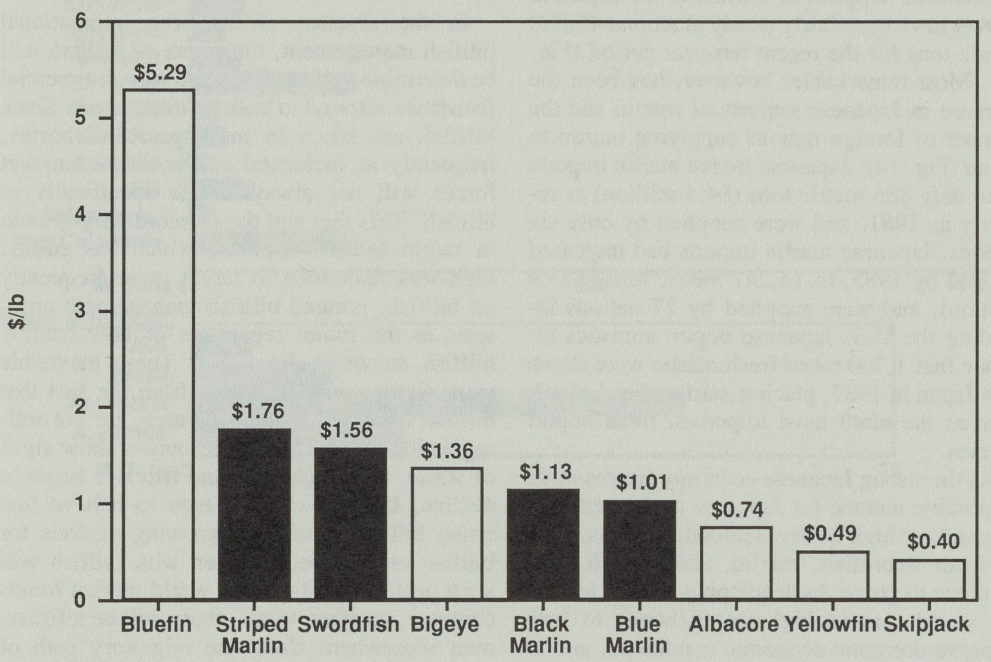


Figure 12. Japanese exvessel tuna and billfish prices in the Yaizu market, 1986. Prices based on January, 1986, exchange rate of 202 yen per U.S. dollar. Source: National Marine Fisheries Service, Foreign Fisheries Information Release, No. 86-5, March 13, 1986.

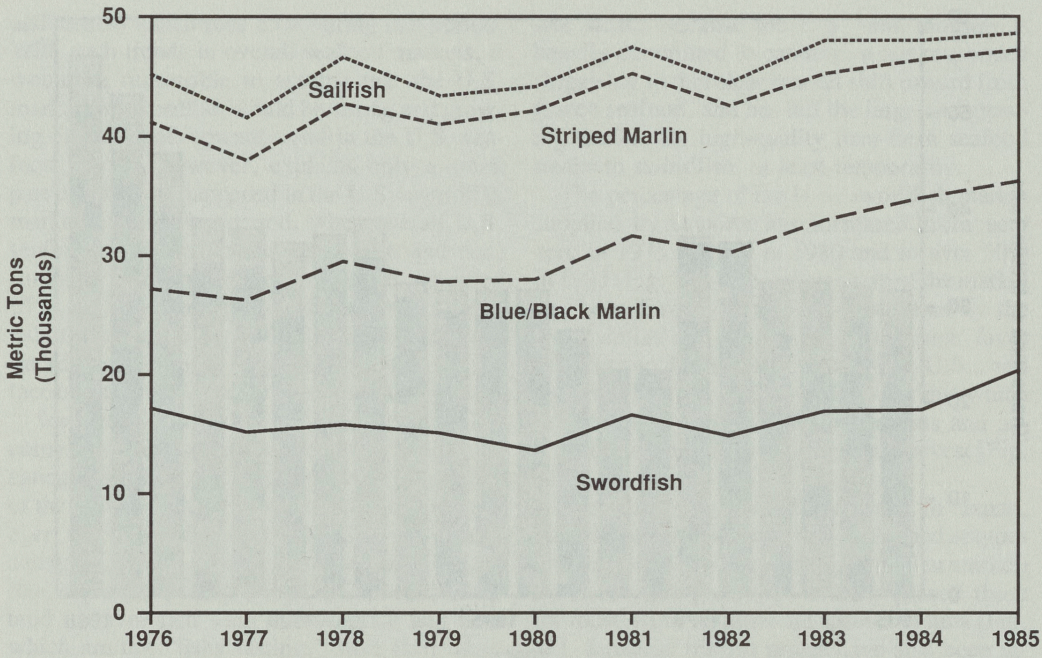


Figure 13. Japanese billfish harvest, 1976-1985. Source: Japan Ministry of Agriculture, Forestry, and Fisheries.

Domestic supplies of billfish to the Japanese market have been fairly steady at around 45,000 metric tons for the recent ten-year period (Fig. 13). Most remarkable, however, has been the increase in Japanese imports of marlin and the number of foreign nations supplying marlin to Japan (Fig. 14). Japanese frozen marlin imports were only 885 metric tons ($4.5 million) as recently as 1981, and were supplied by only six nations. Japanese marlin imports had increased 16-fold by 1985, to 15,247 metric tons ($33.9 million), and were supplied by 27 nations including the U.S. Japanese import statistics indicate that 1,760 mt of fresh marlin were flown into Japan in 1987, placing marlin ahead of salmon as the ninth most important fresh import species.

As the strong Japanese economy creates more disposable income for Japanese consumers, the demand for high quality seafood products, such as fresh swordfish, marlin, and sailfish, will continue to grow. As developing nations around the world turn to high-seas fisheries to help improve domestic economic conditions, and to improve trade deficits with Japan, worldwide interest in commercial billfish fishing will also increase.

Summary

In the absence of effective international billfish management, the future of billfish will be determined primarily by the way commercial fishermen respond to basic market forces. Since billfish are taken in multispecies fisheries, frequently as incidental catches, these market forces will not always relate specifically to billfish. This fact and the extraordinary growth in world billfish markets, which has caused high-seas fishermen to target more frequently on billfish, portend billfish management problems in the future regardless of how healthy billfish resources are today. These inevitable management problems stem from the fact that billfish fisheries, by their natures, are not self-regulating. When billfish resources show signs of stress, and catch rates and fish size begin to decline, there is every reason to believe that rising billfish prices and growing markets for billfish and/or species taken with billfish will keep profits up. If current world market trends continue, in other words, there will be a fisherman somewhere along the migratory path of each billfish, however scarce, who can earn income from fishing activity that will result in the harvest of that billfish. Eventually, some

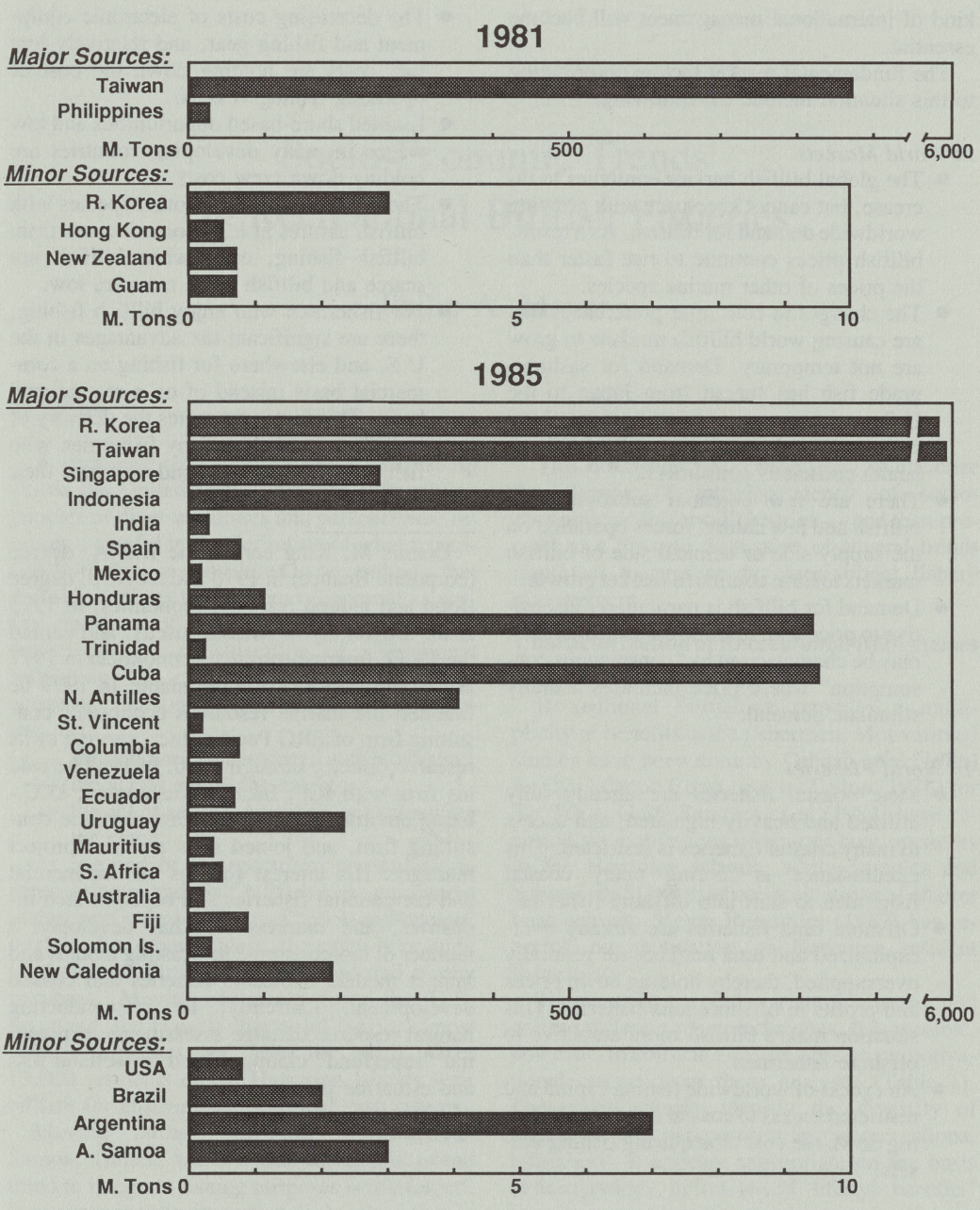


Figure 14. Japanese marlin imports, 1981, 1985. Source: Japan Ministry of Agriculture, Forestry, and Fisheries; Japan Fishery Import Statistics. Major sources >10 metric tons; minor sources <10 metric tons.

kind of international management will become essential.

The fundamental market factors contributing to this situation include the following:

In World Markets

- The global billfish harvest continues to increase, but cannot keep pace with growing worldwide demand for billfish. As a result, billfish prices continue to rise faster than the prices of other marine species.
- The changes in consumer preferences that are causing world billfish markets to grow are not temporary. Demand for sashimi-grade fish has spread from Japan to the U.S. and Europe, and is growing, along with overall demand for seafood among health-conscious consumers.
- There are few potential substitutes for billfish and few natural forces operating on the supply side or demand side of billfish markets to limit continued market growth.
- Demand for billfish is particularly insensitive to price and, in some up-scale markets, may be characterized by "conspicuous consumption" where price increases actually stimulate demand.

In World Fisheries

- Most coastal fisheries are already fully utilized and heavily regulated, and access to many coastal fisheries is restricted. This circumstance is forcing many coastal fishermen to shift into offshore fisheries.
- Offshore tuna fisheries are already overcapitalized and tuna markets are generally oversupplied, thereby holding down prices and profits in offshore tuna fisheries. This situation makes billfish more attractive to offshore fishermen.
- An excess of worldwide fishing capital and restricted access to coastal fisheries is holding down the cost of acquiring fishing vessels.
- The decreasing costs of electronic equipment and fishing gear, and relatively low fuel costs are holding down the cost of operating fishing vessels.
- Limited shore-based opportunities and low wages in many developing countries are holding down crew costs.
- The expected harvest of other species with billfish assures at least some income from billfish fishing, even when billfish are scarce and billfish catch rates are low.
- For fishermen who enjoy billfish fishing, there are significant tax advantages in the U.S. and elsewhere for fishing on a commercial basis instead of on a recreational basis. This factor promotes the delivery of billfish to market even by fishermen who fish primarily for sport and who earn their livelihoods elsewhere.

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Socio-Economic Trends in Recreational Billfish Fisheries

Philip A. Meyer

A review of recreational trends in billfishing across ten United States time zones, involving peoples of diverse cultures and perspectives, requires a careful initial definition of what recreation billfishing is considered to be, and how that definition relates to social and economic values. For purposes of clarification, and to offer a framework for consideration of recreational billfishing, this chapter identifies three socio-economic phenomena associated with billfishing, viz:

— the "enjoyment" associated with billfishing;
— the act of eating the catch;
— the act of selling, bartering or exchanging the catch.

At one end of the spectrum, particularly in some Atlantic and Gulf billfisheries, enjoyment of the catch is the sole focus of "hook-and-release" anglers. For other anglers, the catch is brought to shore and further used for food and trophy purposes. Moving westward from the U.S. mainland, the Hawaii charter billfishery almost always processes and sells the catch. Over 10,000 residents of the Hawaiian Islands seek billfish for enjoyment, food, and cash returns.

Moving farther westward to American Samoa, Guam, and the Marianas, this island trend to integrate fishing purposes is reinforced. It is consequently important to be clear that in some U.S. jurisdictions billfish recreation is reasonably separable from subsistence and earning objectives. In others, however, the three objectives are pursued interdependently. Artificial separation of goals can lead to inappropriate analysis of data, subsequent mistakes in management perspective, and unnecessary conflict between fishing groups.

This discussion will consequently characterize the degree of interdependency of socio-economic goals for billfisheries — and then proceed to a discrete discussion of several trends important to present day recreational fishery management.

Characterization of Recreational Billfisheries

Motivation for Billfishing

Recreational billfishing provides a multiplicity of benefits to the fishermen. Motivational studies have been done by Orbach et al (1986) for the Atlantic Coast, and by Ditton (1978) for the Texas Gulf. Samples et al (1984) have reported on motivations of charter boat operators in the Hawaiian Islands, while Samples and Schug (1985) reported on motivations of charter boat patrons. Meyer Resources (1987) has reported on motivation of Hawaiian resident fishermen.

These studies asked variant questions and utilized differing rating techniques. It is possible, however, to construct a table of relative motivational ratings from these analyses (Table 1). These data clearly identify the diversity of fishermen and perspectives in the recreational billfishery. It appears appropriate on the basis of this typology, in fact, to add "lifestyle benefits" as an important category that has not always been designed into earlier motivational studies. This category is clearly applicable in the case of charter skippers, and may also apply where native peoples fish for billfish (not shown in Table 1).

Scope of Benefits Associated with Recreational Billfishing

It will be recognized that the degree to which

Table 1. Relative rating of U.S. billfisherman motivation.

Motives	Fishing Area				
			Hawaiian Islands		
	Atlantic Tourney[1]	Texas Gulf[2]	Charter Skippers[3]	Charter Patrons[4]	Resident Fishermen[5]
	(Rank score: 1 = most important)				
Catching a fish	—	3	—	2	1
Relaxing/Close to Nature	—	4	—	4	2
Social/Family	2	2	2	3	5
Lifestyle/Culture	3	—	1	—	6
Earning a living/money	3	—	3	—	6
Having fish to eat	—	5	—	—	4
Having fun/sport	1	1	—	1	3

[1]Orbach, Maiolo, and Ketner (1986)
[2]Dilton, Mertens, and Schwartz (1978)
[3]Samples, Kusabe, and Sproul (1984)
[4]Samples and Schug (1985)
[5]Meyer Resources (1987)

benefits from fishing enjoyment, fishing expenditure, fish selling, and subsistence/lifestyle are identified with particular recreational billfisheries is, in significant part, determined by regional circumstance and institutional convention. Catch-and-release fishing will generate enjoyment and will create spending in the economy. It may also create lifestyle benefits depending on the characteristics of the billfishermen/charter skippers. If the billfish is killed, it can also generate subsistence benefits — and, if sold, will generate a further round of fish marketing benefits.

Thus, billfishing benefits can either be cumulative or separable, depending on fishing circumstance and convention. These relationships are outlined in Table 2. Information in the table is not complete, because some data are not presently available, at least not to this author. Table 2 is important, however, in that it identifies the potential impact that forces active in billfish management may have — and, consequently, the range of necessary management understanding. By comparing Tables 1 and 2, several conclusions important to management of recreational billfishing seem evident, viz.:

1. Viewed nationally, the potential socio-economic values associated with recreational billfishing are as varied as the circumstances and and perceptions of fishermen across America — and these circumstances and fishing perceptions have evolved in interesting and differing ways in each regional area.

Table 2. Potential range of interest involved in recreational billfishing.

Institutional Circumstances	Category of Benefits			
	Enjoyment	Sport Fishing Expenditure	Fish Consumption & Related Economics	Lifestyle/ Cultural
Catch & Release	Yes	Yes	No	Possible
Catch & Keep	Yes	Yes (+ trophy)	Own Use	Yes
Catch/Keep & Sell	Yes	Yes	Yes	Yes

2. It follows, from (1), that assessment of value and development of recreational billfishing initiatives must be sensitive to this regional diversity if the full benefits associated with recreational billfishing are to be realized, and if adverse impacts upon subgroups who have traditionally been part of the billfishing family are to be avoided.
3. Following this line of thinking further, there is nothing "wrong" with "releasing" or "keeping" or "selling" sport-caught billfish. Rather, some combination of these actions will be uniquely "right" in any particular region of the United States, given the beneficial interests traditionally associated with each billfishery and having regard for the status of stocks.

These generalized conclusions provide a conceptual underpinning for the discussion of trends that follows.

Description of Socio-Economic Benefits Associated with Billfishing

Information concerning socio-economic benefits of recreational billfishing is sparse. Nonetheless, some exists, and it is described here. Perhaps more data are available in this area than for any other benefit category associated with billfishing. Private and charter vessel expenditures have been estimated for the Atlantic region by the South Atlantic Fishery Management Council (SAFMC 1988). Additional data are available for New Jersey fishermen from Brown and Ofiera (1987). Similar data are available for Southern California from Wegge et al (1986). Finally, data for the Hawaiian Islands are available from the already cited documents by Samples et al (1984), Samples and Schug (1985) and Meyer Resources (1987). SMS Research (1983) also provides useful data for the Hawaiian Islands. Extrapolating from these sources, and updating to 1986 dolalrs, we obtain estimates of expendi-

tures per billfish trip and per billfish caught for private boaters and for charter parties (Table 3). The same sources consider economic proxy estimates of the value of "enjoyment" over and above actual expenditures associated with billfishing. These values are presented in Table 4. We conclude from this brief passage through available data that recreational billfishing is highly valued, multi-dimensional, and diverse, particularly on a comparative region-by-region basis.

Table 3. Estimated expenditures by recreational billfish fishermen in the United States.

Type of Fisherman/Value Indicator	Fishing Area: Atlantic & Gulf[1]	California[2]	Hawaiian Islands
	Expenditures in 1986 dollars		
A. *Private Billfishermen*			
1. Expenditure per boat day	212	185	120[3]
2. Billfish catch per day	.27	.40	.33[4]
3. Expenditure per billfish caught	785	462	364
B. *Charter Patrons*			
1. Expenditure per boat day	426[5]	—	443[4]
2. Billfish catch per day	.27	—	.33[4]
3. Expenditure per billfish caught	1,578	—	1,342

[1]From South Atlantic Fishery Management Council (SAFMC 1988)
[2]From Wegge et al (1986)
[3]From Meyer Resources (1987). Includes all resident sport fishermen
[4]From Samples and Schug (1985)
[5]Includes charter costs only

Future Trends in Recreational Billfishing

Forecasters understand that prediction of future trends is more complex than simple statistical extrapolation. Further, the French futurist, De Jouvenel (1967) points out that prediction of human futures can actually be affected by the predictors or other human actors — who can intervene on behalf of the predictions they have made. It is consequently the perspective of this author that, while certain generalized trends can be identified in recreational billfishing, there is a considerable opportunity for management intervention and, consequently, choice, in recreational billfish futures.

Increased Technical Efficiency in Catching Billfish

Increased technical efficiency in sport billfishing, including the capability of relative novices, supported by modern technology, to hook and land a billfish has perhaps been the driving trend of the past 30 years — expanding the billfish experience from "old men and the sea" and a select group of specialists to anyone who can gain access to a moderately sized boat and appropriate gear. In short, over the past 3 decades or so, billfishing has "gone public." This "democratization" is perhaps the major social result of the revolution in gear technology, and has opened recreational billfishing up to tendencies and pressures that are generally operative in public recreation at large.

Table 4. Estimated value of enjoyment associated with billfishing — over and above actual expenditures.

Value	Fishing Area: Atlantic & Gulf: Value per Trip	Atlantic & Gulf: Value per fish[1]	California: Value per Trip	California: Value per fish[1]	Hawaiian Islands: Value per Trip	Hawaiian Islands: Value per fish[1]
	Value in 1986 dollars					
Value of present billfishing	—	—	272	680	301	912
Value of catching one more white marlin/trip[2]	107	107	—	—	—	—
Value of catching one more blue marlin/trip[2]	365	365	—	—	—	—
Value lost due to 50% decline in catch rate	—	—	—	—	74	224

[1]Based on catch rates from Table 3
[2]About a 5-fold increase in catch rate
Sources: Brown and Ofiera (1987), Atlantic; Wegge et al (1980), California; Meyer Resources (1987), Hawaiian Islands

Increased Public Need for Recreation

The first "public" trend that will significantly affect future recreational billfishing is increased need for recreation, as human populations expand, urbanization continues, and attendant stresses multiply. It is less important to know what the exact rate of this increase will be than to understand that, by the turn of the century, many more anglers will be looking to hook up with a billfish than today. In fact, this development will simply be a continuation of the trend noted by Schmied and Burgess (1988).

Increased Demand for Food

It is likewise clear that expanding populations increase the value of world food supplies, including pelagic fish. While vagaries of market demand and available supplies may cause fish prices to fluctuate over relatively short time periods, the long-term trends are clear. There will be more selective targeting of commercial species, better fish handling techniques, and higher quality products reaching higher priced (often specialty) markets. This trend occurred in herring in the 1970s; it is affecting salmon

and Pacific bottomfish in the 1980s. It will occur in other fisheries, including billfish, in the 1990s. A major socio-economic conclusion is that billfish will become more valuable in future commercial markets.

Increased Tendency to Manage Ocean Fisheries to Meet National and/or Regional Stability Objectives in Discrete Sub-Areas

Implementation of the 200-mile fishery zonal concept, signing of accords between the United States and Pacific Island nations/territories, and progressive institution of commercial fishing limited access plans are proceeding in the U.S. sub-regions. All these actions move the status of the fisheries in a single socio-economic direction — toward generation of stable benefits on a region-by-region basis, and away from a high-mobility, high-tech fleet that ranges from region to region, fishing stocks down and then moving on. This process, analogous to the closing of open range in the American west, has two major implications for recreational billfishing. Both are related to the future expected behavior of commercial fleets.

First, virtually all plans to manage regional access to America's fisheries focus on benefits to those persons perceived to be "within" the region — residents, local fishermen, grandfathers (persons with a fishing history within the region) — and mitigate against "foreigners" and boats from "elsewhere." This means that, while a sector of the recreational billfishery will remain highly mobile (hop on an airplane and you're there), negotiations between recreational billfishermen and commercial/subsistence fishermen over fishing conditions and shares of catches in each regional area, will increasingly invoke fellow-constituents, neighbors, even friends. Conversely, we can expect less concern for the views of "outside" parties struggling for shares of "local" catches. Given the focus of the Magnuson Act, this should not be a surprising development.

Second, closing of ocean fisheries under U.S. jurisdiction to unlimited entry by fishermen has not been entirely orderly. Commercial access management plans for salmon and for some bottomfish are in place or under development. Some other fisheries are still treated as being in "open range." Today, when a high-tech commercial fisherman fishes down stocks in an area below economically sustainable levels, and moves on, the reentry door may be slammed shut behind him. In consequence, we now see highly mobile vessels competing within less and less ocean acreage. This has been particularly observable around the Hawaiian Islands, where the Leewards commercial bottomfishery was fished down over a period of three or four years by an influx of vessels that have now turned to tuna longlining.

The vulnerability of billfish to tuna by-catch is the subject of much discussion at this symposium. The point to be made here is that as the open ocean range closes, a segment of the domestic comercial fleet will be forced from remaining open fisheries to open fisheries until they either target billfish directly or obtain significant by-catch of billfish while seeking other species. This latter possibility should be of particular concern due to the failure of present regional management plans to incorporate tuna.

Increased Conservation Concern for Billfish

Traditionally, conservation concern for billfish has focussed on overfishing. The growth of catch-and-release recreational billfishing has, in part, responded to this concern. In the future, we can expect conservation concern to accelerate. First, as noted, increased pressure from both recreational and commercial fishing will continue.

Second, preservationist successes with respect to large marine species can be expected to expand from whales to other large identifiable marine creatures, such as billfish. Third, the possible advent of ocean mining, presently under EIS review in the Pacific, and under contemplation along the Pacific coast, may bring a level of vulnerability to billfish not heretofore identified. Consequently, the 1990s will likely see an increasing emphasis on protection issues associated with billfish management.

Trends Affecting the Recreational Billfishery, A Summary

In sum, recreational billfishing on into the 21st century will be increasingly public. The activity of catching billfish will become more valuable and sought after, as will billfish as a food source. As value increases, management of billfish will become increasingly protective — emphasizing national over international interest and conservation over consumption. These are the broad trends that I believe will affect recreational billfishing over the next 20 years. As noted, they pose both opportunities

and challenges for billfish managers who, will by their actions, as De Jouvenel notes, determine which recreational billfish futures actually occur.

Future Options for Billfish Management

The first important choice to be considered is whether to manage or half manage billfisheries. This issue is closely tied to the issues of management of tuna. Potential impacts on billfish by tuna fishermen clearly render imperative the inclusion of tuna in FMPs if billfish are to be adequately managed, both with respect to domestic and foreign fishermen. Without this step, billfish management will be largely reactive, and will fail to optimize joint returns to U.S. fishermen.

Second, angling interests and associated billfish managers, need to decide whether to build flexible recreational billfish policies, sensitized to regional circumstance, or whether to attempt to shape regional circumstances to a national mold. Most sensitive issues will be whether to release billfish, whether to sell sport-caught billfish, how to relate to other billfish catching sectors of the fishery, and what positions to take on protection issues. I noted earlier that diversity of circumstances is a feature of U.S. recreational billfishing and, under the Magnuson Act, it is reasonable to expect that such diversity will continue. Thus, while catch-and-release tournaments seem increasingly popular in some regions, sport fishermen in the Hawaiian Islands consume 23 percent of their catch, give 21 percent to friends, and sell 47 percent (Meyer Resources 1987). For billfish, the percent sold is likely higher. Neither of these approaches is "wrong." Both are probably appropriate to their circumstances. Perhaps, as recreational billfishing becomes more pressured, each can learn from the other. As fishing pressure increases, it is likely that the Hawaiian approach will need to become more conservationist. Conversely, as demand for food increases, selling of catch may prove a viable option that may supplement benefits of recreational enjoyment.

In the final analysis, the degree of success that billfish managers have over the next two decades will depend in significant part on their ability to understand and to sensitize their plans to the niches filled by various fishermen in the billfishery. Managers understand the concept of niches well at a biological level, but spend little time considering their human dimensions. We know that failure to consider biological niches carefully can lead to widespread impact and often adverse results. This is also true socio-economically, where policies that disrupt traditional ways of doing things are said to have "frictional" costs.

Preceding analysis, together with the emergent trends we have discussed here, makes it possible to identify policy initiatives that will likely yield substantial benefits to the recreational billfishery into the 21st century, viz:

1. Include tunas in the regional FMPs so that fishing effort impacting billfish can be adequately considered and managed.
2. Respect the diversity of niches and associated arrangements that have been established by both recreational and commercial billfishermen in various regions of the United States.
3. Insist on conservation as the glue to unify niche-holders in each billfishery, and as the issue of common concern with the general public.
4. Where niche-holder arrangements must be modified, respect "grandfathers." Attrition is far more acceptable socio-economically as a device for change than rapid removal of fishermen from needed employment or desired lifestyle. In fact, I know of no fishery limitation plan that does not incorporate "grandfathers."
5. Protect existing niche-holders and their arrangements from relatively short-term excursions from "outside" fishing interests by development of suitable access control mechanisms.

Development by angling interests of a futures policy along these lines would, I believe, ensure the future of recreational billfishing in the United States, and do so on a basis acceptable to a broad spectrum of Americans. Alternatively, future events can also offer the opportunity for increased conflict between sport billfishermen and other important niche-holders. This is largely a matter of choice.

Summary

Recreational billfishermen variously enjoy fishing, eat their catches, and sell their catches. Motivations for fishing also vary, and are associated with having fun, catching a fish, being close to nature, spending time with family or friends, obtaining food or income, and meeting lifestyle goals. The appropriate view of billfish-

ing practices and motivations varies from area to area in the United States but, for all, both dollar and non-dollar benefits from billfishing are high.

In the future, public needs for marine food and recreation will increase, driving the value of billfish still higher. Further, to an increasing degree, fisheries management decisions will reflect national concerns for conservation and regional concerns on fishing allocation issues. These concerns will tend to protect the niches of regional users and, most notably, grandfathered fishermen.

Recreational billfish futures are not entirely predetermined, but offer challenges and opportunities for effective intervention by billfish interest groups in their own fishing futures. Among the strategies that would seem most effective in furthering billfish recreational interests would appear to be: inclusion of tuna in regional FMPs; respect for regional diversity in formulating billfish plans and strategies; commitment to adequate conservation standards for billfish on a nation-wide basis; consideration for "grandfathers" in processes that change management schemes for billfish; and favoring of longer-term stability concerns in regional billfish management over single-minded pursuit of short-term economic opportunity.

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Panel 1 Discussion

Frank Carlton, National Coalition for Marine Conservation:

In the interest of being even handed, Mr. Chairman, since we have talked about the Japanese longline by-catch, I think it only fair to ask, what is the U.S. purse seine billfish by-catch?

Peter Goadby:

From the data that I've seen, for the western Pacific area, one or two blue marlin are occasionally caught in purse seines, particularly where they are set in proximity to log rafts. When purse seines are set in open water, few marlin are caught. The number would depend on the number of sets and the number of log rafts fished.

August Felando, American Tunaboat Association:

Rather careful data were taken by the New Zealanders aboard U.S. vessels when the tuna purse-seine fisheries developed off New Zealand, starting in 1974. The record is quite clear that it was a very insignificant take. With respect to the eastern Pacific, the general impression we have is that billfish are very insignificant in the take by purse-seine vessels. With respect to the western Pacific, Japanese data indicate that, from January to June, an average of four to five individual fish were taken per cruise, whereas, from July to October, eight to nine fish were taken per cruise. I believe that any careful examination will show a small take of billfish while fishing for tuna with purse seines. We think it's a non-problem.

Jeannette Foster, Audubon Magazine:

In light of the presentations by Steven Berkeley, which painted a dismal picture of the Atlantic swordfish fishery, and then by Dr. Sakagawa which gave a more optimistic picture of the Pacific swordfish fishery, what if anything is being done right now while the Pacific fishery is still productive so that we don't get into a situation like that in the Atlantic? Is there anything going on in any country right now to manage the swordfish resource?

Gary Sakagawa:

A number of indirect management actions are in place in all countries that have major fisheries — licensing systems, gear restrictions, etc. These measures are for the target species, but these fisheries are not targetting on swordfish, except for the U.S. coastal fisheries. In terms of an international agreement, in the Pacific, there is no ocean-wide arrangement.

Jeannette Foster:

Given that there is no ocean-wide arrangement, could we be facing the same experience in a few years that the Atlantic and Mediterranean fisheries are now facing?

Gary Sakagawa:

I don't foresee it happening in a few years. I don't anticipate a real resurgence of fishing, targetting on swordfish. If you are asking whether we should have some type of long-term management regime in place to address this situation before it gets bad, it might at least be worked on so that we do have some activity. I think the most crucial need is an overview of what's happening to the resource. We do not have any organization in the Pacific, as exists in the Atlantic, in which all of the nations that are exploiting the resource are involved in providing information and helping with its analysis and interpretation. I think that would be the first step that should be taken.

Chris Boggs, National Marine Fisheries Services, Honolulu:

I noticed that Grant Beardsley had some interesting data that had effective catch per unit effort as opposed to the raw data. Those data

must include some correction for deep longline gear, which I believe does reduce the by-catch of billfish. I've also heard some rumors, recently, about other techniques being developed by longline boats to reduce all billfish by-catch, with the possible exception of swordfish. I haven't been able to get any confirmation. Does anyone know of any other potential methods to reduce billfish by-catch on longlines?

Grant Beardsley, National Marine Fisheries Service:

In the Atlantic fleet, I'm not aware of any work that's being done to try to reduce the billfish by-catch by longline gear. They've talked about putting cones over the bait so the tunas can get it while the billfish can't, but I don't know of anything that's being actively explored.

Eric Prince, National Marine Fisheries Service, Miami:

Two years ago, in ICCAT, there was a working document submitted evaluating various deployment strategies for setting longline gear relative to the by-catch of various species, including billfishes. That sort of hits at the periphery of the question that you asked.

Christopher Weld. National Coalition for Marine Conservation:

I'd like to congratulate Grant Bearedsley on a very fine presentation this morning. The members of the ICCAT advisory panel have really been screaming for this kind of presentation for a good number of years. Grant has demonstrated that these kinds of statistics can be presented in a manner that even those of us with no scientific background can understand and appreciate. Your CPUE graphs for white marlin and blue marlin both showed that the CPUEs had remained more or less constant for about seven years. What happened to the nature of the effort in that period? Does that leveling out indicate some kind of stability in the population?

Grant Beardsley:

I really don't know whether there is any indication of stability in the population; it certainly could be. It's my understanding that the Japanese fishery in the Atlantic, during that period, has gone very heavily into bluefin tuna and bigeye tuna. If that's the case, and their fishing pattern is consistent, then the level of catch of white marlin would probably remain fairly constant. I don't think it's very indicative of any change in the population, because most of the Japanese effort during those years was concentrated in very specific areas, much more isolated than in the earlier years when they spanned almost the entire Atlantic.

Greg Cailliet, Moss Landing Marine Laboratories:

Is anybody taking size composition data? Is there any indication, particularly in those species where populations appear to be declining, especially in terms of catch per unit of effort, that there may be a long term problem in terms of the larger fishes being removed from the population? Is there any indication that we're seeing a large population-wide change in size and age composition?

Grant Beardsley:

I've tried to compile size data that various longline nations have contributed to the ICCAT statistics. If you look at those data, there is really no indication of any substantial decrease in the average size of any particular species of billfish. We've been taking data from the recreational fishery ever since 1972. We have a bit of a problem there because there's been a big increase in minimum size in recent years — for example, fish under 200 pounds are released. We're seeing only the larger fish on the docks, so the size data are biased by that fact. From the early years, when everything was taken, we really don't see a significant trend. There are a lot of fluctuations in any given area, of maybe 15, 20, 25 or 30 pounds, but there's no long-term or consistent trend of any kind that we've seen.

Greg McIntosh, South Atlantic Fishery Management Council:

Steve Berkeley, I believe you mentioned that the average size of swordfish has declined over a period of time within the United States EEZ in the Atlantic. Is that correct?

Steve Berkeley:

I indicated that the average size has declined in the U.S. fishery; I didn't specify where. It declined both inside and outside the U.S. EEZ, as well as in Spain and in the Mediterranean.

Greg McIntosh:

Do you see a similar trend in international waters or in the international fishery?

Steve Berkeley:

In the north Atlantic, yes, it seems to be pretty much a similar trend everywhere. You have to understand that all the areas that we're looking at are experienceing increases in effort. Throughout the north Atlantic, there has been quite significant declines in average sizes.

Panel 2

Assessing the Status of the Stocks

Gordon Broadhead, Chairman

Status of Atlantic Broadbill Swordfish Stocks

Peter M. Miyake and J.C. Rey

Broadbill swordfish *(Xiphias gladius)* is one of the major species fished commercially in the Atlantic Ocean and Mediterranean Sea. Annual swordfish catches (in weight) by gear are given in Figure 1 (Atlantic including the Mediterranean) and in Table 1 (Atlantic and Mediterranean separately) for 1950 through 1986 (Anonymous 1988a). Mediterranean catches include many estimates. For the years prior to 1985, Italian catches were underestimated. Size or catch-per-unit-effort data are not available for most Mediterranean fisheries. Therefore, this report concentrates on the Atlantic stocks. Since Mediterranean fisheries are distinct from Atlantic fisheries, swordfish in these two areas could be considered as separate manageable units (stocks) for the time being, even though there remains a fair possibility of a biologically common stock between the Atlantic Ocean and the Mediterranean Sea.

In the northwestern Atlantic, swordfish were traditionally harvested by harpoon by Canada and the U.S. but, when the Japanese longline fisheries started catching swordfish as by-catch in the early 1960s, U.S. and Canadian fishermen began replacing harpoon by longline gear (Hoey and Casey 1988). In the northeastern and southwestern Atlantic, the Spanish and Brazilian fisheries have been catching this species for a long time and use longline gears almost exclusively. Consequently, since 1963, almost all the Atlantic catches have been taken by longline.

Atlantic and Mediterranean swordfish catches, as noted in Figure 1 and Table 1, showed a gradual increase in the 1950s, and a rapid increase in the 1960s. In 1970, however, strict regulations on mercury content in swordfish were implemented in some of the major fishing and consumer countries. This action caused a serious lag in catches; however, there could have been unreported catches by fishermen, whereby real catches remain unknown. The regulations were relaxed in 1978 (Hoey and Bertolino 1988) and the catches started increasing again, from 8,000 metric tons (MT) in 1977 to over 20,000 MT in 1984-1985.

The total nominal swordfish catch is shown in Table 2 by country and by Atlantic Ocean and Mediterranean Sea (Anonymous 1988a). In the Atlantic Ocean, Spain and the U.S. together catch over half of the total, followed by Japan, Canada, Uruguay, and Brazil. Of all the tuna and tuna-like fishes caught in the Atlantic (including the Mediterranean Sea), the proportion of swordfish is very high (6.1%) as compared to other oceans (0.9% of Pacific catches and 0.5% of Indian Ocean catches). This may indicate higher abundance of swordfish in the Atlantic or, more likely, a very strong interest in this species by Atlantic countries.

Japanese longline catches (number of fish) for 1986 are shown in Figure 2 by 5° x 5° areas. Generally, swordfish are not the main target species of Japanese longliners; therefore, catches do not necessarily correspond to the real abundance of swordfish.

In the last few years, the Spanish fishery has expanded its fishing grounds toward the west and south (Rey et al 1988; Hoey et al 1988), while the U.S. fishery has expanded eastward (Hoey and Bertolino 1988). As a result, the fishing grounds of both fleets meet in the central north Atlantic and a continuous ground from the east to the west Atlantic has been formed. This is demonstrated in Figure 3, which shows the catch per unit of effort (number of fish per fishing days) of Spanish longliners in 1985 and U.S. catches (in thousands of fish) by area in 1986. The original Spanish catch-per-unit-of-effort data (Mejuto and González Garcés 1988) are by

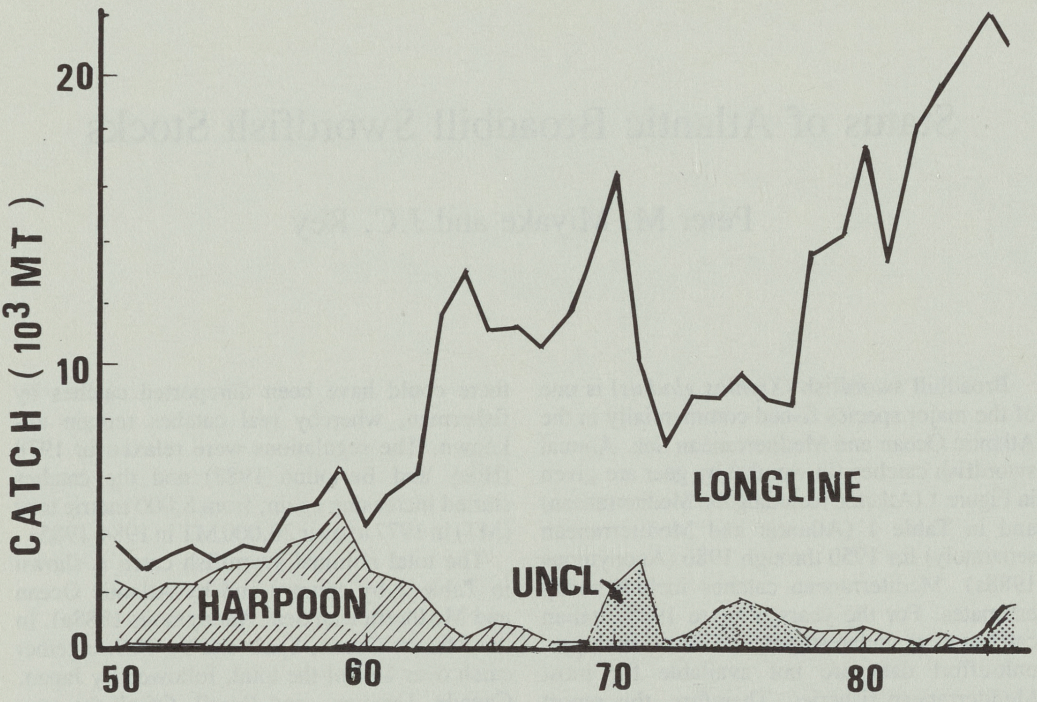

Figure 1. Total annual swordfish catches (in weight) in the Atlantic Ocean and Mediterranean Sea, accumulative by gears. 1960 to 1986.

quarters. Since no catch or effort data by these areas are available, the arithmetic means of the quarterly CPUEs are shown in this Figure.

As the catches increased rapidly, and the fishing grounds expanded, concern on the stock conditions has been expressed. The U.S. National Marine Fisheries Service held a workshop to assess swordfish resources on April 16 through 26, 1986, at the Miami laboratory of its Southeast Fisheries Center (Anonymous 1986). At this workshop, discussion was limited to the northwestern Atlantic. The International Commission for the Conservation of Atlantic Tunas (ICCAT) considered that it was essential to review swordfish stocks in the entire Atlantic and held a workshop on October 6-13, 1987, in Madrid (Anonymous 1988b). Due to time constraints, it was not possible to carry out analytical stock assessments at the ICCAT workshop. Consequently, the ICCAT held another work-

Table 1. Atlantic and Mediterranean swordfish catches (in metric tons), by gear.

	Year															
	1972	**1973**	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**
TOTAL	12598	13247	13365	15344	13491	13933	19814	19841	23975	20649	24419	25571	32269	35906	34943	23038
Atlantic	7108	8800	8752	11426	9261	9056	14345	14721	18585	14945	19127	19753	21406	22982	21676	22950
Longline	6811	8245	7529	9665	7799	8090	13616	13932	17714	14289	18792	19132	21000	22139	20195	21880
Baitboat	21	37	92	58	32	38	17				7	6	7	2	0	
Purse seine							14								13	
Trap	28	8	3			1				1		1		5	2	
Surface						12	5	30	128	18	56	8	64	254	1177	
Harpoon					0	0	656	715	585	532	142	421	91	71	104	
Unclassified	248	510	1128	1703	1430	915	37	44	158	105	130	185	244	511	185	1070
Mediterranean	5490	4447	4613	3918	4230	4877	5469	5120	5390	5704	5292	5818	10863	12924	13267	88
Longline	1529	1288	893	207	3343	3784	4242	3888	4003	4123	3211	3745	3552	3473	1444	
Trap	1		3									1	5	3	0	
Surface														3		
Harpoon					279	372	675	424	447	412	318	327				
Unclassified	3960	3159	3717	3711	608	721	552	808	940	1169	1763	1745	7306	9445	11823	

NOTE: 1987 catch data are preliminary for the Atlantic and incomplete for the Mediterranean.

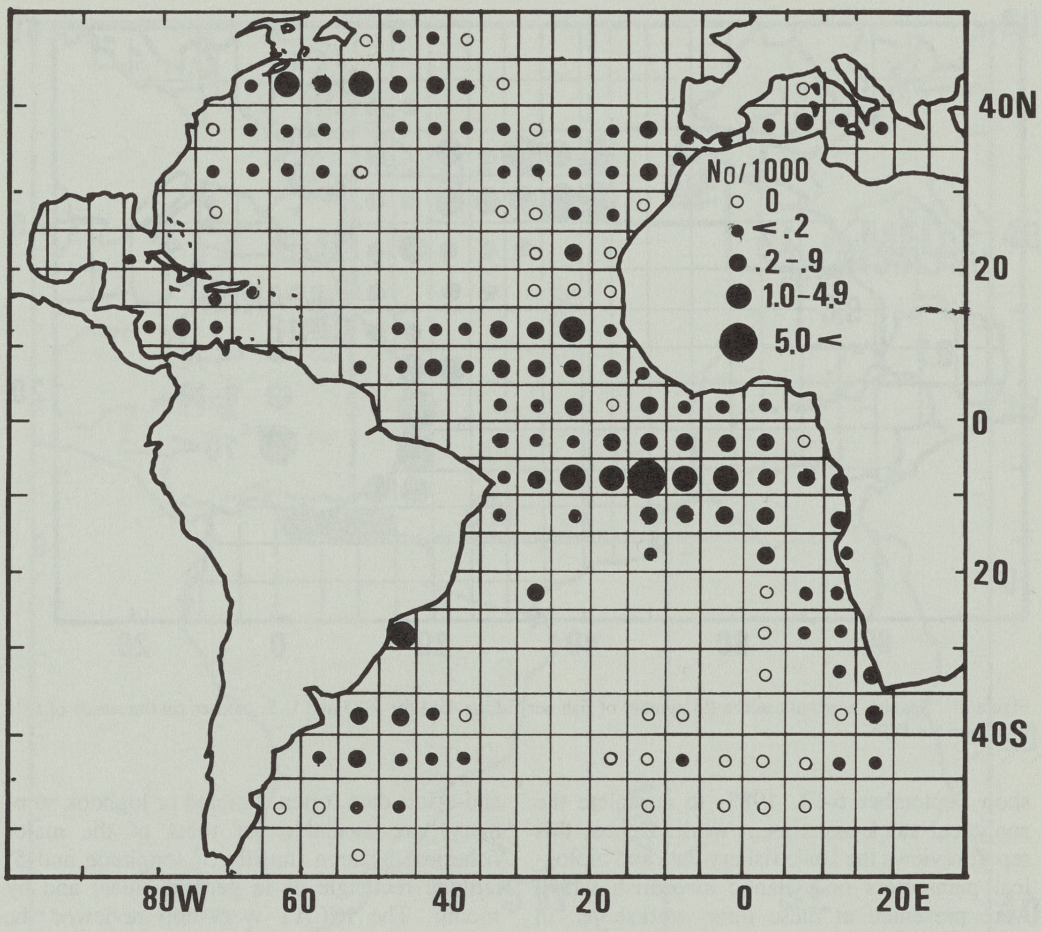

Figure 2. Distribution of Japanese longline nominal catches (in number of fish per 1000 hooks) in 1986. Open circles indicate no swordfish catches for existing effort.

Table 2. Atlantic and Mediterranean swordfish catches (in 1,000 metric tons), by country.

	Year															
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
TOTAL	12.6	13.2	13.4	13.6	13.0	13.4	19.2	19.5	22.9	19.4	23.2	25.4	31.5	35.1	34.0	
Atlantic	7.1	8.8	8.8	9.7	8.8	8.5	13.7	14.4	17.5	13.7	17.9	19.6	20.6	22.2	20.8	23.0
Brazil	0.1	0.1	0.3	0.3	0.4	0.4	0.3	0.4	1.5	0.6	1.0	0.8	0.5	0.4	0.4	0.9
Canada	0.0	0.0	0.0	0.0	0.0	0.1	2.3	3.0	1.9	0.6	0.6	1.1	0.5	0.6	1.1	1.0
China (Taiwan)	0.8	1.1	0.8	0.9	0.9	0.7	0.6	1.3	0.6	0.5	0.6	0.4	0.3	0.3	0.3	0.6
Cuba	0.1	0.5	1.1	0.5	0.6	0.7	0.6	0.4	0.6	0.4	0.7	1.2	1.4	1.5	0.7	0.9
Japan	1.8	1.0	1.4	3.3	1.3	1.3	1.4	1.3	3.1	3.5	5.0	2.4	5.1	5.5	3.7	3.8
Korea	0.4	1.0	0.7	0.5	1.1	1.2	1.3	0.6	0.7	0.4	0.7	0.5	0.4	0.3	0.1	0.1
Panama	0.0	0.4	0.1	0.1	0.3	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spain	3.2	3.8	2.9	3.7	2.8	3.3	3.6	2.6	3.8	4.0	4.6	7.1	6.3	7.4	8.0	8.8
USA	0.2	0.4	1.1	1.7	1.4	0.9	3.7	4.6	5.6	4.5	5.1	4.8	4.5	4.6	4.9	4.9
Uruguay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.7	1.5	2.5	1.7	0.7	0.7
USSR	0.2	0.2	0.1	0.3	0.2	0.1	0.2	0.1	0.2	0.0	0.1	0.0	0.2	0.1	0.0	0.0
Others	0.2	0.2	0.1	0.1	0.2	0.2	0.1	0.4	0.5	0.2	0.3	0.3	0.4	1.0	2.0	1.3
Mediterranean	5.5	4.4	4.6	3.9	4.2	4.9	5.5	5.1	5.4	5.7	5.3	5.8	10.9	12.9	13.3	
Algeria	0.0	0.1	0.2	0.5	0.4	0.4	0.3	0.5	0.6	0.8	0.9	0.9	0.9	0.9	0.9	
Italy	3.7	2.8	3.3	3.0	3.3	3.3	4.0	3.5	3.7	3.4	2.6	2.7	7.6	9.6	9.6	
Malta	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.1	0.1	
Morocco	0.2	0.2	0.2	0.1	0.2	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Spain	1.3	1.1	0.7	0.1	0.1	0.7	0.7	0.8	0.8	1.1	0.9	1.3	1.2	1.2	1.3	1.1
Others	0.1	0.1	0.0	0.0	0.1	0.2	0.1	0.2	0.1	0.2	0.7	0.8	1.0	1.1	1.2	

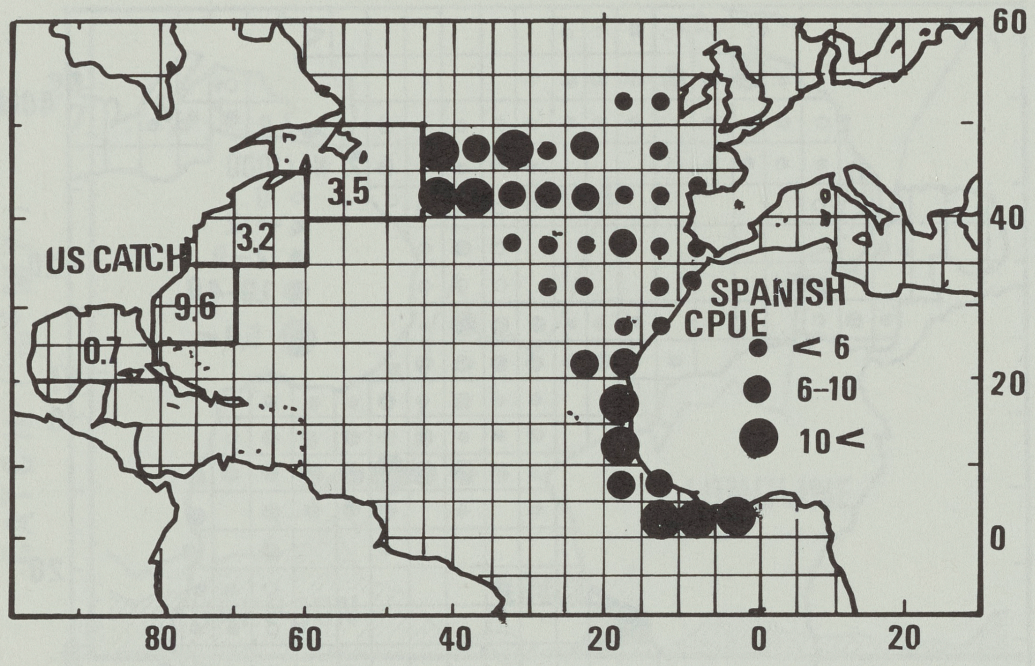

Figure 3. Spanish nominal catches (in number of fish per fishing day) for 1985 and U.S. catches (in thousands of fish) by region for 1986.

shop September 6-13, 1988, to complete the analytical stock assessment work. Hence, this report reviews the basic fishery data and biological parameters on Atlantic swordfish which were presented at these three workshops, in terms of their usefulness for stock assessment. The results of stock assessments carried out at the second ICCAT workshop held in September, 1988, are also reported. The report was first drafted in December, 1987, by both authors and later completed by the senior author. Since the 1988 workshop was held shortly after the report was presented at the billfish symposium, it has been revised to include this new material. The results of the analytical stock assessments made during the 1988 workshop were very similar to the preliminary analysis presented somewhat earlier at the symposium.

Materials

Catch data

The total nominal annual catches by vessel flag, by gear, and by region (north and south Atlantic) are available for all countries fishing swordfish in the Atlantic Ocean (Miyake et al 1988). Besides these nominal catches, catch-and-effort data (often sampled or logbook summary) are available for most of the major fisheries, by area (mostly 5° longitude and 5° latitude rectangle or in general areas) and by month. The ICCAT workshop reviewed the catch distribution and established six basic areas (Fig. 4) into which the catch data were to be combined.

Size data

Age determinations on individual swordfish, using hard parts, are very scarce and not yet validated; therefore, size data are used to estimate the age composition of catches. Table 3 summarizes the availability of size data for the major fisheries (Anonymous 1988b and ICCAT data base).

The catches were matched to size, and catch at size was estimated. As indicated in Table 3, size data are available for the major fisheries (Spain, U.S.A., Japan, and Brazil). Sometimes, size-data substitutions were made, but only at the smallest time-area strata for which data were available.

For the fisheries for which no adequate size data were available, those of the four major

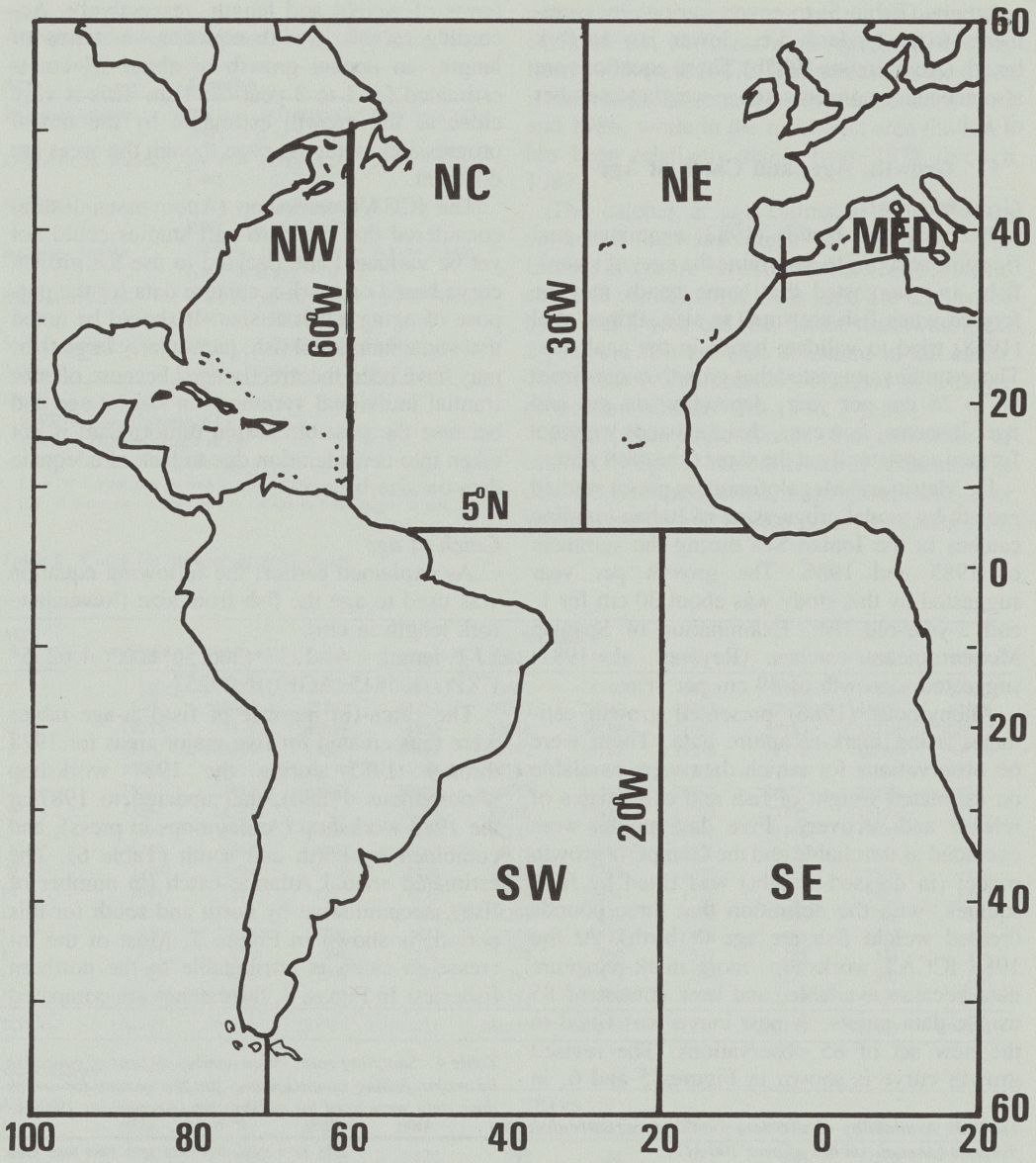

Figure 4. Six areas agreed upon by the ICCAT workshop for data preparation.

fisheries were used to substitute. The sampling rate (in number of fish) for the major fisheries, and for groups thus substituted, is summarized in Table 4. The sampling rate seems adequate to estimate catch at size (Anonymous 1988b). At the 1988 workshop the data were futher updated to 1987.

Catch-at-size tables, thus created, are in various units. For example, Spanish catches are in lower jaw — fork length (5 cm intervals); Japanese and Brazilian data are in eye socket — fork length (5 cm intervals); and U.S. data are in dressed weight (in pounds).

Miyake et al (1988) reviewed studies on the relationship between various length and weight measurements. The workshop decided to use six

equations (Table 5) to covert various measurements to a standard, i.e., lower jaw to fork length (Anonymous 1988b). These equations are also needed to convert catch in weight to number of fish.

Growth, Age, and Catch at Age

Growth curves

Berkeley and Houde (1983) examined anal fin spine sections to determine the ages of swordfish, and suggested that some bands may be formed when fish are small in size. Prince et al (1988) tried to validate bands in the anal fins. These studies suggested that growth ranges from 18 to 26 cm per year, depending on sex and age. It seems, however, that the bands were not formed consistently at the same time each year.

De Metrio and Megalofonou (in press) studied growth by modal progression of Italian longline catches in the Ionian Sea during the summers of 1985 and 1986. The growth per year suggested by this study was about 30 cm for 1- and 2-year-old fish. Examination of Spanish Mediterranean catches (Rey et al 1987) suggested a growth of 49 cm per year.

Anonymous (1986) presented growth estimates using mark-recapture data. There were 66 observations for which data were available on estimated weight of fish and exact dates of release and recovery. Five data points were excluded as unreliable and the Gompertz growth model (in dressed weight) was fitted by least squares, with the definition that three pounds dressed weight fish are age 0 (birth). At the 1988 ICCAT workshop, more mark-recapture data became available, and now consist of 85 usable data points. A new curve was fitted to the new set of 85 observations. The revised growth curve is shown in Figures 5 and 6, in terms of weight and length, respectively. According to this growth equation, in terms of length, an annual growth of about 27 cm is estimated for 1 to 3 year-old fish. This is very close to the growth estimated by the modal progression methods, even though the areas are different.

The ICCAT workshop (Anonymous 1988b) considered that the hard-part studies could not yet be validated and decided to use the growth curve based on mark-recapture data for the purpose of aging catch at size. It should be noted that some individual fish, particularly large fish, may have been incorrectly aged because of substantial individual variations in size at age and because the possible sexual dimorphism is not taken into consideration due to lack of adequate data on size by sex.

Catch at age

As explained earlier, the following equation was used to age the fish from size (lower jaw-fork length in cm):

LJ-F length = 44.2237*(305.56*EXP(-4.6235*EXP(-.305815*AGE)))*.29257

The catch-(in number of fish)-at-age tables were thus created for five major areas for 1978 through 1985 during the 1987 workshop (Anonymous 1988b), and updated to 1987 at the 1988 workshop (Anonymous in press), and combined by north and south (Table 6). The estimated annual Atlantic catch (in number of fish), accumulative by north and south for this period, is shown in Figure 7. Most of the increase in catch is attributable to the northern fisheries. In Figure 8, the catches are compared

Table 3. Availability of size data for the major swordfish fisheries (annual catches of over 100 MT).

Countries	Data	Measurements	Class	Period	# fish sampled/Yr
Angola	No				
Argentina	No				
Brazil	Yes	Eye-Fork	5 cm	1978-87	3300-16000
Canada	No				
China-Taiwan	Yes	Eye-Fork	5-10 cm	1980-86	600-1800
Cuba	No				
Japan	Yes	Eye-Fork	5 cm	1978-87	1100-5400
Korea	Yes	Lower jaw-Fork	2 cm	82,83,85	100-500
Morocco	Yes	Weight		87	100
Portugal*	Yes	Lower jaw-Fork	1 cm	86-87	100
Spain	Yes	Lower jaw-Fork	5 cm	1978-87	5000-47000
Uruguay	No				
USA	Yes	Dressed weight	1 lbs	1978-87	8000-50000
USSR	No				

*Mainland and Madeira

Table 4. Sampling rates (% in number of fish) of swordfish by major fishing countries and for the groups for which their data were used for substitution (Anonymous 1988b).

	1978	1979	1980	1981	1982	1983	1984	1985	1986
North Atlantic									
Japan 6.2	8.5	8.9	9.1	4.1	9.6	11.4	11.8		
Japanese group[1]	2.1	3.2	4.7	6.0	2.4	3.6	5.4	8.0	
Spain	10.1	12.6	11.7	52.5	12.9	32.6	20.7	35.5	
Spanish group[2]	10.0	11.5	11.3	50.8	12.6	32.0	20.4	35.0	
U.S.A.	16.3	45.7	47.8	45.5	57.7	57.4	57.1	67.0	65.0
U.S.A. group[3]	9.9	27.2	34.9	40.3	51.8	46.5	51.2	58.9	
South Atlantic									
Brazil	100	100	100	100	100	100	100	100	
Brazilian group[4]	40.4	55.0	76.1	55.2	36.9	21.3	11.6	9.2	
Japan	11.4	4.7	6.2	4.4	6.0	4.1	5.7	6.5	
Japanese group[1]	.1	1.1	3.0	2.5	0.7	2.1	3.8	4.3	
Spain							92	?	
Spanish group2							72	?	

[1]China-Taiwan, Cuba, Korea + Panama, South Africa and USSR
[2]Benin, Ghana, Liberia, Morocco, Nigeria, Portugal and Togo
[3]Canada and Venezuela
[4]Argentina and Uruguay

Table 5. Conversion equations selected by the ICCAT swordfish workshops for various areas (see Figure 8).

Area	Equation
Northeast Atlantic	RWT = .0000028833 * LJ-F ** 3.2623 DWT = 0.76 * RWT
Central North Atlantic	RWT = .0000042030 * LJ-F ** 3.2134 DWT = 0.76 * RWT
Northwest Atlantic	DWT = .0000045920 * LJ-F ** 3.1370 RWT = 0.75 * RWT
Southeast Atlantic	GWT = .0000043491 * E-F ** 3.1880 GWT = 0.8772 * RWT
Southwest Atlantic	GWT = .0000124000 * LJ-F ** 3.0400 GWT = 0.8009 * RWT ** 1.015
Mediterranean	DWT? = .0000057010 * LJ-F ** 3.1600
All areas	LJ-F = 7.821534 + 1.0897 * E-F

Where
RWT = Round weight in kg
DWT = Dressed weight in kg
GWT = Gutted weight in kg
LJ-F = Lower jaw to fork length in cm
E-F = Posterior corner of eye socket to fork length in cm

among three areas in the north Atlantic. The catch in the northeast area increased steadily from 1979 until 1987. The increase in the catch is marked in the central north area between 1983 and 1986, while in the northwest area the catch has been relatively stable from 1978 through 1987.

The catches at age estimated for 1987 are compared between areas in Figure 9. The catches at age are very similar between the northeast and central north areas, and are dominated by 3- and 4-year-old fish. In the northwest area, 2-year-old fish are also abundant in the catch. The south Atlantic catch consisted of a larger proportion of older fish (5 to 7 years).

Figure 10 demonstrates the evolution of catches by age in the entire north Atlantic. It is obvious that the dominant age groups in earlier years were 3- and 4-year-olds. As catches in-

Table 6. Catch (in number of fish) at age.

North Atlantic

AGE	YEARS									
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
0	580	1178	3306	2953	3697	4149	5222	4989	13140	14877
1	6402	10406	25881	14761	20357	29247	28733	32602	44092	62073
2	19279	27379	46023	34832	31038	54189	51951	57783	88748	100052
3	36184	33384	49655	40423	43192	55267	55518	65338	82864	91744
4	35416	32012	39174	34777	39982	48455	44301	51359	63560	61361
5	26021	22812	25817	20987	26889	30545	25892	26827	33138	31312
6	13661	14327	14852	11283	13260	15415	12703	12735	15379	15160
7	8664	8992	9327	7282	7745	8367	6432	7156	7645	6613
8	4269	4694	4697	4143	4971	4023	3222	3525	3974	3340
9	3290	3494	3228	2428	2932	2599	2020	2234	2595	1756
10	2051	2057	1927	1557	1678	1381	1135	1159	1481	1417
11	1074	1470	1151	928	1209	873	766	668	928	880
12	820	825	707	622	619	522	416	433	613	478
13	712	851	496	511	478	367	317	285	411	316
14	507	651	399	376	315	352	296	229	301	285
15+	5228	5985	5113	4758	6193	3808	2914	2814	3696	3164
TOTAL	164158	170517	231753	182621	204555	259559	241838	270136	362565	394828

South Atlantic

AGE	YEARS									
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
0	67	83	166	122	297	52	977	816	276	334
1	485	616	1015	1306	3268	1546	5345	7584	4197	5142
2	1485	3329	3729	3156	11297	7974	16049	20184	9438	14775
3	1463	7372	8442	4370	18886	12928	24197	22605	13923	11325
4	2204	5523	12494	5894	16699	11739	21655	29350	14678	14011
5	3883	5384	9641	6533	15222	13536	17066	22559	14990	16061
6	4886	3756	11210	5564	10711	10979	10937	11499	9681	13824
7	2798	2587	7154	3818	5570	3185	6992	4770	5096	6220
8	1045	1592	2608	2328	2772	2091	3075	3197	2471	2451
9	1342	1640	1341	1685	1426	681	1742	1591	1716	1571
10	871	1235	827	1301	1127	707	1395	980	1246	987
11	506	920	349	797	536	135	812	438	540	628
12	221	139	158	252	283	62	380	200	186	372
13	305	129	257	202	198	150	220	229	141	170
14	245	95	164	164	183	122	158	213	160	137
15+	2757	977	1072	3529	1473	800	2184	2709	1142	2050
TOTAL	24562	35378	60629	41021	89948	66687	113182	128923	79882	90056

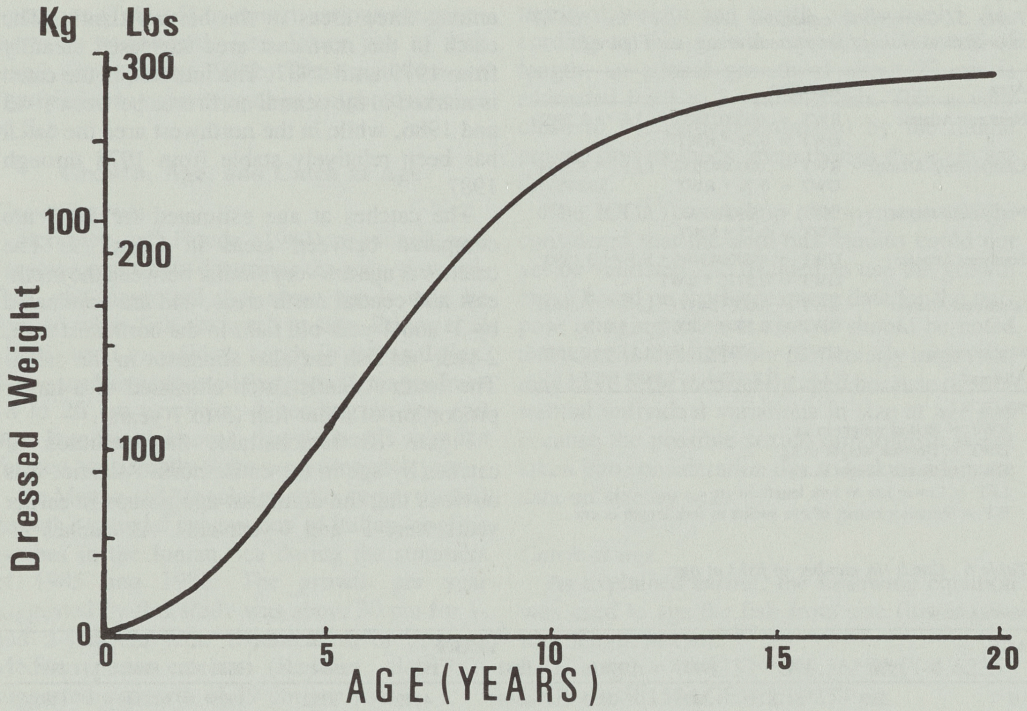

Figure 5. Swordfish growth curve (in dressed weight) fitted to the revised mark-recapture data set in 1988.

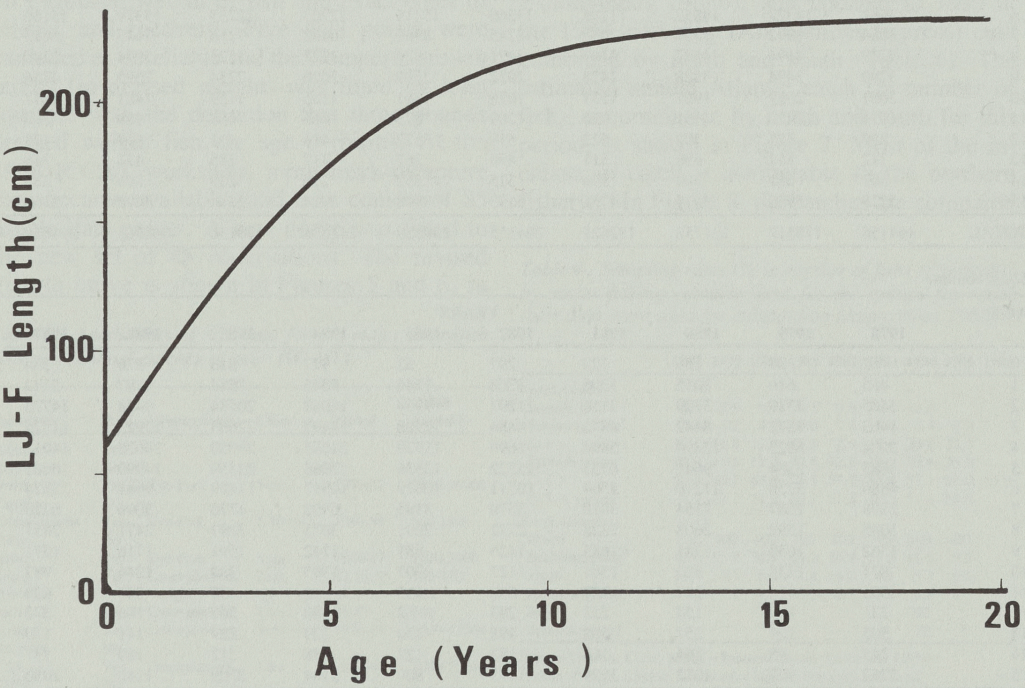

Figure 6. Swordfish growth curve (in lower jaw — fork length) to the revised mark-recapture data set in 1988.

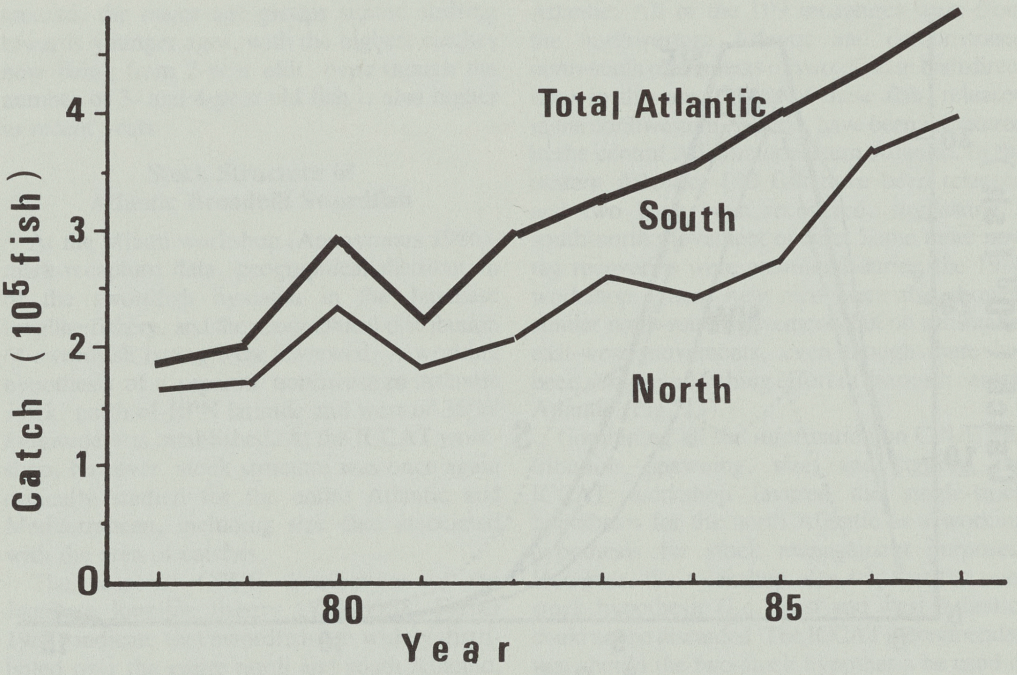

Figure 7. Cumulative swordfish catches for the North and South Atlantic.

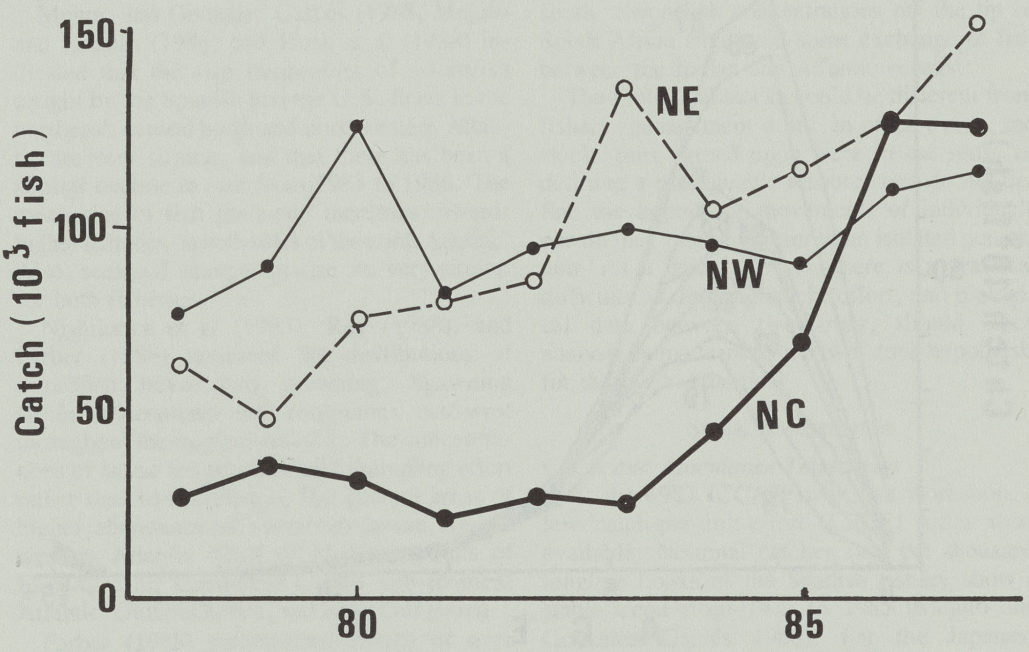

Figure 8. Estimated total catches (in number of fish) by three areas in the North Atlantic for 1978-1987.

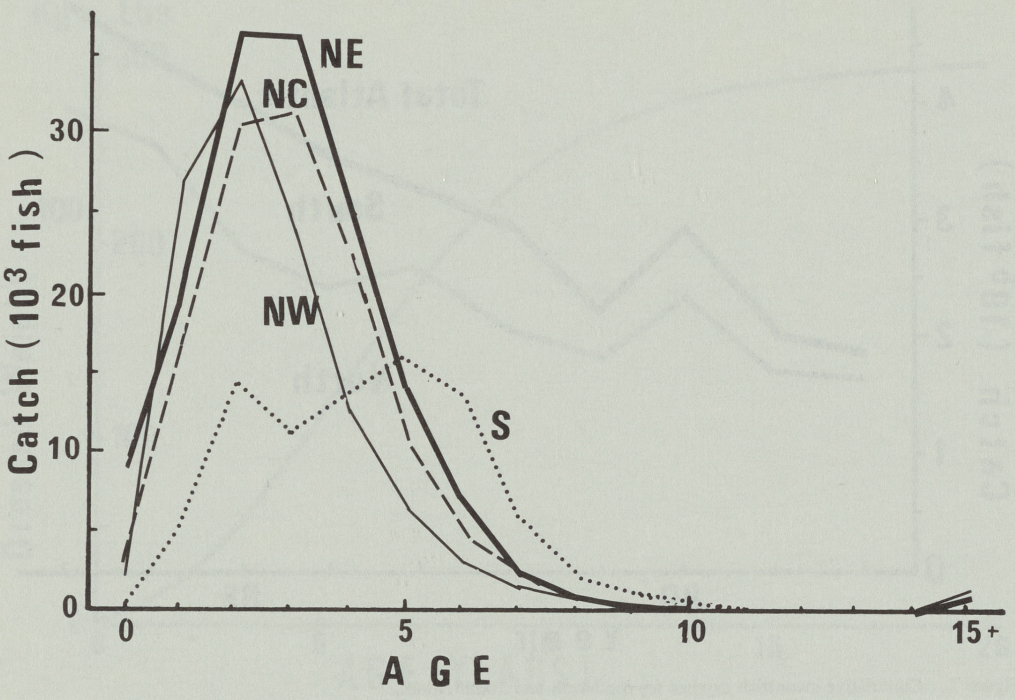

Figure 9. Catch at age (in number of fish) estimated for four major areas in the Atlantic Ocean. 1987.

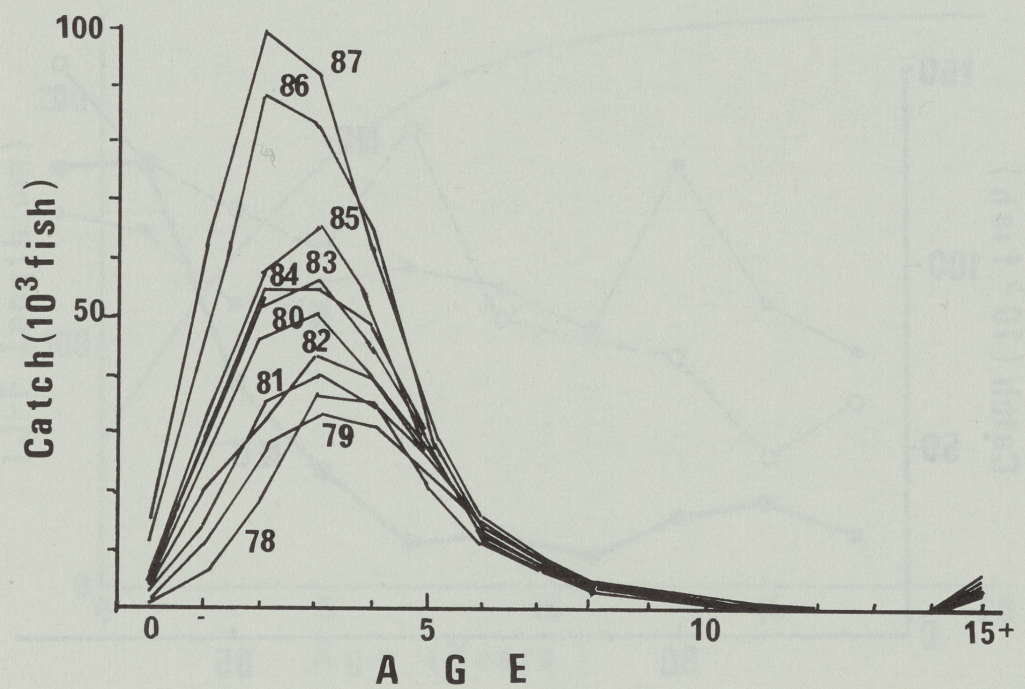

Figure 10. Catch at age (in number of fish) estimated for the total North Atlantic, 1978 through 1987.

creased, the major age groups started shifting towards younger ages, with the highest catches now being from 2-year olds, even though the number of 3- and 4-year-old fish is also higher in recent years.

Stock Structure of Atlantic Broadbill Swordfish

At the Miami workshop (Anonymous 1986), mark-recapture data, geographical distribution of the swordfish by-catch in the Japanese longline fishery, and the geographical distribution of swordfish larvae were reviewed. A working hypothesis of a separate northwestern Atlantic stock, north of 10°N latitude and west of 35°W longitude was established. At the ICCAT workshop, however, stock structure was once again critically studied for the entire Atlantic and Mediterranean, including size data associated with the area of catches.

The seasonal CPUE distributions of the Japanese longline fishery (Yao 1988; Farber 1988) indicate that swordfish are widely distributed over the entire north and south Atlantic, roughly between 40°N and 40°S. Concentrations of swordfish do occur in some areas such as the northwestern Atlantic, the Gulf of Guinea, and off southern Brazil/Uruguay (Fig. 2). There are no clear boundaries, however, which would suggest the existence of different stocks.

Mejuto and González Garcés (1988, Mejuto and Iglesias (1988) and Hoey et al (1988) indicated that the size frequencies of swordfish caught by the Spanish and the U.S. fleets in the northeast, central north and northwestern Atlantic are very similar, and that there has been a similar decline in size from 1983 to 1986. The mean size of fish gradually increases towards higher latitudes on both sides of the north Atlantic. Also, seasonal changes in size are very similar for both fisheries.

Nishikawa et al (1985), Rey (1988), and Farber (1988) reviewed the distributions of swordfish larvae and spawning. Spawning seems widespread and continuous east-west throughout the tropical Atlantic. The concentrations of larvae are proportional to sampling effort rather than to abundance. The general areas of higher abundance of swordfish larvae are the western Atlantic (Gulf of Mexico, Straits of Florida, and Caribbean), mid sub-tropical Atlantic, Gulf of Guinea, and waters off Brazil.

Farber (1988) summarized results of over 2,200 fish released with tags in the western Atlantic. All of the 109 recaptures were from the northwestern Atlantic and demonstrated north-south movements of swordfish in both directions in this area. None of these fish, released in the northwestern Atlantic, have been recaptured in the central Atlantic or eastern Atlantic. In the eastern Atlantic, 190 fish have been released and two have been recovered, suggesting a south-north movement of fish. Some more new tag recoveries were examined during the 1988 workshop. These new recoveries also showed similar north-south movements but no substantial east-west movements, even though there has been substantial fishing effort in the north central Atlantic (Fig. 11).

Combining all the information on CPUE distribution, spawning, size, and tagging, the ICCAT workshop favored the single-stock hypothesis for the north Atlantic as a working hypothesis for stock management purposes. However, the workshop also felt that the two-stock hypothesis (i.e., east and west Atlantic) could not be discarded. The ICCAT recommended that should the two-stock hypothesis be used in any assessment work, the significant mixing of east and west fish should be incorporated into the analysis (Anonymous 1988b).

For the south Atlantic, the workshops' consensus was that the stock should be considered separate from the north, but as one stock in the south. Swordfish concentrations off the tip of South Africa suggested some exchange of fish between the Indian and Atlantic oceans.

The biological stocks could be different from fishery management units. In other words, the stocks thus agreed upon were in the sense of defining a manageable resource and do not define the bounds of movements of individuals nor do they intend to refer to an isolated genetic unit. As a matter of fact, there is a practical difficulty in dividing catch, effort, and biological data between two areas, should stock analysis be made under the two-stock hypothesis for the north Atlantic.

Stock Assessments

Catch and Abundance Tendencies

At the 1987 ICCAT swordfish workshop, a few catch-per-unit-effort (CPUE) series were available. Nominal catches (kg) per thousand longline hooks of the Spanish fishery show a stable trend from 1975 to 1985 (Mejuto and González Garcés 1988). For the Japanese longline fisheries, Yao (1988) presented quarterly

hook rates by four areas, for 1956 to 1985. For the U.S. fishery, Hoey and Bertolino (1988) and Hoey and Casey (1988) presented the number of fish per 1,000 hooks for five areas (Caribbean, Gulf of Mexico, U.S. Southeast, U.S. Northeast, and Grand Banks). Arfelli and Ferreira de Amorim (1988) reviewed the CPUE of the Brazilian fishery based at Santos.

At the 1988 workshop, new standardized CPUE series were presented, this time by categories of fish sizes (Anonymous in press). Several indices for the combined U.S. and Spanish fisheries and several for the U.S. alone were developed by four length and weight categories, for 1981 through 1987 (Table 7). Earlier years were excluded because improvements in fishing gear structure increased efficiency which could not be quantitatively adjusted. Observations with zero catches of specific size groups were eliminated from the analyses. For the Japanese longline fishery, CPUE indices were developed for three areas of the north Atlantic and for the entire north Atlantic and the southeast Atlantic, using general linear models for 1978 through 1987 (Table 7). Figures 12, 13, and 14 compare age specific U.S.-Spanish CPUE with catch (in number of fish) in the north Atlantic, for categories of age 1, 2-4, and 5-10, respectively. The catch of age 1 and 2-4 fish increased sharply in recent years, while the CPUE of age 1 fish showed a moderate increase and that for ages 2-4 has been stable. For age 5+, the catch has been stable, while the CPUE declined sharply. Such discrepancies between the CPUE and catch trends are not very commonly observed in the fishery. They probably indicate: (1) that effort had increased markedly; (2) that catchability had declined, perhaps due to competition among vessels as fleet sizes have grown; (3) an error in standardized indices; and/or (4) an error in catch estimates (Anonymous in press).

Figure 15 compares Japanese CPUE with the north Atlantic catches of age 4-10, 5-10, and 6-10 fish. The CPUE showed a slight declining trend, while the catch of fish ages 5-10 or 6-10 has been stable and the catch of age 4-10 fish increased during this period. What age fish the Japanese index represent was discussed, since it was found later that virtual population analysis (VPA) tuning is extremely sensitive to ages to which the CPUE series was applied. After examining the size frequencies of the Japanese catches, the workshop decided to adopt two scenarios of ages 4-10 and ages 5-10.

For the south Atlantic, only one index series was available, i.e., Japanese longline for the southeast Atlantic (Table 7). The catches of various age categories are comapred with the CPUE for the south Atlantic in Figure 16, which gave a somewhat more realistic look than in the

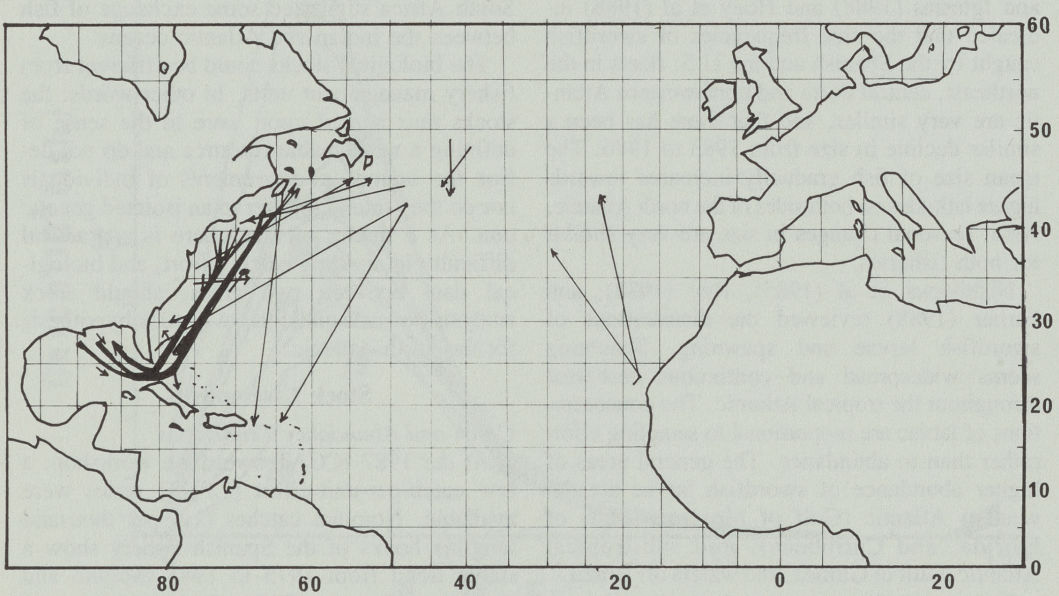

Figure 11. Major swordfish tag recoveries. (Faber 1988 and Anonymous, in press).

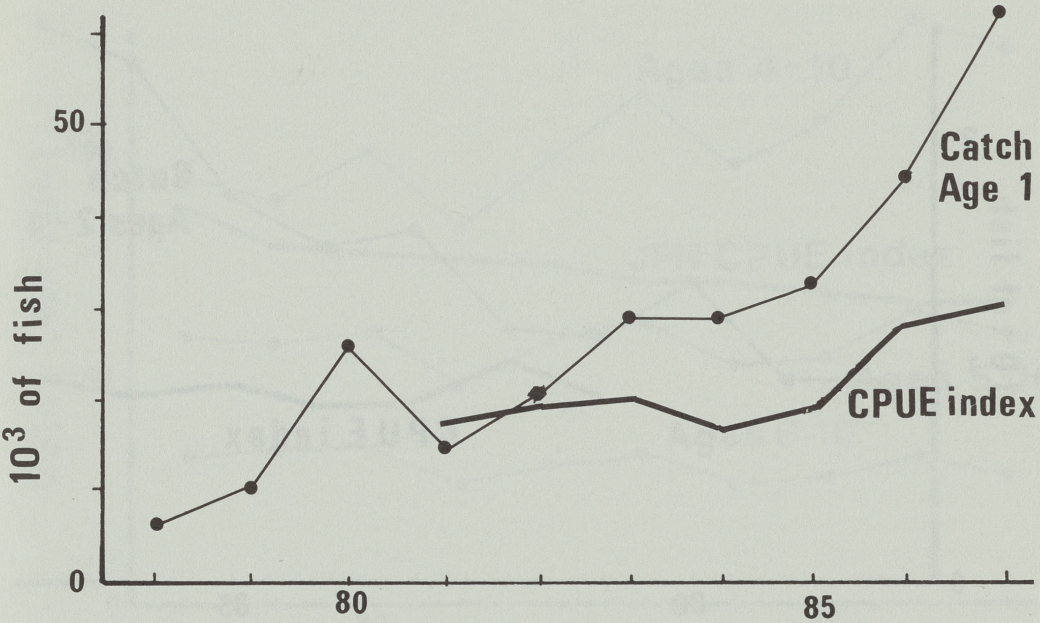

Figure 12. U.S.-Spanish combined CPUE for age 1 fish and catch (in number) of age 1 fish in the North Atlantic.

case of the north Atlantic for 1978 through 1986. The Japanese data for 1987 are still preliminary and, since the proportion of the Japanese catch in the total catch is very high in the South, 1987 data were excluded from the analyses. Japanese CPUE showed a moderate increase until 1983 and then started declining. Catches increased with fluctuation until 1985 and then dropped in 1986. The Japanese CPUE series was applied to ages 4-14 for the South.

Virtual Population Analysis

At the 1988 workshop, virtual population analysis (VPA) was employed to estimate the numbers of fish in each cohort (on January 1 of each year) and the annual, age-specific, instantaneous fishing mortality rates. (Fs), using updated catch-at-age tables for 1978 through 1987 for the north Atlantic, and through 1986 for the south Atlantic. As was recommended at the workshop, the catch-at-age tables were com-

Table 7. CPUE indices examined at the 1988 ICCAT swordfish workshop.

INDEX	SOURCE	AREA	AGES	YEARLY VALUES 1978	1979	1980	INDEX VALUES 1981	1982	1983	1984	1985	1986	1987
1	JPN LL	NW	4-10	0.8670	0.5018	0.4085	0.4786	0.6170	0.3974	0.5573	0.3817	0.3479	0.1606
2	JPN LL	4B N.	4-10	0.6655	0.7151	0.5708	0.5680	0.3292	0.4104	0.4724	0.3248	0.3060	0.2511
3	JPN LL	4B S.	4-10	1.2144	0.8866	1.0202	0.8650	0.7828	0.7498	0.6642	0.6839	0.6186	0.8093
4	JPN LL	7	4-14	0.4548	0.9876	1.0037	1.1216	1.0427	1.2136	1.0271	0.8922	0.7794	1.2074
5	USA LL	NW	5-14				8.5049	6.5812	3.3169	2.7322	2.9251	1.9984	1.8386
6	USA LL	NW	3-4				6.5981	5.3089	3.2352	3.7392	4.0947	3.4439	3.4441
7	USA LL	NW	2				3.3713	3.2309	3.2658	3.3966	3.3579	4.4856	4.5275
8	USA LL	NW	0,1				1.3159	1.8827	1.5822	1.4411	1.8183	2.4051	2.3670
9	USA LL	NW	19+				1.1986	0.7637	0.7003	0.4227	0.4870	0.3754	0.4056
10	USA LL	NW	5-18				5.5288	4.5887	2.1423	1.8319	1.9723	1.3250	1.2424
11	USA LL	NW	2-4				5.3746	5.6733	4.3836	4.5527	5.1265	4.9861	5.1194
12	USA LL	NW	0,1				0.6880	0.9883	0.8108	0.7654	0.8369	1.0157	0.9070
13	USA+SPAIN LL	N. ATL.	0,1				0.2905	0.3250	0.3326	0.2750	0.3217	0.4759	0.5181
14	USA+SPAIN LL	N. ATL.	2-4				12.5171	14.6887	12.2499	12.0392	13.3643	12.6759	13.7271
15	USA+SPAIN LL	N. ATL.	5-18				31.4657	24.4869	13.2140	12.1369	11.5874	8.9684	8.1298
16	USA+SPAIN	N. ATL.	19+				0.9159	0.4912	0.5451	0.4266	0.4416	0.3934	0.3654
17	JPN LL	N. ATL.	4-10	1.4615	1.2979	1.2742	1.2598	1.2381	1.1716	1.1769	1.1376	1.1097	1.1092

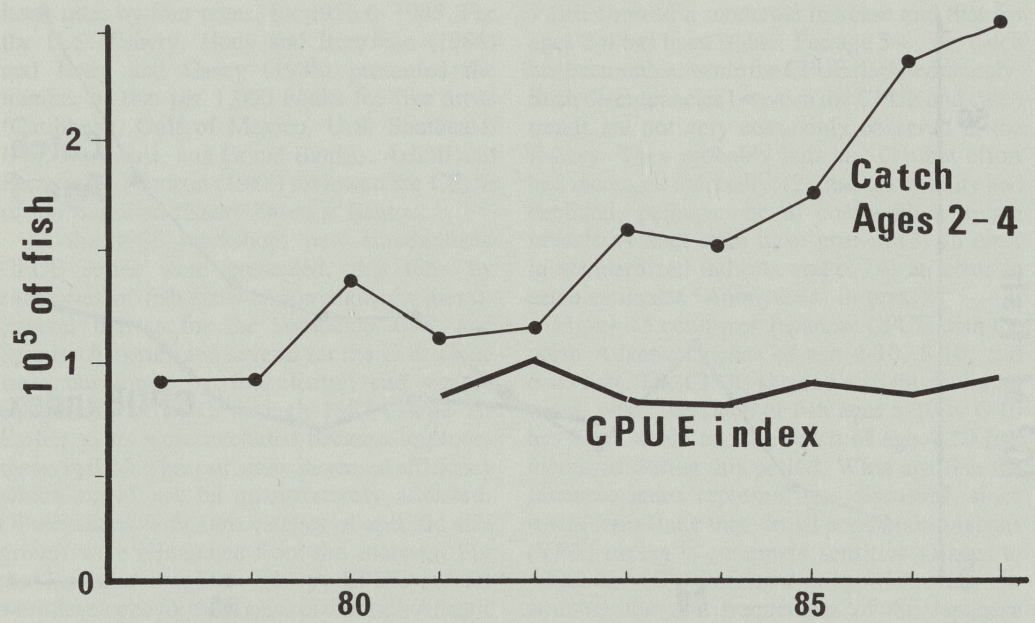

Figure 13. U.S.-Spanish combined CPUE for age 2-4 fish and catch (in number) of age 2-4 fish in the North Atlantic.

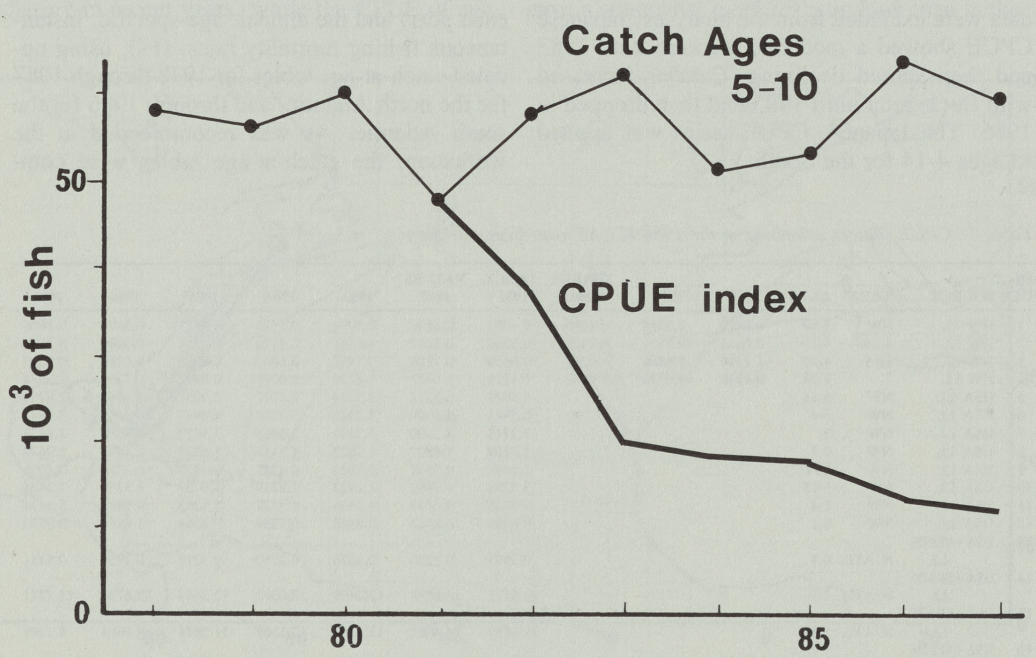

Figure 14. U.S.-Spanish combined CPUE for age 5-14 fish and catch (in number) of age 5-10 fish in the North Atlantic.

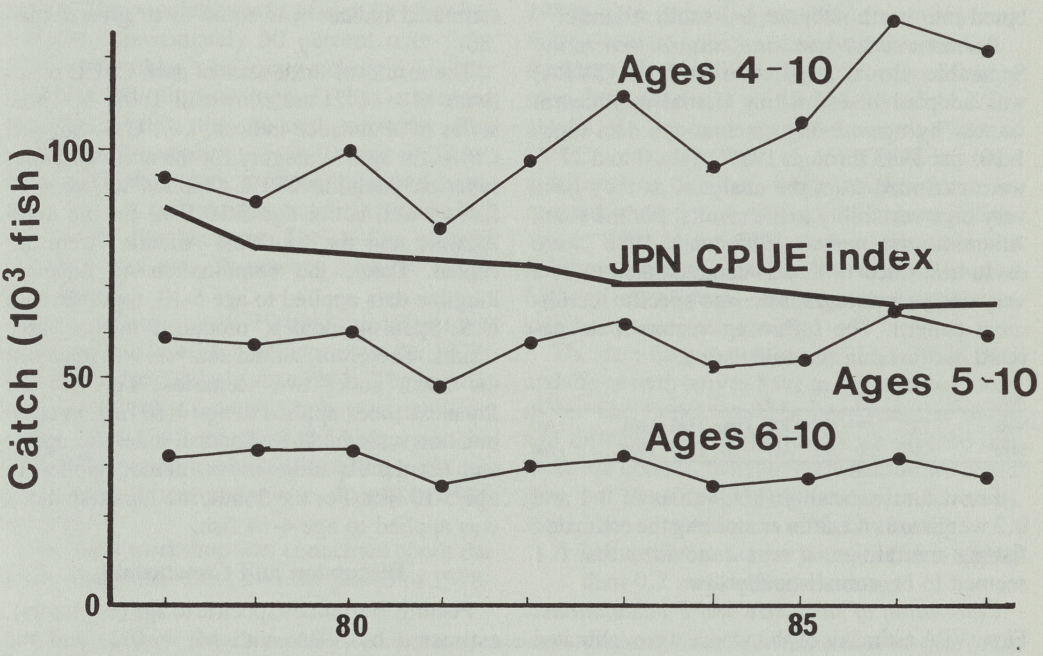

Figure 15. Japanese CPUE and catch (in number) of age 4-10, 5-10 and 6-10 fish in the North Atlantic.

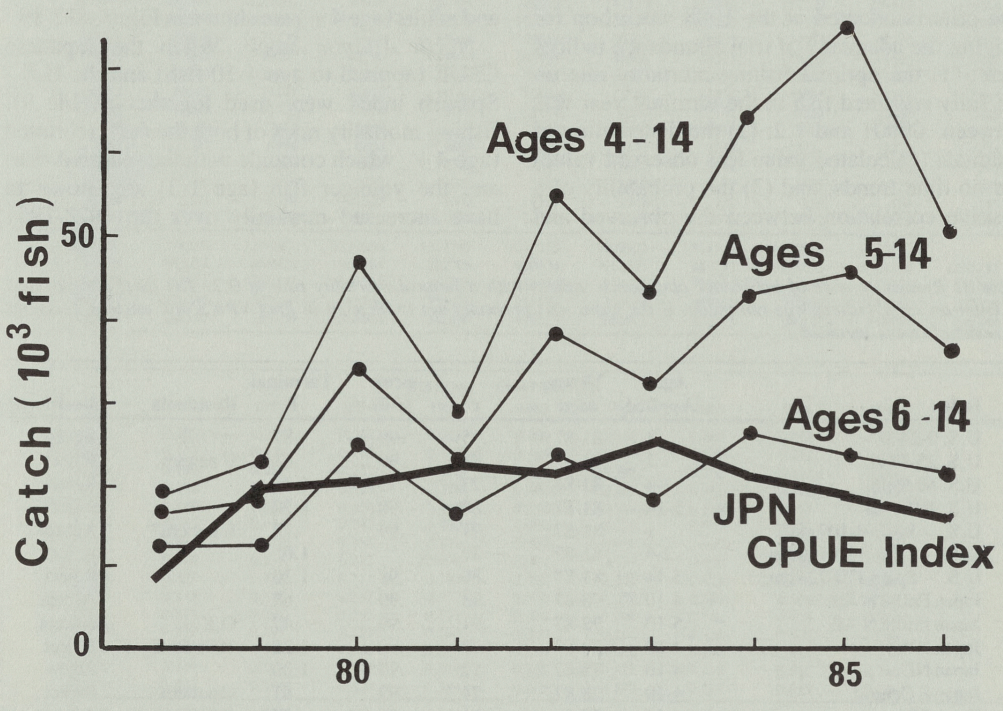

Figure 16. Japanese CPUE and catch (in number) of age 4-14, 5-14 and 6-14 fish in the South Atlantic.

bined into north Atlantic and south Atlantic.

Partial recruitment and natural mortality. Separable virtual population analysis (SVPA) was adopted in estimating partial recruitment vectors by ages, using catch-at-age data (ages 1-10) for 1983 through 1987. Ages 0 and 11+ were excluded from the analysis, as they gave very high variability to the results. For the south Atlantic, the years 1985 and 1986 were excluded, since 1985 was demonstrated to be a very odd year as regards the age-specific recruitment pattern. The following vectors were derived and used in the calculation:

Ages	1	2	3	4	5	6	.....	.....	15+
North	.117	.338	.902	1.000	1.000	1,000	1.000	.....	1.000
South	.022	.130	.313	.444	.743	1.000	1.000	.....	1.000

For natural mortality (M), values of 0.1 and 0.2 were used and, after examining the estimated fishing mortalities, it was concluded that 0.1 seemed to be unrealistically low.

Calibration of stock size and F calculations. First, VPA estimates of abundance were calibrated independently to several series of abundance indices to examine their acceptability, with M = 0.1 and 0.2. The least squares procedure minimizes the squared difference between observed abundance indices and VPA estimates. The criteria adopted at the 1988 workshop for judging the adequacy of trial abundance indices were: (1) the optimal fishing mortality rate on the fully recruited fish in the terminal year was between .00001 and 1.2; (2) the distribution of residuals (calculated value less observed value) has no time trends; and (3) the probability of a positive correlation between the observed and estimated indices was equal to or greater than .80.

The results of these tests of each CPUE series (with M = 0.2) are shown in Table 8. Three series of abundance indices, i.e., U.S.-Spanish CPUE for age-1 category for the north Atlantic, Japanese longline CPUE (applied to age 4-10 fish as well as for age 5-10 fish) for the north Atlantic and the southeast Atlantic, were accepted. Later, the combination of Japanese longline data applied to age 5-10, together with U.S.-Spanish indices, produced unacceptable results. Therefore, a final analysis was made for the north under two scenarios, i.e., (1) the Japanese index applied to age 4-10 fish, in combination with the U.S.-Spanish index for age 1; and (2) the Japanese index, alone, applied to age 5-10 fish. For the South, the Japanese index was applied to age 4-14 fish.

Discussion and Conclusions

Fishing mortalities specific to age (F-vectors), estimated by VPA with M = 0.2, and the estimated number of fish in each cohort at the beginning of each year, are shown in Tables 9 and 10 for the north Atlantic (under the two scenarios) and in Table 11 for the south Atlantic. The estimated stock size for juveniles (ages 1-3) and adults (age 4+) are shown in Figures 17-19.

North Atlantic stock. When the Japanese CPUE (applied to age 4-10 fish) and the U.S.-Spanish index were used together (Table 9), fishing mortality rates of both the fully recruited (age 4+, which coincide with the matured fish) and the younger fish (age 1-3) are shown to have increased markedly over the 1978-1987

Table 8. Results of tests of individual abundance indices with a natural mortality rate of 0.2. The final accept/reject decision on some indices was not made, if the index was probably not to be used in final VPA's and unclear decisions on residuals were involved.

	Index	Ages Applied	Years used	r	prob (r>0)	Terminal F	Residuals	Decision
8	U.S. 0-24 lb	1	81-87	.85	.99	.87	±O.K.	Accept
7	U.S. 25-49 lb	2	81-87	.88	.99	.81	U pattern	Reject
6	U.S. 50-99 lb	3-4	81-87	.23	.73	1.30		Reject
5	U.S. 100+ lb	5-14	81-87	.80	.98	1.30		Reject
13	U.S. – Spain 0-109 cm	1	81-87	.91	.99	.78	U pattern?	Accept
14	U.S. – Spain 110-169 cm	2-4	81-87	–.39		1.05		Reject
15	U.S. – Spain 170-224 cm	5-14	81-87	.80	.98	1.30		Reject
17	Japan Entire N Atl.	4-10	78-87	.93	.99	.68		Accept
17	Japan Entire N Atl.	5-10	78-87	.91	.99	.47	O.K.	Accept
1	Japan NW	4-10	78-87	.79	.99	1.30	1978 Outlier?	Reject
2	Japan NE	4-10	78-87	.82	.99	1.30		Reject
3	Japan E Central	4-10	78-87	.74	.99	.81	U pattern	Reject
4	Japan SW	4-14	78-86	.71	.98	.73	O.K.	Accept

period. The population size of age 4+ fish has declined approximately 50 percent over this period (the older age groups show a sharper decline). Recruitment (age 1) has increased steadily. Under the second scenario (the Japanese index applied to 5- to 10-year-old fish), the trends in the fishing mortality rates and population size are very similar, but are more modest than for the first scenario. The decline of fully recruited ages was 28 percent over the 1978-1987 period.

South Atlantic stock. Fishing mortality rates have also increased for all ages over the 1978-1986 period (particularly after 1984). The population size of fully recruited fish was stabilized during 1978-1985, but declined sharply in the 1986-1987 period to about 60% of the previous year's level. Recruitment rose sharply in 1986 and 1987.

The 1988 workshop was concerned about the steady sharp increases, over the period of 1978-1987, in the estimated population sizes of young fish (ages 0-3), which seemed rather unrealistic. Besides, the unrealistically high levels of fishing mortality cast doubt on the validity of the VPA results. As has been seen in the comparison of CPUE with catch (Figs. 11-15), CPUE has been stabilized or declined while catches have increased sharply, particularly for young fish. When VPA is tuned to such a situation, the fishing mortality naturally has to be estimated high in recent years and estimated population size has to increase rapidly.

The data base (catch-at-size) and CPUE data and the growth curves have to be examined once more. The model would be very sensitive to the age distributions. However, if we assume that these are correct, then any explanation we could give to these apparently conflicting results would be a combination of the following:

1. Natural mortality for younger fish is higher than 0.2 and declines with age:

Table 9. Age-specific initial population size and fishing mortality estimated by VPA, tuned to Japanese longline CPUE (Series 17) applied to ages 4-10 and U.S.-Spanish CPUE (Series 13) applied to age 1, with M = 0.2.

	INITIAL POPULATION SIZE										
AGE	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
1	377171	393277	399635	393580	455011	480731	495248	571999	655391	824392	0
2	270128	303021	312593	303843	308911	354158	367200	379548	438895	496810	618964
3	201863	203771	223403	214477	217371	224932	241159	253841	258709	279502	316748
4	142538	132704	136776	138260	139224	139111	134494	147535	149130	137494	146571
5	93078	84876	79879	76816	81950	78096	70470	70392	74765	65272	57747
6	52601	52842	49003	42246	44045	42984	36600	34505	33613	31602	25497
7	32848	30794	30397	26793	24454	24162	21381	18581	16844	13785	12345
8	20457	19112	17141	16518	15397	13074	12283	11734	8807	6962	5385
9	13819	12909	11429	9816	9802	8148	7095	7162	6444	3660	2720
10	8785	8357	7431	6459	5855	5394	4340	3995	3860	2954	1430
11	5847	5349	4994	4353	3889	3287	3175	2533	2231	1834	1154
12	4247	3820	3059	3054	2729	2099	1907	1911	1474	996	717
13	3747	2739	2386	1869	1941	1678	1250	1187	1175	659	389
14	2174	2427	1479	1507	1072	1159	1044	738	716	594	257
15+	22416	22312	18956	19073	21066	12542	10277	9075	8792	6596	2808
1+	1251719	1278310	1298561	1258664	1332717	1391555	1407923	1514736	1660846	1873112	—
2+	874548	885033	898926	865084	877706	910824	912675	942737	1005455	1048720	1192732
3+	604420	582012	586333	561241	568795	556666	545475	563189	566560	551910	573768
4+	402557	378241	362930	346764	351424	331734	304316	309348	307851	272408	257020
5+	260019	245537	226154	208504	212200	192623	169822	161813	158721	134914	110449

	FISHING MORTALITIES									
AGE	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
1	0.019	0.030	0.074	0.042	0.051	0.069	0.066	0.065	0.077	0.087
2	0.082	0.105	0.177	0.135	0.117	0.184	0.169	0.183	0.251	0.250
3	0.220	0.199	0.280	0.232	0.246	0.314	0.291	0.332	0.432	0.446
4	0.318	0.308	0.377	0.323	0.378	0.480	0.447	0.480	0.626	0.668
5	0.366	0.349	0.437	0.356	0.445	0.558	0.514	0.539	0.661	0.740
6	0.335	0.353	0.404	0.347	0.400	0.498	0.478	0.517	0.691	0.740
7	0.342	0.386	0.410	0.354	0.426	0.477	0.400	0.547	0.684	0.740
8	0.260	0.314	0.358	0.322	0.436	0.411	0.339	0.399	0.678	0.740
9	0.303	0.352	0.371	0.317	0.397	0.430	0.374	0.418	0.580	0.740
10	0.296	0.315	0.335	0.307	0.377	0.330	0.338	0.383	0.544	0.740
11	0.226	0.359	0.292	0.267	0.417	0.344	0.308	0.342	0.606	0.740
12	0.239	0.271	0.293	0.253	0.286	0.319	0.274	0.286	0.606	0.740
13	0.234	0.416	0.259	0.356	0.315	0.275	0.326	0.306	0.482	0.740
14	0.296	0.349	0.351	0.320	0.389	0.405	0.372	0.415	0.615	0.740
15+	0.296	0.349	0.351	0.320	0.389	0.405	0.372	0.415	0.615	0.740
5+	0.290	0.347	0.351	0.320	0.389	0.405	0.372	0.415	0.615	0.740

2. Fishing effort has been increasing sharply and fishing mortality in recent years is high in reality;
3. CPUE does not represent total population due to the slow mixing of fish between areas;
4. CPUE does not represent an abundance of age groups to which the VPA was tuned;
5. Catchability changed through gear competition or a change in natural environment;
6. Applying a single growth curve to males and females is not valid.

Summary

In the last several years, European (mostly Spanish) longliners fishing for swordfish expanded their fishing grounds toward the northwest and along the west African coast, while the North American longline fishery has expanded eastwards. Both fisheries now operate in the same fishing grounds in the central north Atlantic.

Catch per unit of effort (CPUE) for age 1 fish has been on an upward trend and that for age 2-4 fish has been stable, whereas catches of age 1-4 fish have increased sharply in the last few years in the north Atlantic. The CPUE for ages over 5 has been declining, while catches have been stabilized. In the south Atlantic, both catch and CPUE have declined slightly in the last few years.

At the stock asessment workshop which met in Miami in April, 1986, and at the two workshops on Atlantic swordfish held by the International Commission for the Conservation of Atlantic Tunas (ICCAT) in 1987 and 1988, all the biological and catch information available on swordfish in the Atlantic was used to create a data base of catch at size (for 1978 through 1987). A growth curve estimated from tag mark-

Table 10. Initial population size and fishing mortality estimated by VPA with M = 0.2, tuned to the Japanese CPUE (Index 17) for ages 5-10.

					INITIAL STOCK SIZES						
AGE	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
1	384465	400702	411158	412191	489786	539322	599551	765159	963913	1278605	0
2	274658	308992	318671	313276	324148	382628	415167	464939	597033	749390	990812
3	204330	207479	228291	219451	225092	237404	264457	293097	328590	408878	523407
4	144169	134722	139810	142257	143293	145426	144690	166586	181220	194575	252274
5	94543	86209	81529	79294	85217	81419	75622	78714	90311	91413	104263
6	53381	54039	50092	43592	46070	45650	39308	38706	40398	44259	46777
7	33280	31432	31375	27683	25554	25815	23556	20791	20271	19306	22647
8	20807	19464	17662	17317	16124	13972	13632	13510	10608	9751	9879
9	14041	13195	11717	10241	10454	8741	7828	8265	7895	5127	4990
10	8907	8538	7665	6695	6203	5927	4824	4595	4761	4137	2623
11	5951	5449	5142	4544	4082	3571	3611	2929	2720	2569	2117
12	4307	3906	3141	3175	2886	2257	2139	2268	1798	1395	1315
13	3804	2789	2456	1936	2040	1806	1378	1377	1467	923	714
14	2207	2474	1520	1564	1126	1240	1148	844	871	832	472
15+	22756	22742	19472	19797	22138	13418	11306	10366	10699	9237	5152
1+	1271606	1302132	1329701	1303013	1404213	1508596	1608217	1872146	2262555	2820397	—
2+	887141	901430	918543	890822	914427	969274	1008666	1106987	1298642	1541792	1967442
3+	612483	592438	599872	577546	590279	586646	593499	642048	701609	792402	976630
4+	408153	384959	371581	358095	365187	349242	329042	348951	373019	383524	453223
5+	263984	250237	231771	215838	221894	203816	184352	182365	191799	188949	200949

					FISHING MORTALITIES					
AGE	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
1	0.019	0.029	0.072	0.040	0.047	0.062	0.054	0.048	0.052	0.055
2	0.080	0.103	0.173	0.131	0.111	0.169	0.148	0.147	0.179	0.159
3	0.217	0.195	0.273	0.226	0.237	0.295	0.262	0.281	0.324	0.283
4	0.314	0.302	0.367	0.312	0.365	0.454	0.409	0.412	0.484	0.424
5	0.359	0.343	0.426	0.343	0.424	0.528	0.470	0.467	0.513	0.470
6	0.330	0.344	0.393	0.334	0.379	0.462	0.437	0.447	0.538	0.470
7	0.336	0.376	0.394	0.341	0.404	0.439	0.356	0.473	0.532	0.470
8	0.255	0.308	0.345	0.305	0.412	0.379	0.300	0.337	0.527	0.470
9	0.297	0.343	0.360	0.302	0.368	0.394	0.333	0.352	0.446	0.470
10	0.291	0.307	0.323	0.295	0.352	0.296	0.299	0.324	0.417	0.470
11	0.221	0.351	0.282	0.254	0.393	0.312	0.265	0.288	0.468	0.470
12	0.235	0.264	0.284	0.243	0.269	0.293	0.240	0.236	0.467	0.470
13	0.230	0.407	0.251	0.342	0.298	0.253	0.291	0.258	0.367	0.470
14	0.291	0.341	0.340	0.306	0.366	0.373	0.332	0.354	0.475	0.470
15+	0.291	0.341	0.340	0.306	0.366	0.373	0.332	0.354	0.475	0.470
5+	0.285	0.339	0.340	0.306	0.366	0.373	0.332	0.353	0.475	0.470

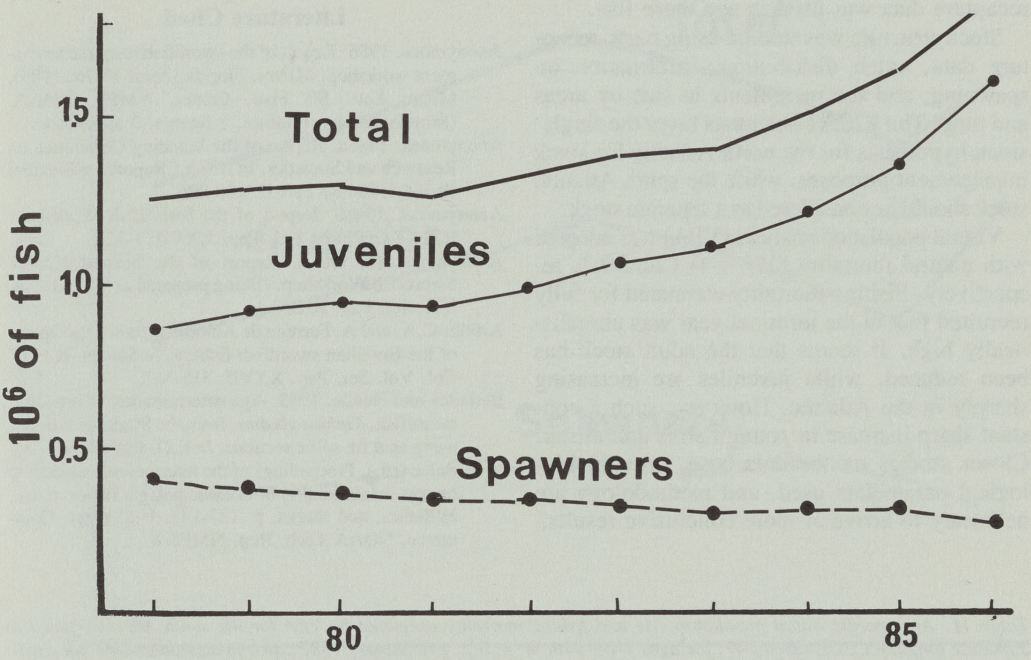

Figure 17. Estimated number of juveniles (age 1-3) at the beginning of the year, spawners (age 4+) and total population based on VPA tuned to the Japanese index applied to age 4-10 fish with U.S.-Spanish combined index for age 1 fish, North Atlantic (M = 0.2).

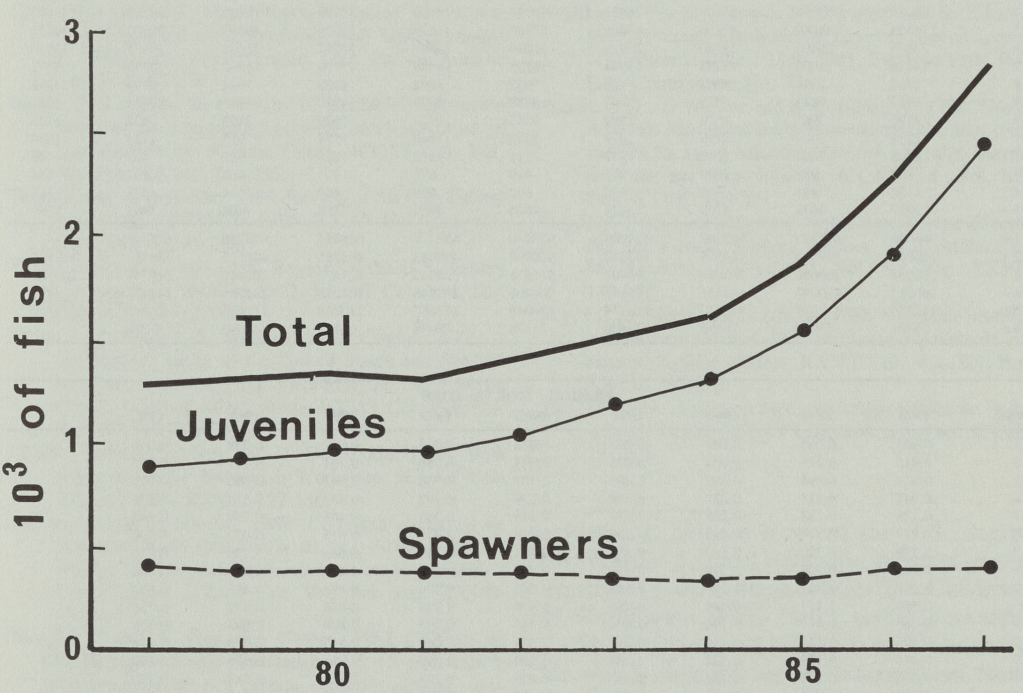

Figure 18. Estimated number of juveniles (age 1-3) at the beginning of the year, spawners (age 4+) and total population based on VPA tuned to the Japanese index applied to age 5-10 fish, North Atlantic (M = 0.2).

recapture data was used to age these fish.

Stock structure was studied using mark-recapture data, catch distribution, information on spawning, and the increments in size by areas and time. The ICCAT scientists favor the single-stock hypothesis for the north Atlantic for stock management purposes, while the south Atlantic stock should be considered as a separate stock.

Virtual population analysis (VPA) was adopted with natural mortality (M) = 0.1 and 0.2, respectively. Fishing mortality estimated for fully recruited fish in the terminal year was unrealistically high. It seems that the adult stock has been reduced, while juveniles are increasing sharply in the Atlantic. However, such a constant sharp increase in young fish is unrealistic. Closer studies on the data base, growth, biological parameters used, and methodology are necessary to arrive at more conclusive results.

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Table 11. Age-specific initial population size and fishing mortality estimated by VPA for the south Atlantic, tuned to Japanese longline CPUE (Series 47) for ages 4-14, with M = 0.2. Preliminary 1987 catch-at-size data were not used.

	INITIAL POPULATION SIZE									
AGE	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
1	157991	150191	171167	191316	199651	166331	144758	148621	289864	0
2	111971	128914	122410	139223	155457	160510	134784	113692	114836	233530
3	72081	90333	102540	96854	111136	117087	124218	95888	74916	85508
4	53289	57694	67309	76339	75353	73989	84209	79930	58188	48807
5	36523	41640	42256	43865	57185	46679	50006	49490	39153	34453
6	23693	26402	29240	25929	30030	33147	26067	25645	20371	18636
7	14496	15003	18233	13904	16225	14989	17294	11562	10723	8037
8	8764	9351	9955	8525	7955	8292	9408	7904	5199	4231
9	6317	6233	6223	5808	4889	4029	4910	4945	3611	2051
10	4190	3965	3630	3889	3242	2723	2686	2459	2622	1425
11	2274	2647	2139	2229	2017	1645	1594	956	1136	1034
12	1366	1407	1343	1437	1111	1170	1225	581	391	448
13	884	919	1027	957	949	655	902	662	297	154
14	1160	451	636	610	602	599	402	541	337	117
15+	13057	4635	4160	13121	4844	3929	5550	6880	2403	1081
1+	508056	539785	582268	624006	670646	635774	608013	549756	624047	—
2+	350065	389594	411101	432690	470995	469443	463255	401135	334183	439512
3+	238094	260680	288691	293467	315538	308933	328471	287443	219347	205982
4+	166013	170347	186151	196613	204402	191846	204253	191555	144431	120474
5+	112724	112653	118842	120274	129049	117857	120044	111625	86243	71667
6+	76201	71013	76586	76409	71178	70038	62135	47090	37214	

	FISHING MORTALITIES								
AGE	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	0.003	0.005	0.007	0.008	0.018	0.010	0.042	0.058	0.016
2	0.015	0.029	0.034	0.025	0.084	0.056	0.141	0.217	0.095
3	0.023	0.094	0.095	0.051	0.207	0.130	0.241	0.300	0.229
4	0.047	0.111	0.228	0.089	0.279	0.192	0.332	0.514	0.324
5	0.124	0.153	0.288	0.179	0.345	0.383	0.468	0.688	0.542
6	0.257	0.170	0.543	0.269	0.495	0.451	0.613	0.672	0.730
7	0.238	0.210	0.560	0.358	0.471	0.266	0.583	0.599	0.730
8	0.141	0.207	0.339	0.356	0.480	0.324	0.443	0.583	0.730
9	0.266	0.341	0.270	0.383	0.385	0.206	0.492	0.435	0.730
10	0.259	0.417	0.288	0.456	0.479	0.335	0.833	0.572	0.730
11	0.280	0.479	0.198	0.496	0.345	0.095	0.809	0.693	0.730
12	0.196	0.115	0.139	0.214	0.328	0.060	0.415	0.473	0.730
13	0.474	0.168	0.321	0.264	0.260	0.290	0.311	0.476	0.730
14	0.264	0.263	0.332	0.350	0.405	0.253	0.562	0.563	0.730
15+	0.264	0.263	0.332	0.350	0.405	0.253	0.562	0.563	0.730
6+	0.264	0.263	0.332	0.350	0.405	0.253	0.562	0.563	0.730

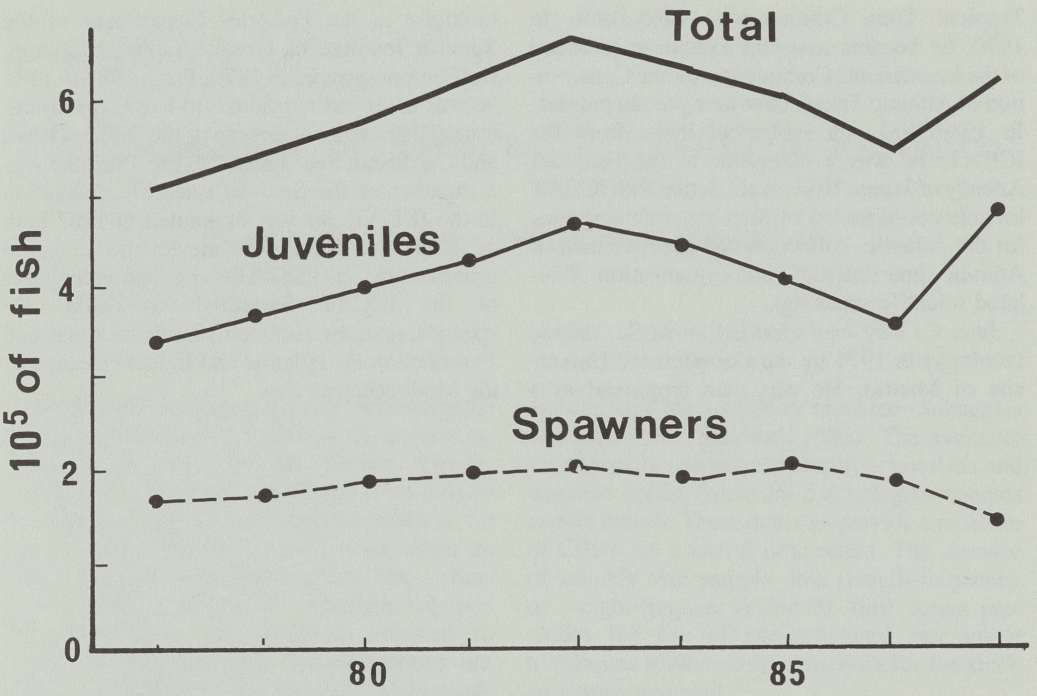

Figure 19. Estimated number of juveniles (age 1-3) at the beginning of the year, spawners (age 4+) and total population based on VPA tuned to the Japanese index applied to age 4-14 fish, South Atlantic (M = 0.2).

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An Assessment Of The Pacific Swordfish Resource

Norman W. Bartoo and Atilio L. Coan, Jr.

The swordfish *(Xiphias gladius)* is cosmopolitan in its distribution, found in all tropical to temperate oceans. In the Pacific Ocean, swordfish are generally distributed from Asia to the Americas and from 50 degrees north to 50 degrees south latitude. Swordfish are taken by many countries with various gears. For a complete discussion of Pacific swordfish fisheries and their trends the reader is referred to Sakagawa (this volume). These fisheries are both coastal and high-seas in nature. Data available from these fisheries provide the basic information from which to draw inferences about the state of the swordfish stocks, in this chapter the condition of the Pacific swordfish resource.

We have chosen two stock structure hypotheses which are consistent with previous reviews of the condition of the resource (Sakagawa and Bell 1980). One hypothesis envisions a single Pacific stock, under the rationale that the resource appears to be contiguous, with zones of local high catches due to high abundance or high vulnerability, and the assumption that the population is sufficiently mobile to make the concept of local depletion on an annual basis a non-issue. Our second hypothesis is to separate out 3 general areas of apparent high abundance in the northwest, southwest and east Pacific, made contiguous by a broad region of lower catches.

Data and Rationale

Each country and fishery reports different data ranging from estimated total catch to detailed catch and effort by area. A review of all available Pacific swordfish data indicates that only the Japanese longline fishery data are suitable in their detail and time period covered to provide a basis for a catch-per-unit-effort (CPUE) assessment of the Pacific swordfish stock. This conclusion was reached by others who previously investigated the swordfish resource (Sakagawa and Bell 1980, Shomura 1980). The available longline data contain both catch in numbers and nominal hooks fished by 5×5 degree squares and by month. These data can provide a measure of CPUE for a useful time series. The absence of reliable size sample data (length-frequency or weight-frequency) for the time series precludes the use of age-structured assessment techniques such as cohort analysis for the stock structures assumed.

Total Catch

Table 1 shows Pacific swordfish catches in weight by country. Figure 1 shows both the Japanese longline catch and the estimated Pacific total catch in weight. The Japanese longline catch represents a large proportion of the annual catches throughout the time series. Note from Table 1 that estimates of catch for many countries are available only for the second half of the time series. As a result, the total catch for the first half of the time series is underestimated by an unknown but presumably significant amount. These catch estimates are from the FAO (1971-1987) and published and private sources within various countries. After 1970, when all countries shown in Table 1 are represented, the Japanese longline catch has maintained a relatively constant and high proportion of the total catch.

Catch and Effort

The Japanese catch-and-effort series of data, 1952 to 1980 (Fisheries Agency of Japan 1965-1982, Agricultural Resource Agency of Japan 1953-1964), have changed within the time series, due mostly to substantial changes in the way the fishery is operated (Shomura 1980, Sakagawa et al in press, Ueyanagi 1974). During

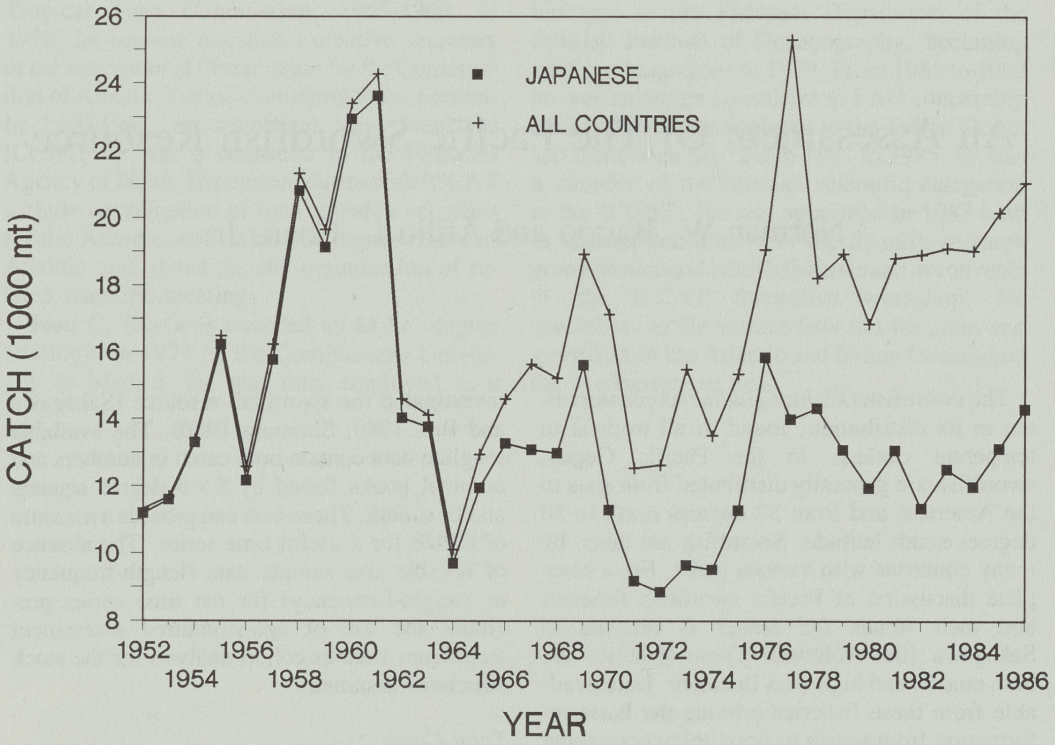

Figure 1. Japanese longline catch and the estimated catch of all countries fishing for swordfish in the Pacific Ocean.

the period 1952 through about 1962, swordfish were specifically targeted in some areas by fishing at night with squid for bait. The fishery changed substantially in the early 1960s (approximately 1962 — 1964). Day operations with mixed bait types became the norm, which has continued to the present. The strategy of Japanese longlining tuna changed at about this same time, de-emphasizing albacore *(Thunnus alalunga)* and emphasizing sashimi grade tunas (Sakagawa et al in press), mostly bigeye tuna *(T. obesus),* bluefin *(T. thynnus),* and yellowfin *(T. albacares).* Thus, the data series is broken in two in the early 1960s. To further complicate matters, portions of the fleet began "deep longlining" in 1974 to increase the catch rate on bigeye tuna (Suzuki and Warashina 1977). The effect was that the CPUE of the deep longline operations was about 80% as efficient as the standard operations for albacore, swordfish, and yellowfin tuna. The different operations are not distinguished in the published data, and therefore cannot be compensated for in the calculations without additional information, but must instead by considered qualitatively in the results.

Previous assessments of Pacific billfish and swordfish in particular have relied on "Honma's method" (Honma 1973, Shiohama 1971) to calculate the portion of the total effort fished in any particular area that is presumed to be effective for the species of interest. Because of the changes in the fishery and qualitative differences in the data with passage of time and the fact that swordfish appear to be a target species in a few areas and a true incidental catch in others, we suspect that the assumptions required to implement Honma's method for swordfish are not fully met. Consequently, we have chosen to use nominal CPUE and a data stratification which allows the separation of target or high catch rate areas from areas where swordfish appear as incidental catches. This procedure is done to account for the spatial distribution of populations, a concept presented by MacCall (1983).

This approach to segmenting or stratifying the population is based on the premise that

different portions of the population may react differently to exploitation and should be examined independently. An example of different reactions expected might include a shrinking of the areal distribution and decline in CPUE of low density areas as the stock is reduced and the remaining population continues to concentrate itself in higher density areas. Fortunately, this approach appears robust with respect to strata chosen, as our analysis was unaffected by several different choices of strata. We have chosen three strata, a high density or CPUE stratum (target areas), a low density or CPUE stratum (incidental catch areas), and an intermediate or buffer stratum. The primary purpose of the latter is to separate the signals from high and low CPUE strata by minimizing the subjectivity in defining the high and low strata.

Stratification

The annual distribution of catch in numbers by 5×5 degree square shows 3 areas or regions of concentrated catches. These 3, northwest (N.W.), east (E), and southwest (S.W.) Pacific, appear year after year in the data series. Figure 2 shows the catch distributions for 4 years chosen throughout the time series. Of interest is the fact that the exact squares producing high catches may shift slightly from year to year. This presumably mirrors the shift in fish distribution caused by environmental or oceanographic changes, etc. A great portion of the area fished

Table 1. Pacific Ocean catches (metric tons) of swordfish

YEAR	JAPAN	TAIWAN	KOREA	USA	CHILE	PERU	PHIL	OTHERS	TOTAL
1952	11182			157					11339
1953	11604			85					11689
1954	13301	77		14					13392
1955	16220	185		80					16485
1956	12167	254		163					12584
1957	15771	250		222					16243
1958	20815	247		279					21341
1959	19136	262		265					19663
1960	22944	273		192					23409
1961	23636	432		218					24286
1962	14037	544		23					14604
1963	13775	300		58					14133
1964	9703	300		109					10112
1965	11955	300		194	200	300			12949
1966	13283	600	41	277	200	200			14601
1967	13083	838	47	181	200	1300			15649
1968	12983	974	55	118	200	800		100	15230
1969	15612	1023	89	610	300	1200		100	18934
1970	11301	1053	115	558	200	2400	1400	100	17127
1971	9182	1149	115	91	200	200	1500	100	12537
1972	8846	1111	115	157	100	600	1600	100	12629
1973	9644	1269	115	363	400	1900	1700	100	15491
1974	9517	1157	115	383	218	270	1848	3	13511
1975	11274	1099	115	510	218	158	1976		15350
1976	15843	856	444	49	13	295	1558		19058
1977	13997	8197	265	301	32	420	2103		25315
1978	14333	779	198	1536	56	436	890		18228
1979	13091	1060	365	346	40	188	3845	7	18942
1980	11953	1459	329	706	104	216	1716	380	16863
1981	13078	909	257	674	294	91	1940	1575	18818
1982	11350	1107	194	989	285	154	3468	1365	18912
1983	12511	1268	135	1534	342	225	2974	120	19109
1984	11986	1387	54	2878	103	298	2277	47	19030
1985	13125	1429	56	3064	342	92	2036	18	20162
1986	14295	1357	37	2131	764	33	2089	350	21056
1987				1580					1580

produces relatively low annual catches of swordfish.

The proportion of swordfish to all tunas and billfish in the total catch in each 5×5 degree square (Fig. 3) reveals broad areas of very low representation which generally correspond to areas of low total catch, described above, and appear to be indicative of incidental catch areas. Squares with a high proportion of swordfish in the catch correspond with areas of higher catches.

As stated previously, two stock structure hypotheses are considered. These correspond to the areas described above (Fig. 4) and are approximately the same as those used in previous assessments (Sakagawa and Bell 1980). The exact boundaries chosen are not critical because of the stratification concept employed.

The index of abundance chosen, mentioned previously, is nominal annual CPUE in numbers of fish per 10,000 hooks fished for each 5×5 degree square. To separate high abundance or possible target squares from lower abundance squares where swordfish are an incidental catch, the CPUE for all squares in the Pacific receiving effort in a year were combined into 3 strata. The first stratum, "high CPUE," contains 15% of the total squares fished which produced the highest CPUEs. The second stratum, "low CPUE," contains 50% of those squares fished which produced the lowest CPUEs. The third stratum, "middle CPUE," contains those squares which produced the 35% intermediate values between the first and second groups.

The rationale for this accumulation scheme is that high abundance squares — possible swordfish target areas or centers of high concentrations — are sought by the fishery year after year and produce the bulk of the catch. The squares are not fixed in number of spatial location. This circumstance accounts for spatial shifts in the resource, which happen from year to year. A key assumption is that the fishery will shift to an adjacent square as the resource shifts. An examination for year-to-year shifts (Fig. 5) shows these squares to be in the same

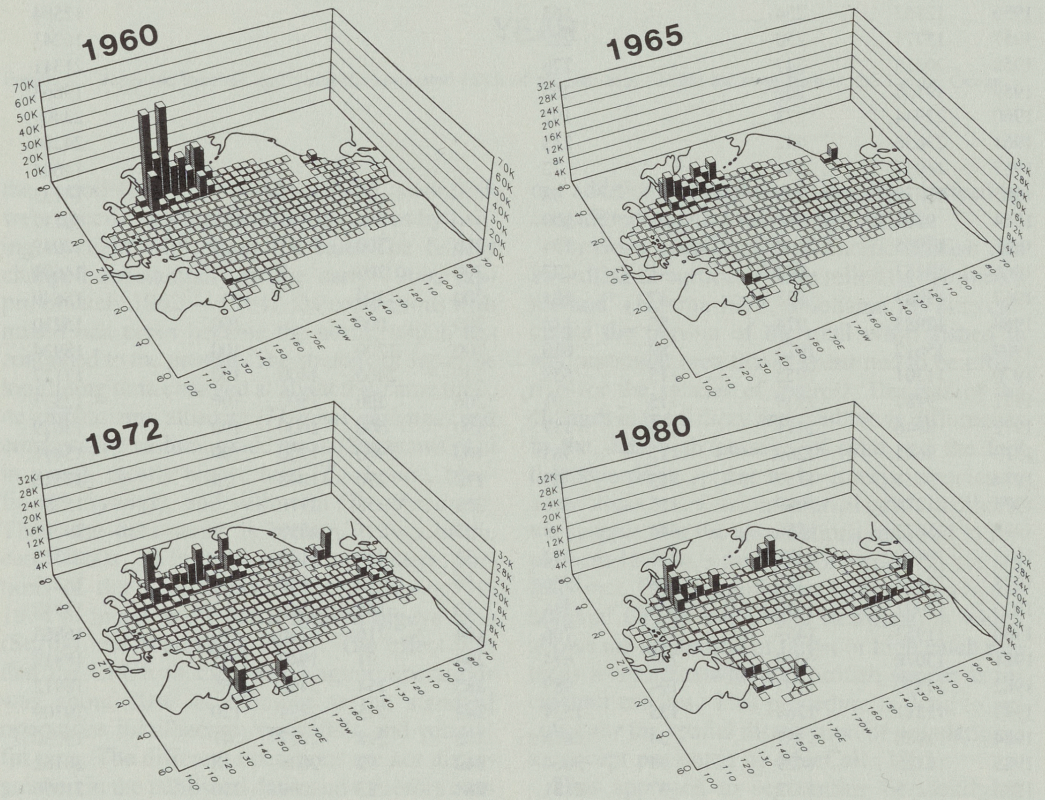

Figure 2. Geographical distribution of Japanese longline swordfish catches in the Pacific Ocean.

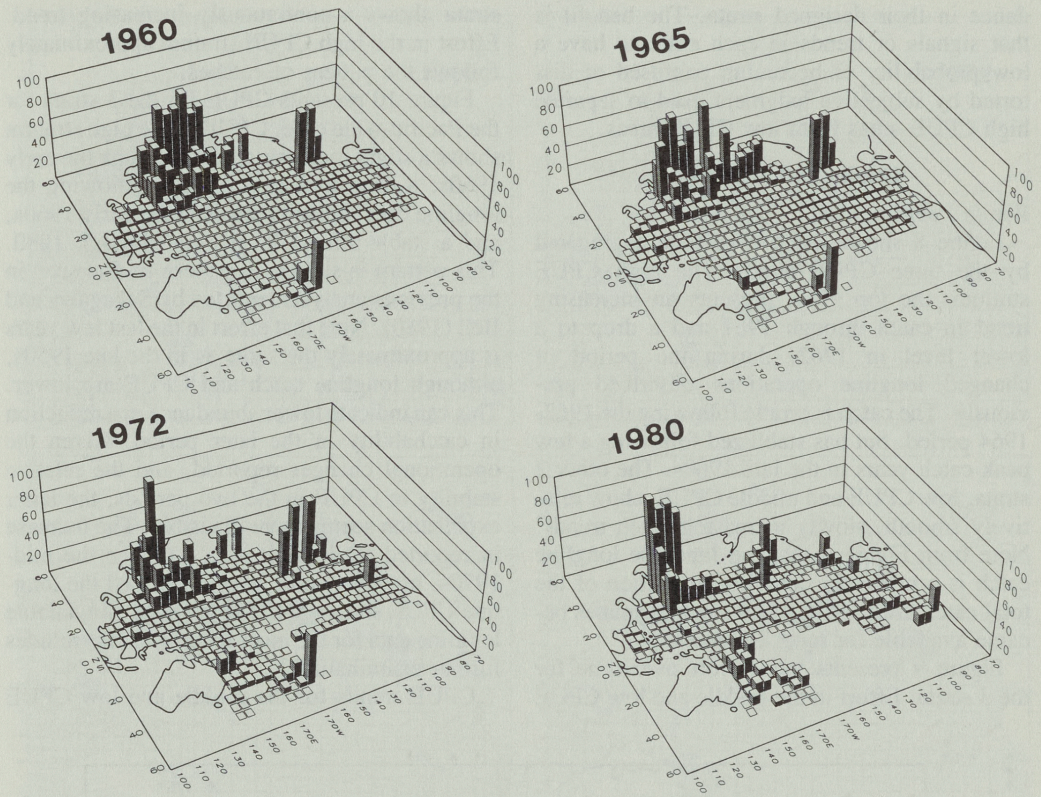

Figure 3. Geographical distribution of Japanese longline percent of swordfish in the total catches of billfishes and tunas in the Pacific Ocean.

general area year after year. The number of squares producing the top catch rates varies for several reasons. The total number of squares fished in the Pacific (Fig. 6) and the concentration of fish, or vulnerability, in each square throughout the entire Ocean varies from year to year. Interestingly, the actual number of squares included in the top catch-rate group each year is remarkably stable. The use of an annual CPUE value removes the effect of seasonality from the data. Although the procedure does lower peak CPUE values, it is consistent throughout the time series.

The stratum of the low catch-rate squares (lower 50%) captures broad areas of the Pacific, mostly contiguous, where low catches, low proportion of swordfish in the overall catch, and low catch rates make swordfish an incidental catch. Figure 7 shows the distribution of these squares for several example years. Figure 6 shows the number of squares contained in the grouping over the time series.

The last stratum of squares, those with the middle 35% of the catch rates, serves two functions. First, it captures into a relatively narrow group those squares where it is uncertain whether swordfish are a target. Second, and more importantly, it serves as buffer separating the high and low catch-rate groups. This buffering obviates the requirement to define precisely the strata where "target" fisheries begin and end. We need only be concerned that the high CPUE stratum has a high enough threshold and that the low CPUE stratum has a low enough one. This condition implies that the CPUE values in the high and low groups will track relative abun-

dance in their designed strata. The benefit is that signals or trends in each extreme have a low probability of becoming confused or distorted by subjective judgment used to separate high CPUE areas from low CPUE areas.

Results and Discussion

Whole Pacific Stock

Figure 8 shows catch over time aggregated by the three CPUE strata. The high CPUE stratum, the top 15%, presents an increasing trend in catch through 1961 and a drop to a lower level in 1962, during the period of changed longline operations described previously. The catch is erratic following the 1962-1964 period, but has stabilized following a few peak catch years in the late 1960s. The other 2 strata, low CPUE and middle CPUE, show relatively smooth, slowly increasing catch trends. Note from Figure 1 that the Japanese longline catch is a relatively constant proportion of the total catch after 1970, when catch estimates became available for most countries.

Figure 9 presents total effort over time for the 3 strata. Effort in the middle and low CPUE strata shows a continuously increasing trend. Effort in the high CPUE stratum approximately follows the pattern of catches.

Figure 10 presents CPUE for the 3 strata for the Pacific-wide case. CPUE in the high stratum shows a slight increasing trend through the early 1960s, a drop to a new plateau following the longline operational changes in the early 1960s, and a stable almost level trend through 1980. This pattern is similar in pattern to that seen in the previous analysis reported by Sakagawa and Bell (1980). Note that effort in the last few years is approximately the same as in the late 1950s, although longline catch and CPUE are lower. This can indicate lower abundance or a reduction in catchability in the later period. Given the operational changes reported, and the relative stability in CPUE in the two periods, the latter explanation seems more plausible. The increase in reported total catch (Fig. 1) since the mid-1970s, however, may have depressed the longline CPUE somewhat. The absence of available longline data for the more recent years precludes further examination.

CPUE trends for the middle and low CPUE

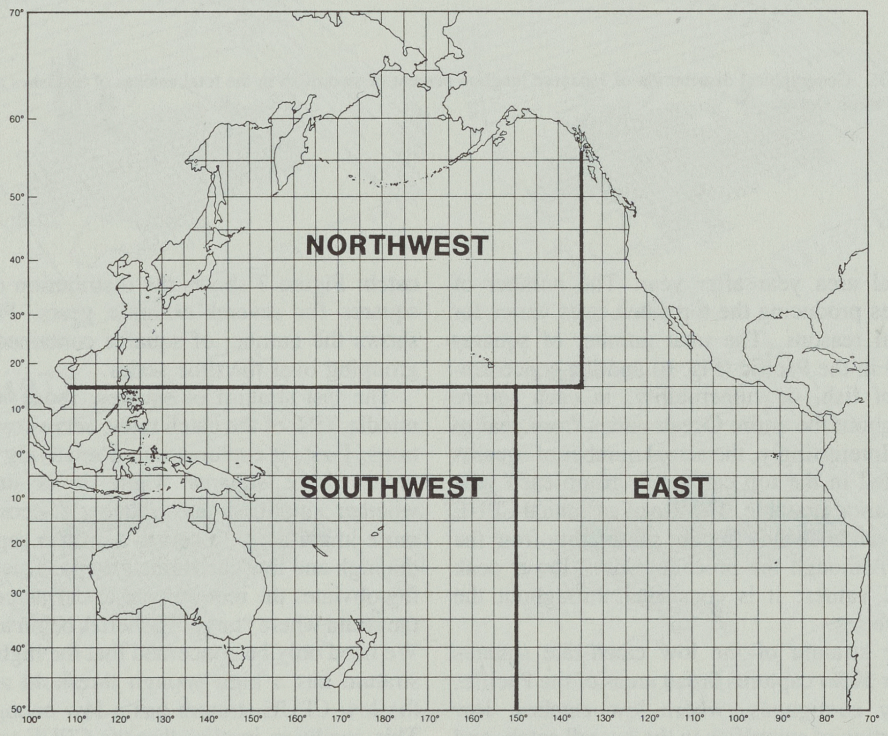

Figure 4. Geographical regions of the Pacific Ocean used as hypothesized stock boundaries.

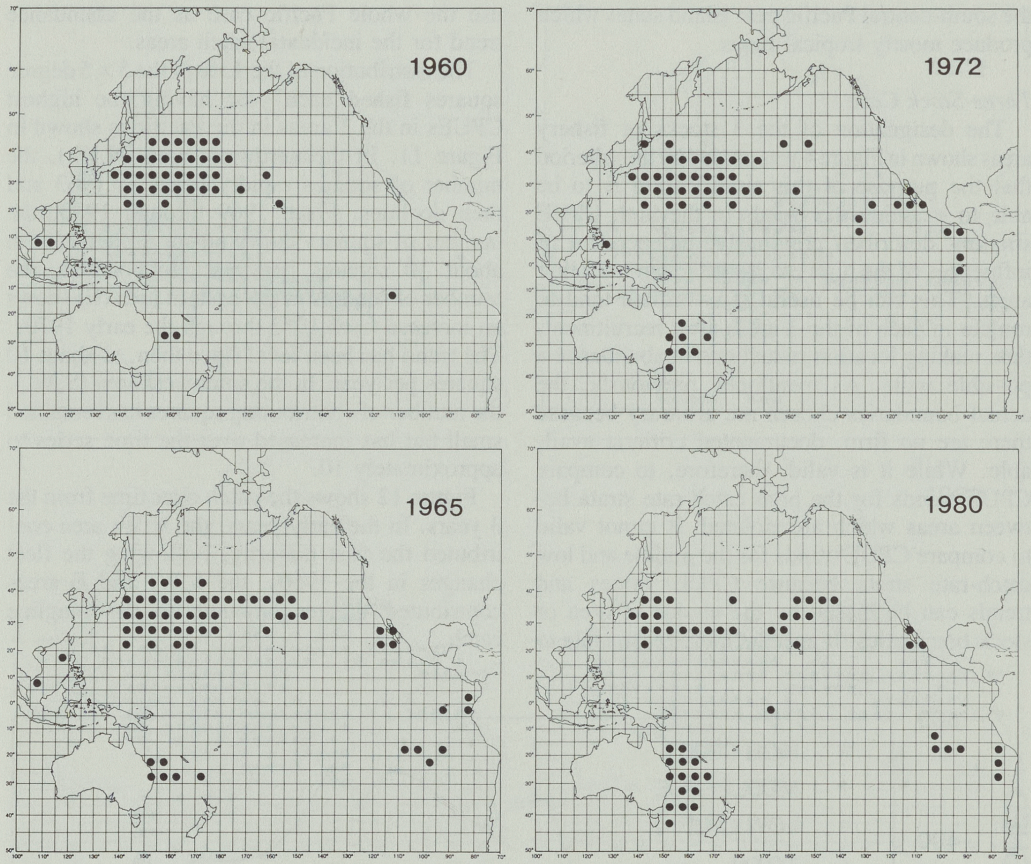

Figure 5. Geographical distribution of 15% of the squares fished by the Japanese longline fishery in the Pacific Ocean that produced the highest CPUEs annually for swordfish.

strata are quite stable and nearly constant, particularly since the mid 1960s. The stable CPUE trends and slowly increasing catch trends are complemented by an increasing trend in effort and does not indicate a decrease in relative abundance over the time series. The large absolute difference in CPUE values between the low CPUE stratum and the high CPUE stratum suggests that swordfish abundance in the lower strata is either considerably lower or that catchability of swordfish in the low CPUE stratum is lower, due to the operational characteristics of the gear. As mentioned preceding, Suzuki and Warashina (1977) indicated that deep longlining techniques used in much of the area covered by the low CPUE stratum reduced catchability of swordfish by approximately 25%. Thus, the effects of deep longlining may affect CPUE values to an unknown degree. If deep longlining effort has increased in proportion to regular effort between 1974 and 1977, as was indicated by Suzuki and Warashina (1977), then catchability of swordfish should be reduced for the deep effort and calculated CPUE will be biased low for the years after 1974. Unavailability of data after 1980 precludes confirmation.

The distribution of squares, or area occupied by the stock in the low CPUE stratum, shows no signs of declining over the time series. The percentage of total squares fished annually from 1960 through 1980 which produced no swordfish is rather stable, ranging from 7% to 13% with most observations at 9%. Any changes in the distributions of catch appear to be due to the complete elimination of effort from areas in

the south-central Pacific near island states which produce mostly tropical tunas.

Three-Stock Case

The designation of the 3 stocks or fishery areas shown in Figure 4 was guided by the criterion that the purpose of this stratification is to be able to examine the trends in the high CPUE stratum, described previously, independent of influences of the high catch-rate squares in other areas. This can be useful if swordfish tend to remain in each of the 3 areas after recruitment, thus making location reductions in abundance a possible issue. As mentioned previously, the actual boundaries chosen are arbitrary because there are no firm, documented critieria available. While it is valid, therefore, to compare CPUE trends for the high catch-rate strata between areas which are isolated, it is not valid to compare CPUE trends for the middle and low catch-rate strata because CPUE values and trends can be biased by the choice of area or stock boundaries. It appears more reasonable to use the whole Pacific case as the abundance trend for the incidental catch areas.

The distribution of the 15% of the 5×5 degree squares fished each year having the highest CPUEs in the 3 areas in the Pacific is shown in Figure 11. In the northwest area (N.W.), the number of squares rapidly peaks in 1963 and then declines. From 1969 through 1980, the number of squares shows no strong trend, with about 30 squares per year. In contrast, the number of squares in the eastern area (E) shows an increase from 1963 through the early 1970s. The trend has been level since then, at about 10 squares per year. In the southwest area (S.W.), the number of contributing squares has remained small but has increased over the time series to approximately 10.

Figure 12 shows the catch over time from the 3 years. In the early years, the N.W. area contributed the vast majority. Following the fleet changes in the 1960s, the S.W. and E areas contributed greater amounts to the longline catch.

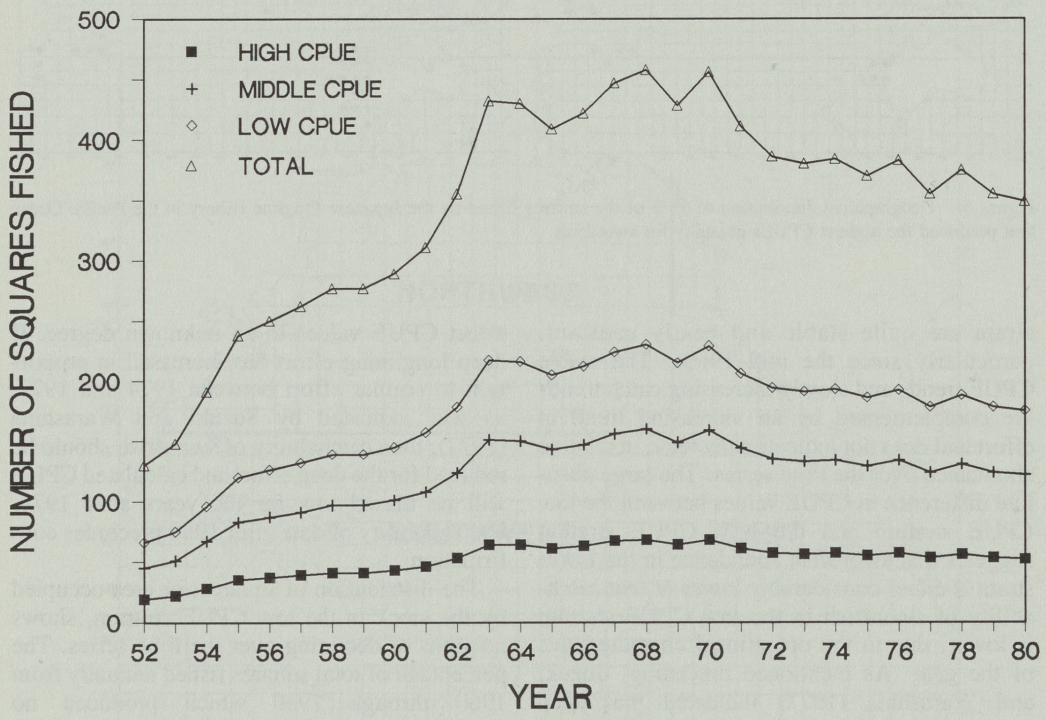

Figure 6. Total number of squares fished annually by the Japanese longline fishery in the Pacific Ocean for three CPUE strata; the top 15% of the squares fished producing the highest CPUEs (HIGH CPUE), the next 35% of the squares fished producing the middle CPUEs (MIDDLE CPUE), and the last 50% of the squares fished producing the lowest CPUEs (LOW CPUE).

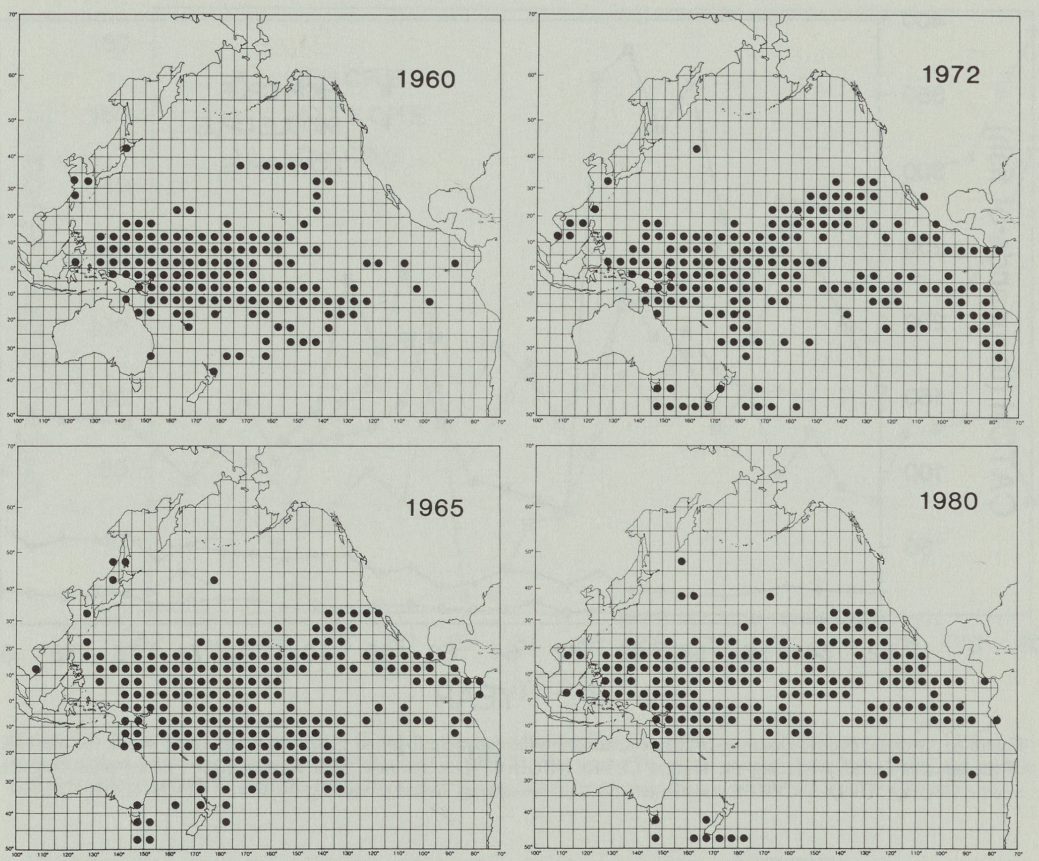

Figure 7. Geographical distribution of 50% of the squares fished by the Japanese longline fishery in the Pacific Ocean that produced the lowest CPUEs annually for swordfish.

CPUE trends for the 3 areas are shown in Figure 13. The pattern in the N.W. is similar to the pattern for the whole Pacific. This similarity is due to the fact that the N.W. area contributes the majority of the catch. The trend in CPUE for E area has been constant or level since the late 1960s, although some of the peak CPUEs are greater than in the rest of the Pacific. This situation also prevailed for the S.W. Pacific. The CPUE trends in the 3 areas in recent years are flat and do not indicate a change in the resource.

Conclusions

The analysis and examination of data leads us to several conclusions, some of which are not qualitatively different than those from previous examinations.

Data for swordfish have changed little since the last Pacific-wide look at swordfish. Many of the data are generally not adequate for assessment purposes, the notable exception being the Japanese longline fishery data through 1980. Total estimated catches in weight appear to be at about the same general level seen in the late 1950s; however, there appears to be incomplete reporting of catches in years prior to the mid-1960s. The historical catch-and-effort data for the Japanese longline fleet were affected by major changes in both the operation of the gear — reduction in night sets and bait changes, and in the strategy of fishing operations — changing from albacore to tunas for the internal Japanese sashimi market.

Swordfish appears to be a target or very important species in at least 3 areas of the Pacific,

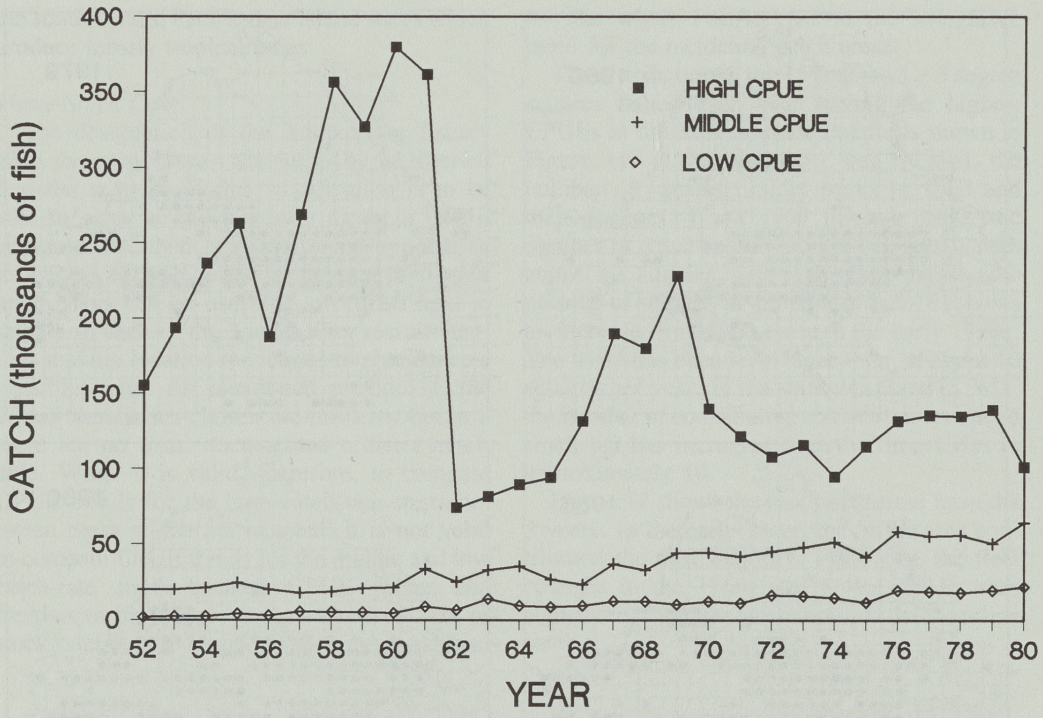

Figure 8. Annual Pacific Ocean swordfish catches from the Japanese longline fishery in three CPUE strata; the top 15% of the squares fished producing the highest CPUEs (HIGH CPUE), the next 35% fo the squares fished producing the middle CPUEs (MIDDLE CPUE), and the last 50% of the squares fished producing the lowest CPUEs (LOW CPUE).

the northwest, east, and southwest. Consistently, year to year, high catch and CPUE areas are fished in each area. Additionally, swordfish appear to be an incidental catch taken in relatively small numbers in a broad contiguous area of the Pacific associated with tropical tuna operations.

When considered as a single, Pacific-wide stock with several high catch-rate areas, the CPUE in the target areas showed a slowly increasing trend through the early 1960s. In the early 1960s, CPUE values dropped by about ⅓ and have remained about the same since. The drop in CPUE coincides with the change in longling operations. The CPUE trend in the area where swordfish are an incidental catch is stable, slowly increasing throughout the time series. The change in operations is not seen in this data series.

If considered as 3 stocks, the northwest stock high catch-rate stratum follows the same CPUE pattern as the total-stock case, mostly because the N.W. stock provides the bulk of the catch. In the eastern stock, CPUE has shown considerable highs and lows since the late 1960s, but the trend is level and this stock yields about ⅕ the catch of the N.W. stock. The southwestern stock also yields about ⅕ that of the N.W. stock and has shown an erratic but level trend in CPUE since 1970. In all 3 areas, the actual CPUE values are similar, with the S.W. area tending to be slightly higher.

The effects of those fisheries with increased reported catches in the latter half of that time series, such as the U.S.A., Peru, and Philippines, is unknown. The longline catches used, however, are based on approximately the same reporting rate throughout the time series and should not be affected by the changes in reporting rates. The CPUE indices developed here show no declining trends. Nothing definitive can be said about yield-per-recruit realized by the various fisheries or about optimum size for capture due to the lack of published size data. As a cursory measure, we note that weight per fish in the Japanese longline fishery has been about the same since 1977 (total weight/total catch in numbers).

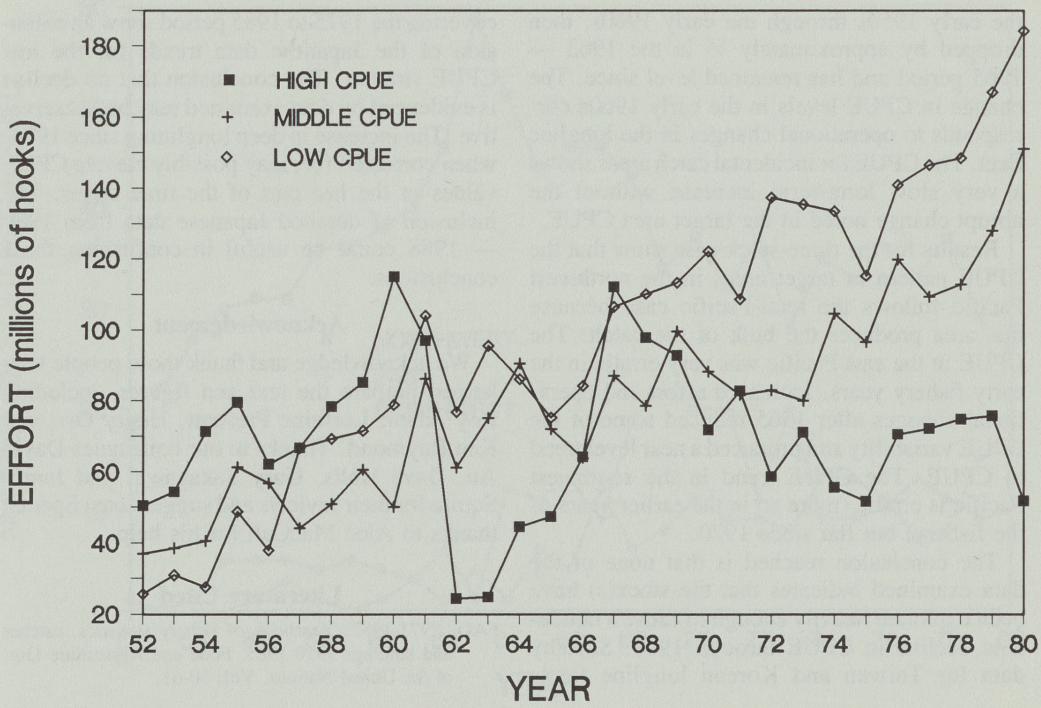

Figure 9. Annual Pacific Ocean hooks fished by the Japanese longline fishery in three CPUE strata; the top 15% of the squares fished producing the highest CPUEs (HIGH CPUE), the next 35% of the squares fished producing the middle CPUEs (MIDDLE CPUE), and the last 50% of the squares fished producing the lowest CPUEs (LOW CPUE).

Based on our examination of the Japanese longline CPUE data, and our interpretation of the changes which occurred in the fishery over time, we conclude that the stocks do not appear to have been exploited heavily enough to cause a declining trend in CPUE and, by extension, in abundance, through 1980. It is actually possible that CPUE may have trended upward slightly since 1974 as the practice of deep longlining increased and estimated CPUE was biased downward, an unknown amount. In an attempt to confirm our conclusions we have examined total swordfish catch and total effort data for the Taiwan and Korean longline fleets. The Taiwan data cover the period 1975 through 1985, with 1980, 1981 and 1982 missing. The Korean data cover the 1975 through 1982 period. The calculated CPUE values for both fleets are very low, less than 1.2 fish per 10,000 hooks. The trend in CPUE is realtively stable, varying between 0.4 and 1.2, similar to that observed for the Japanese fleet's low CPUE stratum over the entire time series (1952 — 1980).

Summary

The Pacific swordfish resource is assessed using catch-per-unit-effort (CPUE) realized by the Japanese longline fleet as an indicator of abundance. Lack of data for other fisheries, and absence of reliable size sample, limits the assessment to CPUE trends and comparisons. A time series of data from 1952 through 1980 is used. This series of data is not consistent throughout due to changes in the fishery and fishing strategy. Attempts to standardize or calculate effective fishing effort are rejected because of changes which occurred in the fishery and because swordfish are, depending on location, both a target species and an incidental catch. Nominal CPUE (numbers of fish caught per 10,000 hooks fished) is used in conjunction with a stratification methodology which separated high catch-rate "target" areas from low catch-rate incidental catch areas. Two stock structure cases were considered: 1. Pacific-wide and 2. three stocks: northwest, east, and southwest.

Results for the whole-Pacific case show that CPUE for target areas increased slowly from

the early 1950s through the early 1960s, then dropped by approximately ⅓ in the 1963 — 1965 period and has remained level since. The change in CPUE levels in the early 1960s corresponds to operational changes in the longline fleet. The CPUE for incidental catch areas shows a very slow long-term increase without the abrupt change noted in the target area CPUE.

Results for the three-stock case show that the CPUE pattern in target areas in the northwest Pacific follows the total-Pacific case because this area produces the bulk of the catch. The CPUE in the east Pacific was very erratic in the early fishery years. Increased effort and operational changes after 1965 reduced some of the CPUE variability and produced a near level trend in CPUE. The CPUE trend in the southwest Pacific is erratic (more so in the earlier years of the fishery) but flat since 1970.

The conclusion reached is that none of the data examined indicates that the stock(s) have been exploited heavily enough to cause a noticeable decline in CPUE through 1980. Sketchy data for Taiwan and Korean longline fleets covering the 1975 to 1985 period show an extension of the Japanese data trends for the low CPUE stratum. The conclusion that no decline is evidenced by data examined may be conservative. The increase in deep longlining since 1974, when corrected for, may possibly elevate CPUE values in the last part of the time series. The inclusion of detailed Japanese data from 1980 — 1988 could be useful in confirming these conclusions.

Acknowledgment

We acknowledge and thank those people who helped prepare the text and figures, including Roy Allen, Lorraine Prescott, Henry Orr, and Ken Raymond. Thanks to our colleagues David Au, Dave Holts, Gary Sakagawa, and James Squire for their reviews and suggestions. Special thanks to Alec MacCall for his help.

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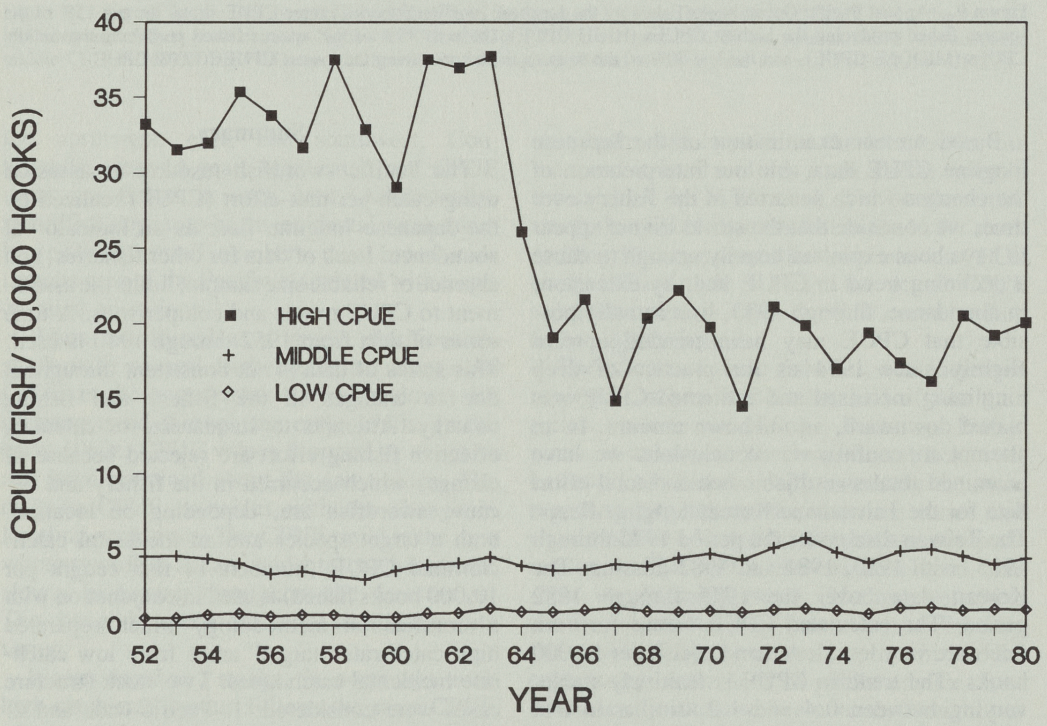

Figure 10. Annual Pacific Ocean catch-per-unit-effort for the Japanese longline fishery in three CPUE strata; the top 15% of the squares fished producing the highest CPUEs (HIGH CPUE), the next 35% of the squares fished producing the middle CPUEs (MIDDLE CPUE), and the last 50% of the squares fished producing the lowest CPUEs (LOW CPUE).

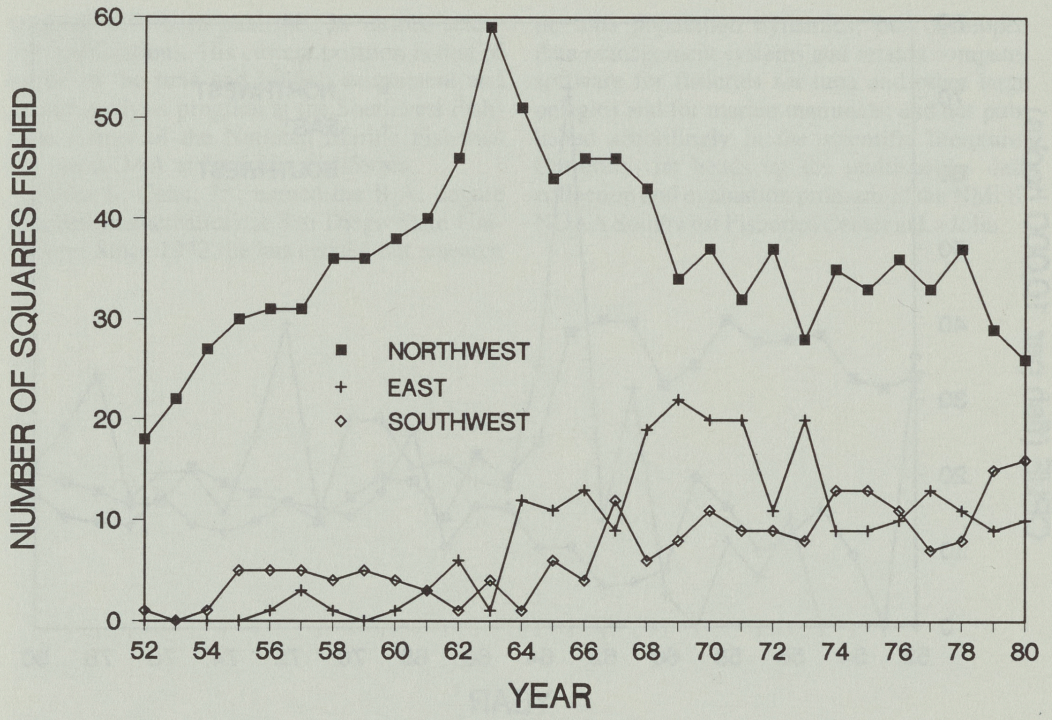

Figure 11. Annual distribution of 15% of the squares fished by the Japanese longline fishery in the Pacific Ocean producing the highest swordfish CPUEs in three hypothesized stock regions, northwest, southwest, and east.

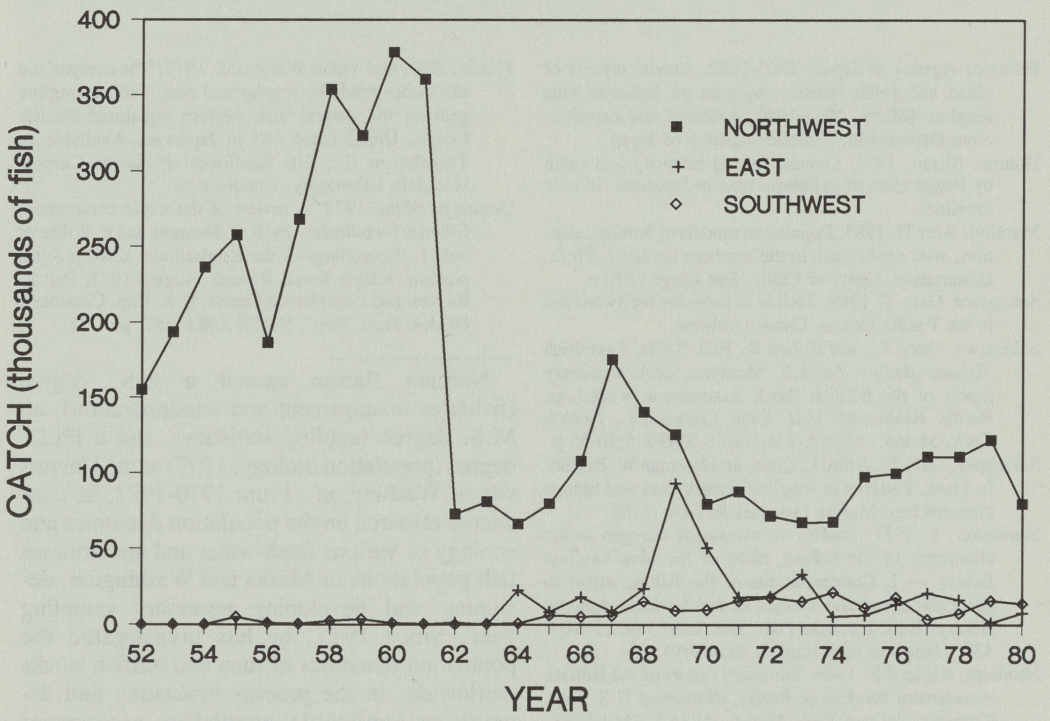

Figure 12. Annual distribution of swordfish catches from the Japanese longline fishery in the Pacific Ocean for squares fished that produced the highest swordfish CPUEs in three hypothesized stock regions, northwest, southwest, and east.

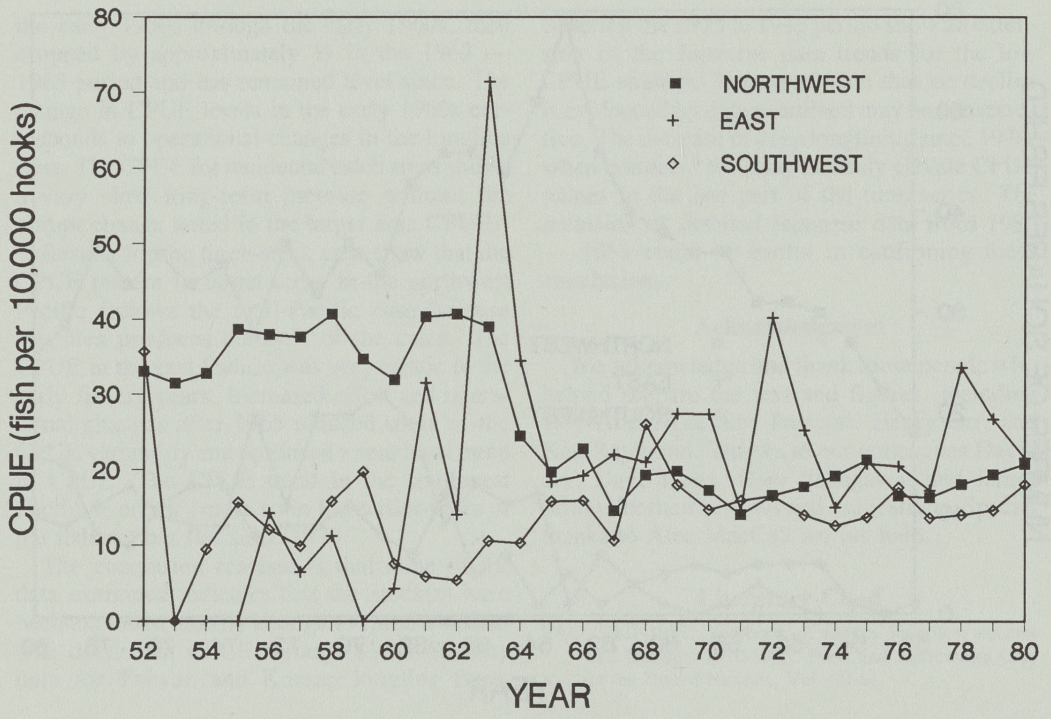

Figure 13. Annual distribution of catch-per-unit-effort by the Japanese longline fishery in the Pacific Ocean for squares fished that produced the highest swordfish CPUEs in three hypothesized stock regions, northwest, southwest, and east.

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Assessing the Status of Stocks of Atlantic Blue Marlin and White Marlin

Ramon J. Conser

Determining the status of stocks, or biological condition, of blue marlin *(Makaira nigricans)* and white marlin *(Tetrapturus albidus)* in the Atlantic Ocean poses some unusual and challenging problems for fisheries researchers. A complete understanding of the status of stocks has been achieved for only a relatively small number of the world's marine fish species. Atlantic marlins, however, remain a highly visible and economically important species group, exploited by the commercial and recreational fisheries of many nations, for which much is unknown concerning their basic population demographics.

Many of the characteristics touted by Ernest Hemingway and Zane Grey which give marlins a majestic and romantic image are the same characteristics that have inhibited progress in stock assessment research on these species. In particular, their highly migratory nature, large size, solitary behavior, and long life span make data acquisition and biological studies expensive and difficult to carry out.

Scientific efforts to assess the status of stocks of Atlantic marlins were first undertaken in the late 1960s. Shortcomings in the basic fisheries data and biological knowledge severely limited the scope of the assessment work that could be effected. Through international cooperation, under the auspices of the International Commission for the Conservation of Atlantic Tunas (ICCAT), improvements in the fisheries data base were realized. This progress led to the first stock assessments during the mid-1970s.

During the period from the mid-1970s through the early 1980s, a great deal of international effort was focused on further improvements to the fisheries data base. Annual assessments were carried out to gauge the effect of both better data from recent years and improvements that had been made in the historical fisheries data base. Little progress was made, however, in advancing the basic biological knowledge, including growth, mortality, and maturity rates. Consequently, while a better understanding of the status of stocks did emerge, the results of those assessments continued to have a great deal of uncertainty associated with them.

Effective management of marine fishes, including the Atlantic marlins, is not practical without the sound foundation provided by a good understanding of the current status of stocks. The process of assessing the status of stocks of Atlantic marlins — past, present, and future — is reviewed in this paper. In doing so, four questions are addressed:

(1) What do we need to know (in order to determine the status of stocks)?
(2) What have we learned (from past stock assessment research)?
(3) Why don't we know more?
(4) Where do we go from here (to understand better the status of stocks)?

Neither the life history aspects of Atlantic marlins nor the commercial and recreational fisheries upon them are reviewed here. Interested readers should consult Conser (1985a) for more detail on the fisheries and Conser (1982) for a review of the life history aspects that are relevant to stock assessment.

Information Needed For Marlin Assessments

The following data and biological information are needed to evaluate fully the status of stocks of Atlantic marlins:

(1) Stock structure — defined here as the geographic and temporal boundaries of a

self-contained, biological unit capable of sustaining itself through reproduction.

(2) Catch data — the total international catch (weight and numbers of animals) for each species, i.e., all mortalities due to fishing.

(3) Fishing effort data — detailed data are not needed from all fleets, but should be available from the major fisheries.

(4) Size, age, and sex of fish in the catch — samples are needed from all fleets and should represent all areas and months fished.

(5) Independent index of abundance — derived from research data collected independently from the fisheries data, and thus not subject to possible biases of catch-and-effort information (e.g., area fished, target species, depth fished, etc.).

Atlantic marlin assessment work has relied heavily on catch-and-effort data, i.e., items (2) and (3), because items (4) and (5) have proven difficult or impractical to obtain. In particular, most stocks assessment studies have assessed the status of stocks through the use of surplus production models. These models have two basic data requirements: (1) total international catch; and (2) an index of stock abundance. Although not without problems, international catch estimates have been available. No fisheries-independent indices of abundance have been available; therefore, the catch-and-effort data have been used to develop indices of abundance, i.e., catch-per-unit-effort indices.

The importance of the index of abundance for stock assessments, when taken in conjunction with the catch data, is illustrated in the following example. Total international landings of the blue marlin (Fig. 1) and white marlin (Fig. 2) are available. They alone, however, tell us little about the status of the stock since we do not know whether the sharp decline in blue marlin landings following 1963, or the decline in white marlin landings after 1965, is due to stock decline or is due to reduced effort in the fishery. If corresponding indices of abundance declined as well, we would probably suspect the former. If indices were stable, however, we would suspect the latter. The value of reliable index of

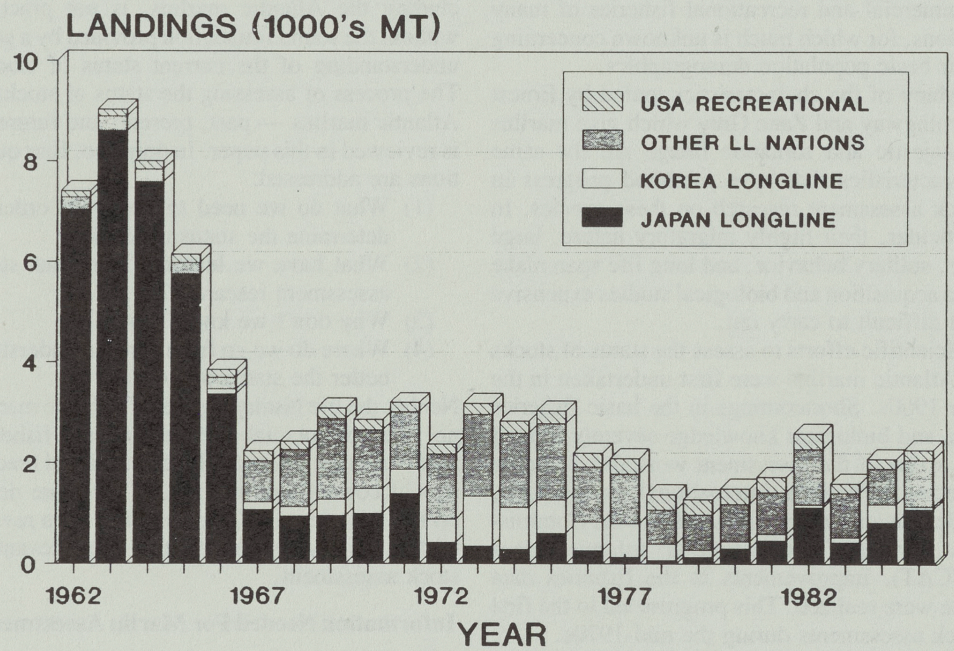

Figure 1. Blue marlin landings (in thousands of metric tons) from the Atlantic Ocean, 1962-1985. The "OTHER LL NATIONS" category is composed largely of the longline landings of Taiwan, Cuba, and Venezuela. In a few years, a small amount of incidental catch by purse-seine gear is included in the "OTHER LL NATIONS" category. An insignificant amount of landings reported from recreational fisheries, other than the USA recreational fishery, is also included in the "OTHER LL NATIONS" category. Data are from ICCAT (1982b) and ICCAT (1988).

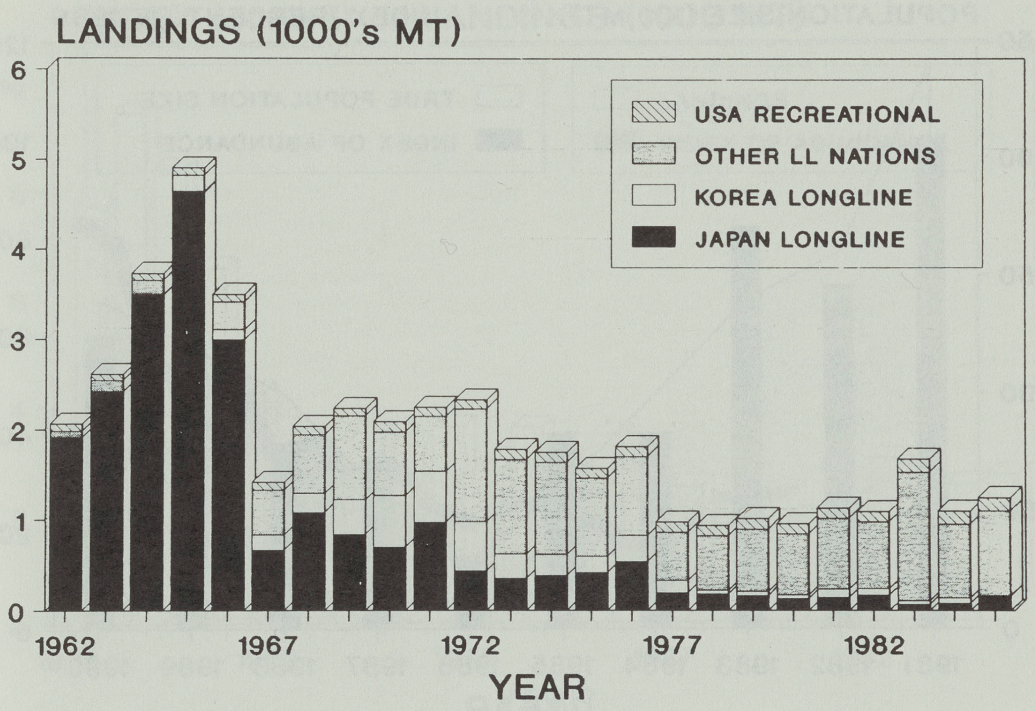

Figure 2. White marlin landings (in thousands of metric tons) from the Atlantic Ocean, 1962-1985. The "OTHER LL NATIONS" category is composed largely of the longline landings of Taiwan, Cuba, and Venezuela. An insignificant amount of landings reported from recreational fisheries, other than the USA recreational fishery, is included in the "OTHER LL NATIONS" category. Data are from ICCAT (1982b) and ICCAT (1988).

abundance is that it helps us to decide which of the two possible explanations has the greater merit (Fig. 3).

Current State of Understanding

Review of Past Assessment Research

The assessment of the status of stocks of blue marlin and white marlin in the Atlantic Ocean first received attention in the late 1960s. The large catches of the Japanese longline fishery in the early and mid-1960s (Figs. 1 and 2) attracted attention. Detailed Japanese catch-and-effort data were provided by the Japanese government in annual publications. However, similar data were not available from other nations that harvested billfishes (either commercially or recreationally), and no international organization was yet in place to coordinate a multi-national research effort. Wise and Le Guen (1969), Wise and Fox (1969), and Ueyanagi et al (1970) developed indices of abundance from Japanese longline catch-per-unit-effort data. These indices suggested that the relative abundance of blue marlin and white marlin had declined during the 1960s. Declining stock size (especially in weight) is a natural occurrence when a fishery is exploited commercially for the first time (the effect is termed "fishing up" of a stock). Without knowing the total catches of all nations, however, it was not possible to determine whether these apparent declines suggested overfishing or whether they merely indicated that the stocks had been reduced from a near virgin state to a lower, more productive level (from the standpoint of obtaining maximum sustainable yield).

The International Commission for the Conservation of Atlantic Tunas (ICCAT) held its first scientific meetings in 1971. International cooperation in assembling synoptic data and information began, in earnest, at that time. The ICCAT treaty covered billfishes as well as tunas, and billfish data were reported to ICCAT routinely by member countries. However, initial priorities were directed to the completeness, adequacy, and quality control of the tuna statistics.

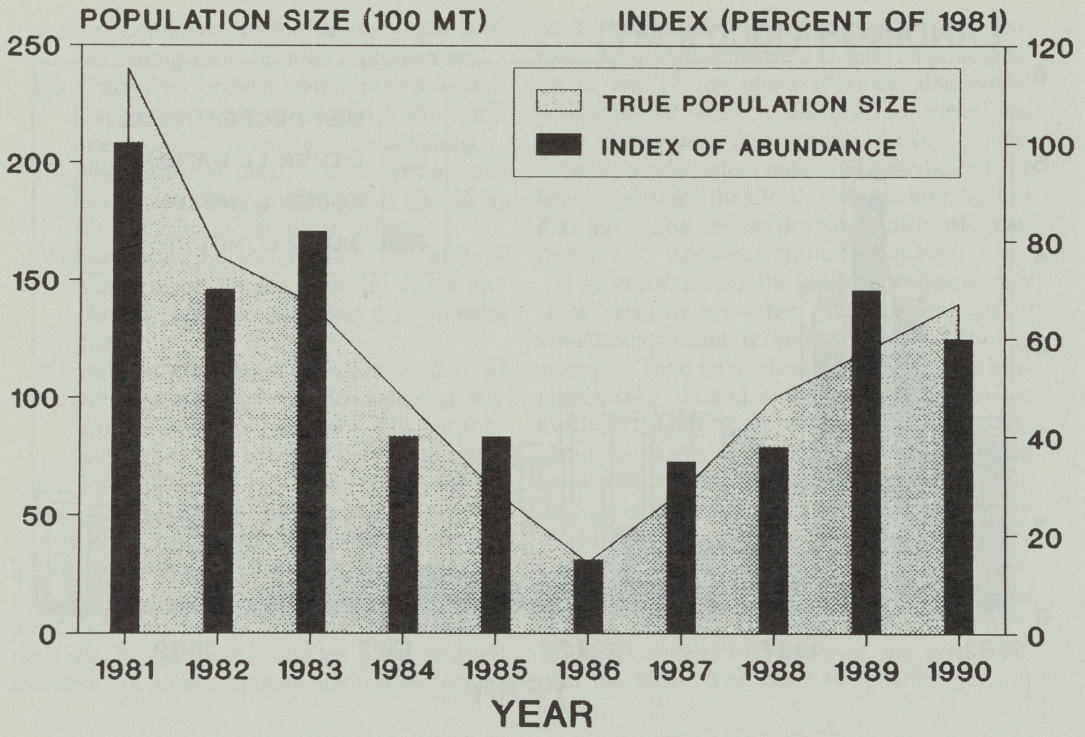

Figure 3. Conceptual depiction of actual population size (in hundreds of metric tons — left scale) and an index of population size (expressed as a percentage of the 1981 index value — right scale) over the hypothetical period, 1981-1990. While actual population size varies continuously, an index of abundance is generally discrete, providing a single estimate of population size per year (frequently a mid-year or beginning-of-the-year estimate). Because of large sampling variability and other statistical and operational problems, the year-to-year trends in the actual population size and the index of abundance are sometimes not concordant.

Billfish data were often reported incompletely or in a fashion not suitable for stock assessment purposes, e.g., for many years, some nations reported billfish catches collectively, but did not provide breakdowns by species.

Kikawa et al (1975) first attempted to estimate the international longline catches of the marlins and to analyze the catch trends in conjunction with indices of abundance. Kikawa and Honma (1976, 1977, 1978, 1979) updated the work of Kikawa et al, improved estimates of the longline catch, refined methods for deriving indices of abundance, and fit the first surplus production models (Fox 1975) to these data. Otto et al (1978) estimated the recreational catches and developed alternative indices of abundance. Conser and Beardsley (1979) revised the longline and recreational catch estimates, and carried out additional work on developing unbiased indices of abundance. These assessments were then updated annually for the next several years (Kikawa and Honma 1980, Conser 1980, Farber and Conser 1981).

The reliability and completeness of the assessments carried out to this point were hampered severely by the limitations of the billfish data reported to ICCAT by some member countries. Assessment scientists often estimated the species breakdowns of landings for nations that reported aggregate billfish catches, and handled other data base shortcomings through the judicious use of judgement and experience. This procedure resulted in assessments that were more tenuous than desired; nevertheless, it provided preliminary determinations of the status of stocks. These preliminary assessments generated more interest in the billfish assessment problems and provided the impetus and feedback necessary for improved data reporting. An ICCAT-sponsored International Billfish Workshop was convened in June 1981 to revise and supplement the historical billfish data base and

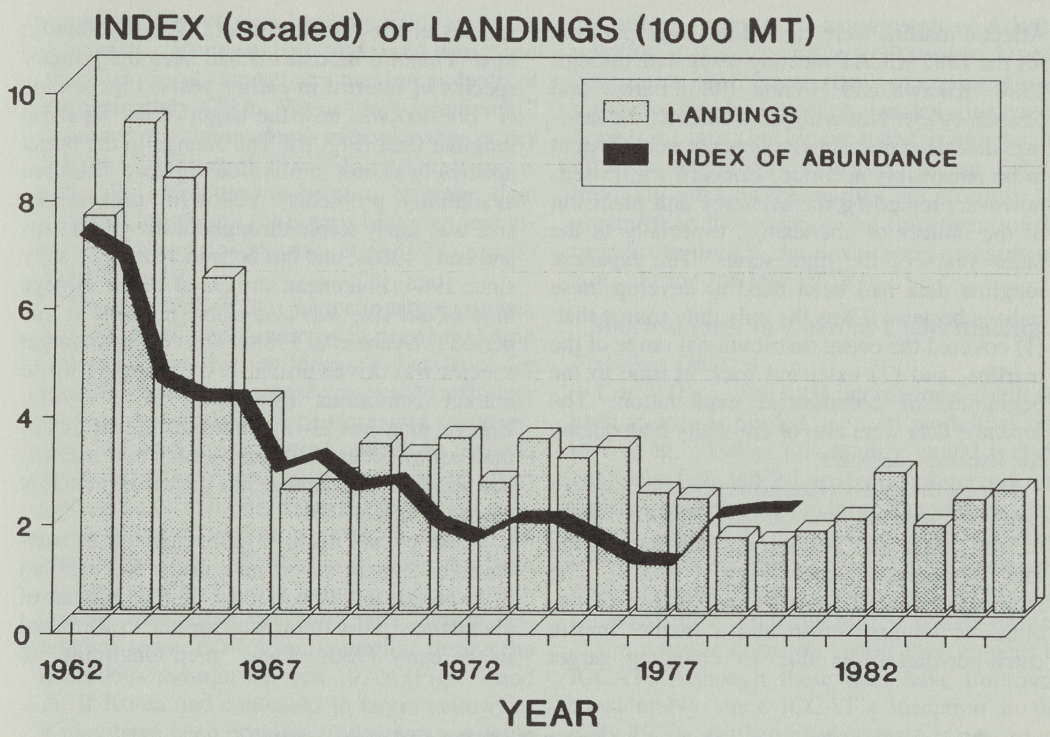

Figure 4. Blue marlin landings (in thousands of metric tons) from the Atlantic Ocean, 1962-1985, and the corresponding index of abundance, 1962-1980, from Farber and Conser (1983). Index of abundance was originally expressed in terms of metric tons landed per unit of effective fishing effort. To compare trends in the index and the landings, the original index values were standardized to the 0-1 interval and multiplied by the 1962 landings.

to establish guidelines for future data reporting. Major revisions to the billfish data base resulted from this Workshop (ICCAT 1982a).

Blue marlin and white marlin assessments were updated to reflect the revised data base (Kikawa and Honma 1982, 1983; Farber 1982; Farber and Conser 1983). The methods employed and the results of these improved assessments were generally similar. Japanese catch-and-effort data were used to develop indices of abundance using the Honma method for spatial-temporal effort standardization (Honma 1974, Conser 1985b), i.e., explicitly examining the distribution of catches and associated effort in space and time, rather than simply lumping such data. Surplus production models were fit to international landings data and the indices of abundance (Fox 1975).

The index of abundance for blue marlin declined from the 1962 level more rapidly than did the landings (Fig. 4). Surplus production models fit the data reasonably well ($R^2 = 0.8$) and indicated that effective fishing effort may have been greater than that associated with maximum sustainable yield (f_{MSY}) during 1971-1977, but was reduced to a level smaller than f_{MSY} during 1978-1980.

The index of abundance for white marlin fluctuated widely and did not decline as rapidly as the landings, especially not during the mid-1960s (Fig. 5). Surplus production models fit the data poorly ($R^2 = 0.1$) and offered little insight into the status of stocks. It remains unclear as to whether the problem lies with the landings or with the index of abundance (or both), but the large year-to-year fluctuations in the index of abundance (in weight) appear unrealistic for a relatively long-lived species (Fig. 5). The general downward trend of the index may provide some information on stock size trend, but the variability appears to be too large for fitting surplus production models and gauging the status of stocks from them.

Current Status of Stocks

The most recent stock assessment studies on

Atlantic marlins were carried out in preparation for the 1982 ICCAT meeting using data through 1980 (Kikawa and Honma 1983; Farber and Conser 1983). Not without problems, the landings data used in these assessments were thought to be reasonably accurate. Concern was raised, however, regarding the accuracy and precision of the indices of abundance, especially in the latter years of the time series. The Japanese longline data had been used to develop these indices because it was the only data source that: (1) covered the entire distributional range of the marlins, and (2) extended back in time to the beginning of commercial exploitation. The Japanese data were also of unusually high quality for fisheries statistics.

During the mid-1970s, however, the Japanese catch of marlins was greatly reduced from former levels and become a small part of the total international catch (Figs. 1 and 2). The reduction resulted from a combination of declines in nominal effort and a smaller marlin catch-per-unit-effort due to changing target species of the Japanese fleet. Where yellowfin tuna *(Thunnus albacares)* had been the primary species of interest in earlier years, bigeye tuna *(T. obesus)* was now the target of the Japanese longline fleet (Fig. 6). The change in the target species was not motivated by any resource availability problems. Yellowfin tuna stocks size was fairly stable throughout the mid-1970s and early 1980s, and has been increasing steadily since 1984 (Fonteneau and Diouf 1988). Bigeye tuna stocks size was also stable throughout this period (Miyabe et al 1988). The change in target species was driven primarily by changing world market conditions (Sakagawa et al 1987). Bigeye tuna has always brought higher prices than yellowfin in the sashimi-grade tuna market, but the price differential has grown appreciably since the mid-1970s.

These events made it more difficult to standardize Japanese effort on marlins and resulted in even greater uncertainty in the indices of abundance. This trend was further exacerbated in the early 1980s, when "deep longlining" in

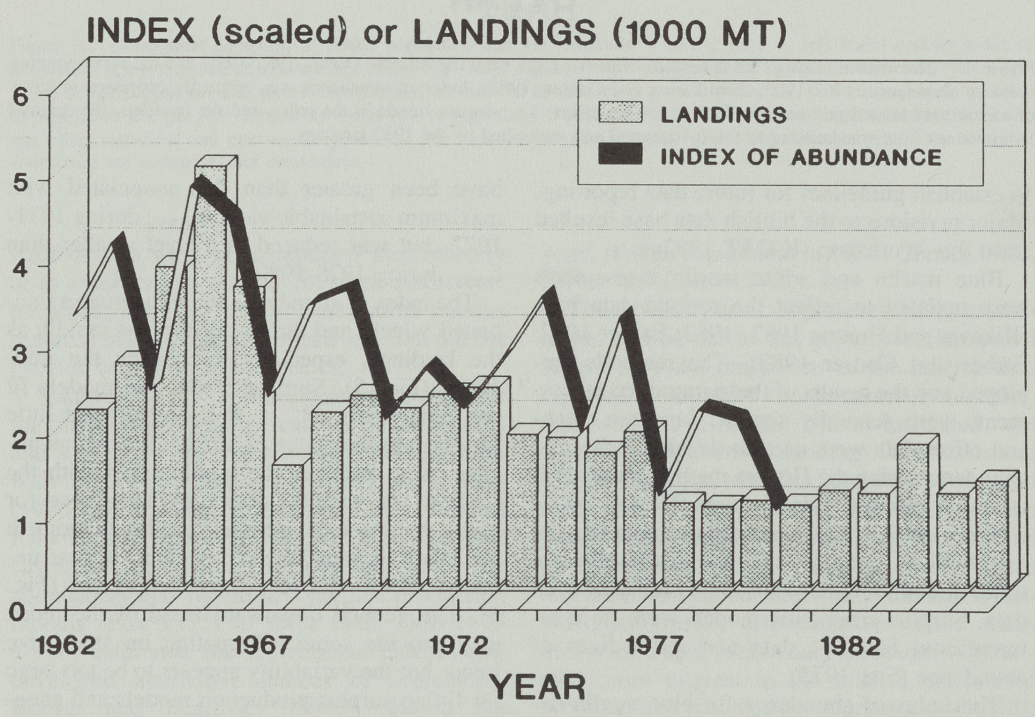

Figure 5. White marlin landings (in thousands of metric tons) from the Atlantic Ocean, 1962-1985, and the corresponding index of abundance, 1962-1980, from Farber and Conser (1983). Index of abundance was originally expressed in terms of metric tons landed per unit of effective fishing effort. To compare trends in the index and the landings, the original index values were standardized to the 0-1 interval and multiplied by the 1965 landings.

pursuit of bigeye tuna became common in the Altantic. When using standard longline practices, hooks are set at a maximum depth of approximately 170 m. When "deep longlining," however, maximum depth of hooks approaches 300 m (Suzuki et al 1977). Deep longlining is generally considered to be more effective than standard longlining for bigeye tuna, but less effective for marlins (Suzuki et al 1977, Suzuki and Kume 1982).

The net result of the change in target species, and the concomitant increase in deep longlining activities, was that the index of abundance for marlins, based on Japanese data, could no longer be considered reliable for assessment purposes. The data on deep longlining operations, needed to standardize properly Japanese (or other) effort data, are not routinely reported to ICCAT.

Attempts to develop reliable indices of abundance from other fisheries have not been successful. The Korean longline fishery, traditionally directed at yellowfin tuna, landed significant amounts of Atlantic marlins during the late 1960s through the mid-1970s (Figs. 1 and 2). If Korea had continued to target yellowfin, it may have been possible to develop a reliable marlin index of abundance from the Korean longline data. Then, taking advantage of the years when both Japan and Korea landed significant amounts of marlins, it might have been possible to standardize the Japanese and Korean indices, creating a single, consistent, long-term index. The Korean longline fishery has, however, also changed its target species to bigeye tuna in recent years (Fig. 7; ICCAT 1988). Korea's marlin landings are now at low levels, as with Japan, and the changing nature of its fishery (i.e., deep longlining) makes it impractical to use Korean data for developing indices of marlin abundance.

Attempts to use catch-and-effort data from other longline nations, that have not undergone major changes in target species, have been less than satisfactory (Farber and Conser 1981, Kikawa and Honma 1983). Indices of abundance developed from the USA recreational fishery data (Beardsley and Conser 1981, Browder and Prince 1987) may prove useful in future assessments, but the problem of local availability will first need to be addressed (since the data come only from coastal areas). Consequently, using formal population dynamics models, it has not been possible to update the Atlantic marlin assessments.

Lacking recent stock assessments of Atlantic marlins, it is not possible to draw conclusions concerning the current status of stocks. Given the recent trends in the high-seas longline operations (i.e., targeting bigeye tuna through the use of deep longlining), however, recent fishing mortality rates on the marlins are probably not greater than they were in the final years of the time series used in the most recent assessments (i.e., during the late 1970s).

Shortcomings In Current Understanding

Fisheries Data

Catch Data. The total international catch for each species is needed, i.e., all mortalities due to fishing. Ideally, this totality would include not only fish landed in the commercial and recreational fisheries but those that are discarded or released and do not survive. Discard and release mortalities tend to be difficult to estimate. Species identification can also be a problem in some fisheries. All major billfish fishing nations in the Atlantic currently report their catches to ICCAT. Although these data have improved considerably since ICCAT's inception in the early 1970s, further improvement is needed.

Detailed Effort Data. Effort data provide quantitative answers to the question, "How hard is a nation fishing for a certain species?" For high-seas longline fisheries, effort is usually measured in the number of hooks fished; for recreational fisheries, effort is usually stated in terms of the number of hours fished, etc. Effort is currently reported to ICCAT by all major billfish fishing nations in the Atlantic. However, the level of detail is not sufficient for stock assessment purposes. In particular, data on the depth of fishing is needed to develop meaningful indices of abundance.

Size and Sex Composition of the Catch. Information on size and sex of the catch is acquired through taking samples of fish as they are caught and then extrapolating information from these samples to the total catch. In the commercial longline fisheries, few fish are sampled for size and virtually none are sampled to determine the sex. Recreational fisheries are better sampled in this regard.

Biological Knowledge

Age and Growth. Without an understanding of how fast marlins grow and the ages that they attain, it is difficult to employ most of the mathematical models that have been developed

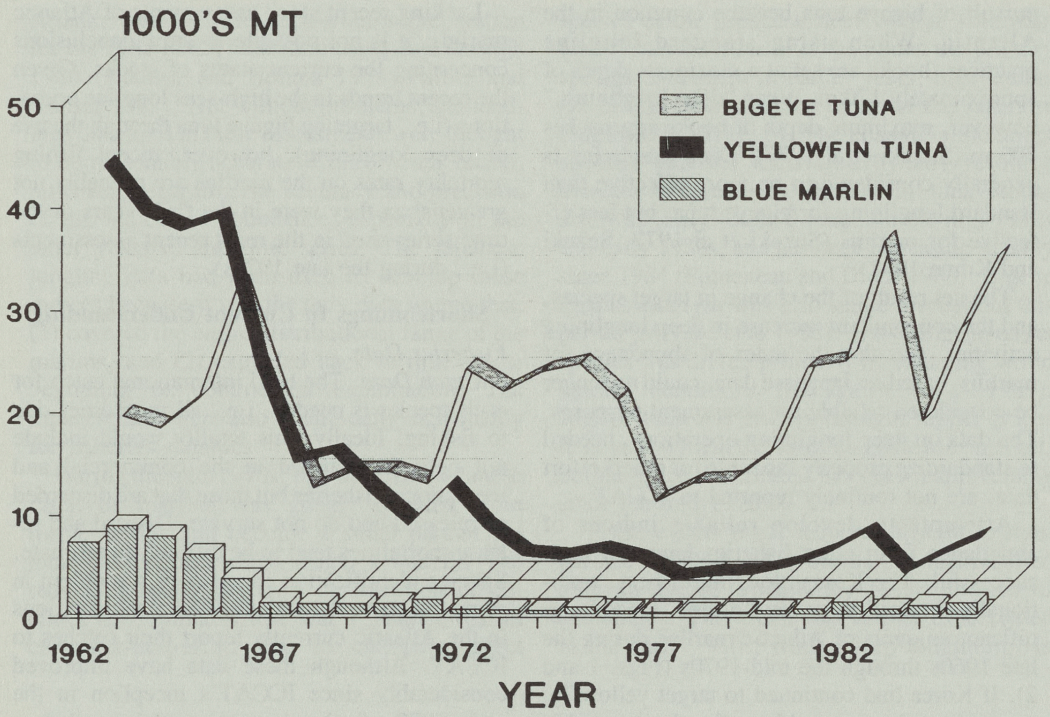

Figure 6. Japanese longline landings (in thousands of metric tons) of bigeye tuna and yellowfin tuna from the Atlantic Ocean, 1962-1985. Blue marlin landings are also displayed on the same scale to demonstrate the magnitude of the tuna landings relative to the marlin landings. Data are from ICCAT (1980), ICCAT(1982b), and ICCAT (1986).

for fish stock assessment. Marlins have proved troublesome to age using skeletal hard parts. Validation of presumed annuli observed on skeletal hard parts has been particularly difficult. While data from tagging experiments have been used to estimate growth rates in some species, these data (particularly the number of recoveries) are too sparse to be used for this purpose in the case of Atlantic marlins.

Maturity. Maturity ogives need to be developed, i.e., the proportion of fish within an age or size group that are mature. Some maturity work has been done on blue marlin (Yeo 1978). Work on white marlin as well as additional work on blue marlin is needed.

Fisheries-Independent Data

Index of Abundance. Indices of abundance that are independent of the fisheries data are extremely valuable for "ground truthing" the mathematical models that are commonly used for stock assessment, e.g., virtual population analysis (VPA). These independent indices are generally obtained from scientific sampling aboard research survey cruises. No such indices are available for billfishes in the Atlantic.

Stock Structure. Catch-and-effort data (fisheries dependent), along with tagging data, have been used to develop working stock structure hypotheses for stock assessment studies. These hypotheses require further evaluation and validation. Fisheries-independent efforts, such as additional tagging and biochemical research, may be needed to do so.

Stock Assessment Methods

Sophisticated stock assessment methods and procedures are available to address the relevant questions related to billfish management. As indicated above, however, neither the fisheries data nor the biological knowledge are sufficiently well in hand to take advantage of these methods. Further, even with increased attention and resources focused on billfishes, it may be many years before the requisite data and information are available. New, simpler methods are needed that can be tailored to the relevant management questions while taking advantage of the availa-

ble data and the developing data base. Some of the "short cut" assessment methods currently used by the International Council for Exploration of the Sea (ICES) may provide good starting points (ICES 1984). It is unlikely that these methods will be useful for billfish management, however, without significant modification and further development.

Future Directions

Atlantic marlin stock assessments were carried out annually from the mid-1970s through the early 1980s. Considerable progress was achieved during this period in both the quality of the assessments and the data on which they were based. It should be recognized that for practical fisheries management purposes, however, the state of the art of billfish stock assessments was rather primitive throughout this period. Further, because the international data bases have not kept pace with the rapid changes in fishing practices during the 1980s, we are less able today to gauge the status of stocks than we were in the early 1980s.

In the previous section, the major shortcomings in the data bases and biological understanding were delineated. Billfish stock assessment studies will provide the kind of scientific advice that is needed to manage this complex international fishery, exploited for both commercial and recreational purposes, only after these shortcomings have been rectified.

An ICCAT program has been initiated recently to improve the international billfish data base. Cooperative research among international scientists, aimed at improving our biological knowledge, should also spring from this program. Advancements that result from the program should aid stock assessment efforts in future years, but benefits of the program will be realized only over the long-term.

In the short-term, progress can be made in several areas. The goal here should be to concentrate on the data base problems and assessment methods research needed to provide general scientific advice on the status of stocks. The short-term efforts are important. The dynamic nature of the international fisheries requires that the

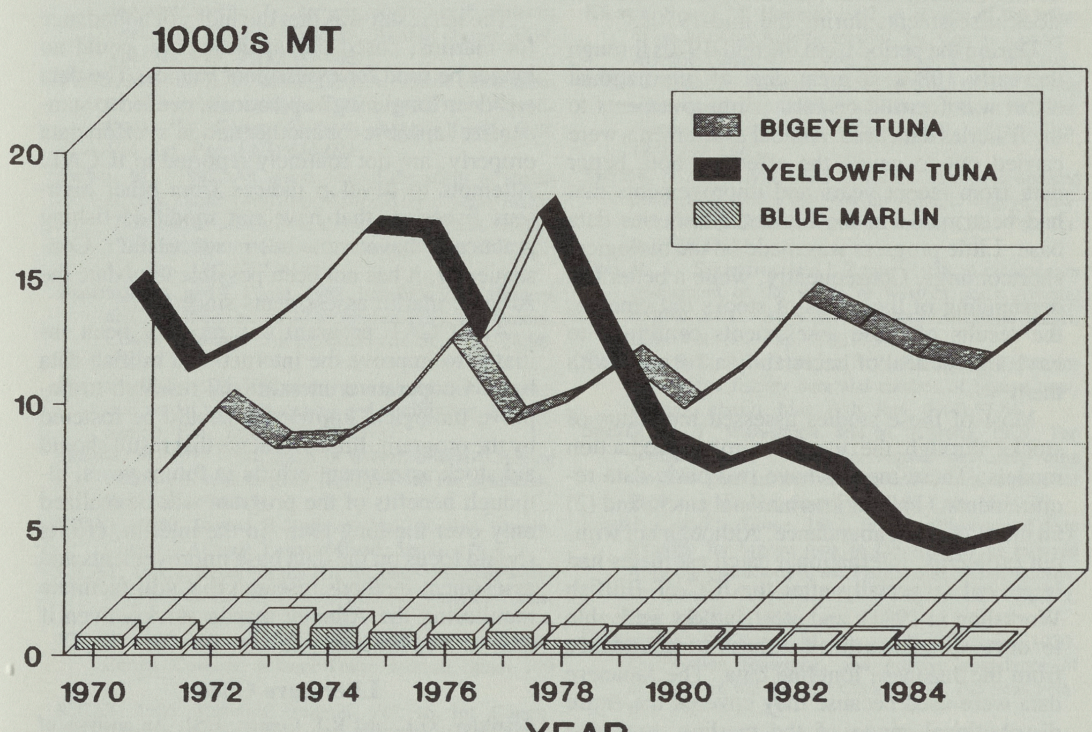

Figure 7. Korean longline landings (in thousands of metric tons) of bigeye tuna and yellowfin tuna from the Atlantic Ocean, 1970-1985. Blue marlin landings are also displayed on the same scale to demonstrate the magnitude of the tuna landings relative to the marlin landings. Data are from ICCAT (1980) and ICCAT (1986).

stocks be monitored (even if only in a rudimentary fashion) during what may be an extended period needed to address the long-term impediments. The most important short-term improvement needed in the fisheries data base is the incorporation into the ICCAT data base of depth of fishing for all longline fleets. With regard to short-term assessment methods research, (1) research on developing better indices of abundance, incorporating depth of fishing and other variates; and (2) examination of "short-cut" assessment methods are most important.

Summary

Efforts to assess the status of stocks of Atlantic marlins were first undertaken in the late 1960s. Shortcomings in the fisheries data base (e.g., catch, effort, size samples, etc.) and biological knowledge (e.g., growth rates, maturity, etc.) severely limited the scope of the assessment work that could be effected. Improvements in the fisheries data base through international cooperation, under the auspices of the International Commission for the Conservation of Atlantic Tunas (ICCAT), led to the first stock assessments during the mid-1970s.

During the period from the mid-1970s through the early 1980s, a great deal of international effort was focused on further improvements to the fisheries data base. Annual assessments were carried out to gauge the effect of both better data from recent years and improvements that had been made in the historical fisheries data base. Little progress was made on the biological shortcomings. Consequently, while a better understanding of the status of stocks did emerge, the results of these assessments continued to have a great deal of uncertainty associated with them.

Most of these studies assessed the status of stocks through the use of surplus production models. These models have two basic data requirements: (1) total international catch; and (2) an index of stock abundance. Although not without problems, international catch estimates had improved (especially after the ICCAT Billfish Workshop in 1981); and most authors were able to develop standardized indices of abundance from the Japanese longline data. The Japanese data were used because they covered the entire distributional range of the marlins, extended back in time to the beginning of commercial exploitation on marlins, and were of unusually high quality for fisheries statistics. Although the assessment results were considered provisional by the researchers involved in these studies, the assessments generally showed blue marlin to be fully exploited (in the late 1970s). They provided little insight, however, into the status of white marlin, mainly due to difficulties in adequately fitting the available data to surplus production models.

By the late 1970s, the Japanese catch of marlins was greatly reduced from former levels and had become a small part of the total international catch. The reduction was the result of a combination of less nominal effort and a smaller marlin catch-per-unit-effort due to changing target species. Where yellowfin tuna and albacore *(Thunnus alalunga)* had been the primary species of interest in earlier years, bigeye tuna became the primary target of the Japanese longline fleet. The combination of these events made it more difficult to standardize Japanese effort on marlins and resulted in even greater uncertainty in the indices of abundance. This trend was further exacerbated in the early 1980s, when "deep longlining" in pursuit of bigeye tuna became common in the Atlantic.

The net result was that the index of abundance for marlins, based on Japanese data, could no longer be used for assessment studies. The data on "deep longlining" operations, needed to standardize Japanese (or another nation's) effort data properly, are not routinely reported to ICCAT. Attempts to develop indices from other high-seas fisheries, that have not modified fishing practices, have not been successful. Consequently, it has not been possible to update the Atlantic marlin assessments since 1982.

An ICCAT program has recently been initiated to improve the international billfish data base. Cooperative international research to improve biological knowledge should be fostered by the program. Improvements that result should aid stock assessment efforts in future years, although benefits of the program will be realized only over the long term. In the interim, efforts should focus on the data base improvements and assessment methods research that will facilitate monitoring the Atlantic marlin stocks, even if only at a rudimentary level.

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Catch and Fishing Effort Relationships for Striped Marlin, Blue Marlin, and Black Marlin in the Pacific Ocean, 1952 to 1985

Ziro Suzuki

Since, the last billfish stock assessment workshop, held in 1977 (Shomura 1980), follow-up studies have not been made on stock status of the Pacific marlins. During roughly a decade, from 1977 to 1988, considerable changes occurred in various fisheries which take billfishes in the Pacific, both on the commercial and recreational sides. However, the relevant knowledge of basic biology and fisheries statistics on Pacific marlins do not appear to have improved during the period. Therefore, the present study adopted the same cursory approach used in the previous work (Suzuki and Honma unpublished). Overall catch-and-effort statistics in the Pacific for striped marlin *(Tetrapturus audax),* blue marlin *(Makaira mazara),* and black marlin *(M. indica)* were derived by referring to Japanese longline statistics as a base of calculation and inferring briefly the status of these stocks. Major findings of the previous paper (Suzuki and Honma *op. cit.)* are summarized in the workshop report (Shomura *op. cit.).* The present study is based on a number of assumptions and on rough estimates of catch and fishing effort statistics by species. Therefore, the results of this study should be interpreted with these limitations borne in mind.

Materials and Methods

Catch-and-Effort Data

Catch and fishing effort by species from 1952 to 1975 was cited from Suzuki and Honma *(op. cit.).* However, the fishing effort on black marlin from 1952 to 1975 was recalculated in this paper according to a change in the assumed stock area as mentioned in the unit stock section. Since the change in unit stock area of black marlin did not appear to change the previously estimated catch (Suzuki and Honma *op. cit.),* the previous estimates were used. Most of the catch for the three species comes from the longline fishery operated by Japanese, Taiwanese, and Korean fleets. The catches from 1976 to 1985 were taken from the FAO yearbooks of fishery statistics (FAO, 1980, 1981, 1983, 1984a, 1984b, 1986), except for those from the Japanese longline fishery operated by boats over 20 gross tons (hereafter simply referred to as the Japanese longline fishery; Fisheries Agency of Japan 1978-1982, and unpublished statistics from 1981 to 1985), one of principally important fractions for assessment of the stock status of the billfishes.

The separation of the Japanese longline catch from that by other fisheries was necessary to estimate overall fishing intensity. This was done by raising the ratio of total catch to the Japanese longline catch to the fishing intensity of the Japanese longline, thus expanding the Japanese fishing intensity to overall fishing intensity. The catch in the Japanese longline statistics, expressed in terms of number of fish, was converted to that of weight with the use of annual average weight tables by 10° latitude and 20° longitude areas. Since annual changes in the average weight appeared to be minor, and without apparent increasing or decreasing trend, the table for 1985 was used for the whole period from 1976 to 1985.

The estimation of catch by species for blue

marlin and black marlin is difficult, in citing the FAO yearbooks as reference, because the black marlin catch is included in the blue marlin catch in many cases. However, the Taiwanese catch appears to have been separated into blue marlin and black marlin under the country item "Other nei" in the FAO yearbooks. The catches of blue marlin and black marlin by the Japanese longline fishery are separable by the catch-and-effort statistics and the average weight table. It was not possible to separate the blue marlin from black marlin for other countries. Therefore, total blue marlin catch, as a first approximation, was estimated by subtracting the Japanese black marlin catch calculated in this study from the total blue marlin catch shown in the FAO yearbooks. Total black marlin catch was estimated by adding the "Other nei" and Japanese longline catches. Therefore, the total catch used in this paper overestimates the blue marlin catch and underestimates the black marlin catch. Magnitude of the misestimation will be more serious for black marlin, due to much smaller catches of black marlin, than for blue marlin.

Standardization of Fishing Effort

Impact of a unit nominal fishing effort on a given stock here, — the number of hooks used in the Japanese longline fishery, changes by various factors such as area, season, kind of gear construction of the longline, vessel size, etc. Among them, the areal and seasonal changes, which probably result from migration and kind of longline gear contruction, i.e., regular and deep longlining, have significantly large effects on changing the impact of nominal effort on the stock (Honma 1974, Suzuki et al 1977). Those two factors were taken into account in standardizing the nominal fishing effort. First, the nominal number of the deep longline hooks was converted to equivalent number of the nominal regular longline hooks. After that step, the nominal number of regular hooks was standardized with regard to the area and seasons.

Necessity of standardizing fishing effort between the deep and regular longline operations comes from the fact that billfishes are a typical surface swimmer compared with tunas. Consequently, the deep longline is considerably less effective in general than the regular one with surface swimming billfishes (Suzuki et al 1977). The Japanese longline boats began to operate with the deep longline aiming at deep swiming bigeye tuna *(Thunnus obesus)* in the tropical areas from the latter half of the 1970s (Suzuki et al 1977). The deep and regular longlining operations are defined by the number of branch lines between the neighboring floats, ranging from 10 and more and from 4 to 6, respectively. Trend of the deep longline deployment by area (Fig. 1) is shown in Table 1 for the period 1975-1976. Since the deep longlining has been applied for deep swimming bigeye tuna, in the tropical areas where the thermocline is located much deeper, this type of operation is predominant over the regular type in the tropical areas (Areas 3 to 6). From the 1980s, the deep longline operation has become dominant in the tropical areas, while its deployment in the higher latitudes has leveled off and remains as a minor portion during the same period. Fishing efficiency of the deep longlining in comparison to the regular type was calculated annually by area, shown in Figure 1, taking a ratio of average hook rate (catch in number per 100 hooks) of the deep longline to that of the regular one.

The fishing efficiency in a given area varied considerably annually and a significant difference was observed in the comparison of fishing efficiency for roughly the same central and western tropical areas with the previous work (Suzuki et al *op. cit.*). This is probably due to low precision of the catch-and-effort statistics used in the present study. Namely, the fishing efficiency calculated by the previous work, based on the logbooks which had been verified, with direct interview of captains by scientists stationed in Yaizu, Japan's major tuna unloading port. Further, the spatio-temporal stratum of one degree square and day in the previous work compared with the 5 degree square and month in the present study. In addition, the Japanese

Table 1. Trend of deep longline deployment as expressed by ratio of the number of deep longline hooks to the total hooks used in the Japanese longline fishery in the Pacific.

Year/ Area	1	2	3	4	5	6	7	8
1975	0.04	0.01	0.13	0.06	0.02	0.02	0	0.06
1976	0.05	0.09	0.18	0.16	0.09	0.07	0	0.10
1977	0.08	0.15	0.27	0.32	0.28	0.26	0	0.20
1978	0.10	0.25	0.35	0.47	0.49	0.46	0.02	0.26
1979	0.16	0.26	0.38	0.62	0.52	0.41	0.06	0.32
1980	0.27	0.24	0.44	0.68	0.52	0.49	0.10	0.33
1981	0.36	0.28	0.50	0.70	0.56	0.28	0.22	0.31
1982	0.42	0.21	0.62	0.81	0.72	0.27	0.12	0.43
1983	0.41	0.25	0.67	0.86	0.81	0.57	0.11	0.48
1984	0.45	0.20	0.90	0.88	0.86	0.51	0.12	0.37
1985	0.39	0.20	0.88	0.90	0.91	0.73	0.14	0.34

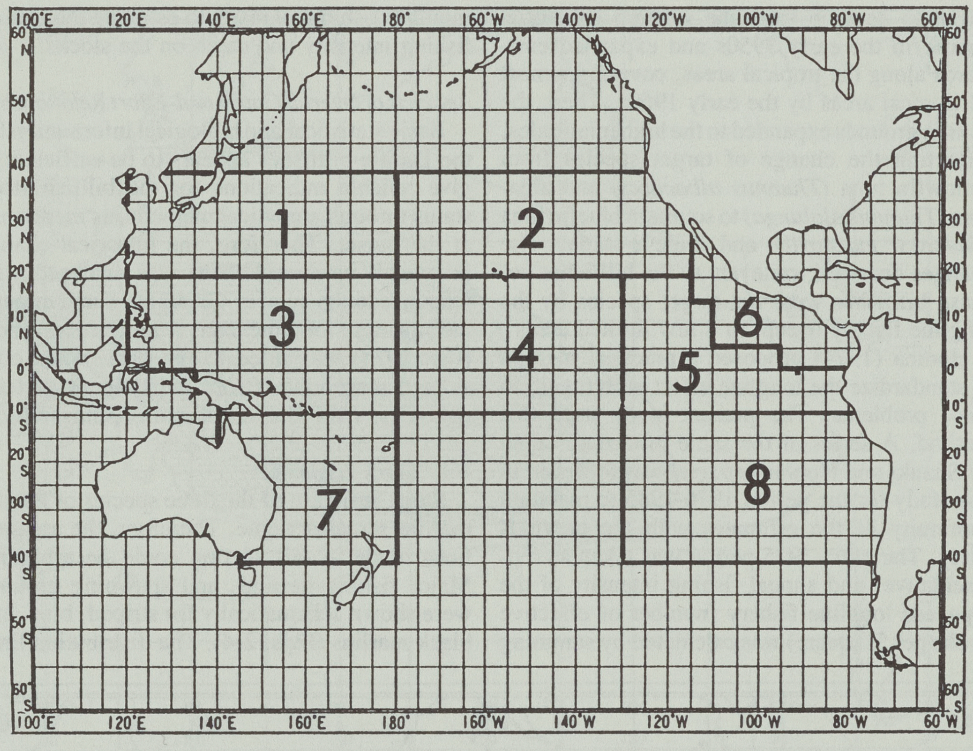

Figure 1. Division of area for calculating deployment rates and fishing efficiency of deep longlining operations by Japanese boats.

domestic law has complicated areal limits for operations of the smaller longline boats which confine their fishing mostly within the north-central and the northwestern Pacific. These complications inevitably incur intentional misreporting of the fishing locations by the small boats to some degree.

Therefore, the fishing efficiencies for areas 3 and 4 were replaced with those estimated by the previous study (Suzuki et al *op. cit.)*, which were considered to be the best estimates for the two areas. For other areas, extreme values and fishing efficiencies calculated from small samples were omitted. Since this procedure resulted in small observations, the remaining annual efficiency values were averaged by area across the years. Average fishing efficiency was calculated only for the major fishing areas of each species (Table 2). The lower the value below 1.0, the lower the fishing efficiency of the deep longlining than that of the regular longlining, and vice versa. The standardization from the deep to the regular longline operations was made only for major fishing areas which differed by species (Table 2). The product of the annual areal deployment ratio (Table 1) and the areal average fishing efficiency (Table 2) was multiplied by the number of the deep longline hooks to obtain an equivalent value of regular longline hooks.

Standardization of fishing effort with regard to the areal and seasonal changes of a unit of fishing effort relates to historical changes of the fishing grounds of the Japanese longline fishery (Suzuki 1988). The Japanese longline fishery

Table 2. Average fishing efficiency of deep longlining over regular longlining for major fishing areas of the Pacific marlins taken in the Japanese longline fishery from 1975 to 1985.

Species/Area	1	2	3	4	5	6	7	8
Striped marlin	1.00	0.74			0.74	0.72	0.76	0.74
Blue marlin			0.55	0.55				
Black marlin			0.34			0.54	1.26	

N.B.: Fishing efficiency is expressed by the ratio of average hook rate of deep longlining to that of regular longlining. See text for further explanations.

began to develop from the western equatorial Pacific in the early 1950s and expanded eastwards along the tropical areas, covering almost all tropical areas by the early 1960s. Then, the fishing grounds expanded to the higher latitudes, reflecting the change of target species from yellowfin tuna *(Thunnus albacares)* and albacore *(Thunnus alalunga)* to southern bluefin tuna *(Thunnus maccoyii)* and bigeye tuna. The changes occurred irrelevant to the billfishes because billfishes were not target species by the longline fishery except in a few limited areas.

Honma (1974) proposed a practical method to standardize the longline effort with regard to these problems. The present study used this method. A series of the same procedure taken by Suzuki and Honma *(op. cit)* was followed in this study for the period 1976-1985 to maintain continuity of the estimates with the previous study. The 1965-1975 period was taken as representative, and annual fishing intensity of the Japanese longline fishery (number of effective hooks per 5° square) was calculated by summing monthly fishing intensity to estimate the overall fishing intensity and catch on the stocks.

Analysis of Overall Catch-and-Effort Relationship

Basic statistical and biological information for the Pacific billfishes appears to be sufficient to give reliable indications for the billfish stock status through analytical methods, as mentioned at the outset. Therefore, the historical change in overall catch-and-effort was analysed with reference to the trend of CPUE measured through the Japanese longline data. A production model (Fox 1975) was fitted to the data, when considered appropriate, to obtain maximum sustainable yield (MSY) and optimum fishing effort.

Unit Stock Assumed

Stock structure of the three species of Pacific marlins remains vague. Therefore, the assumptions made in this section could be arbitrary. Major fishing grounds and spawning grounds were shown schematically for striped, blue, and black marlins (Figs. 2-4). The distribution limit

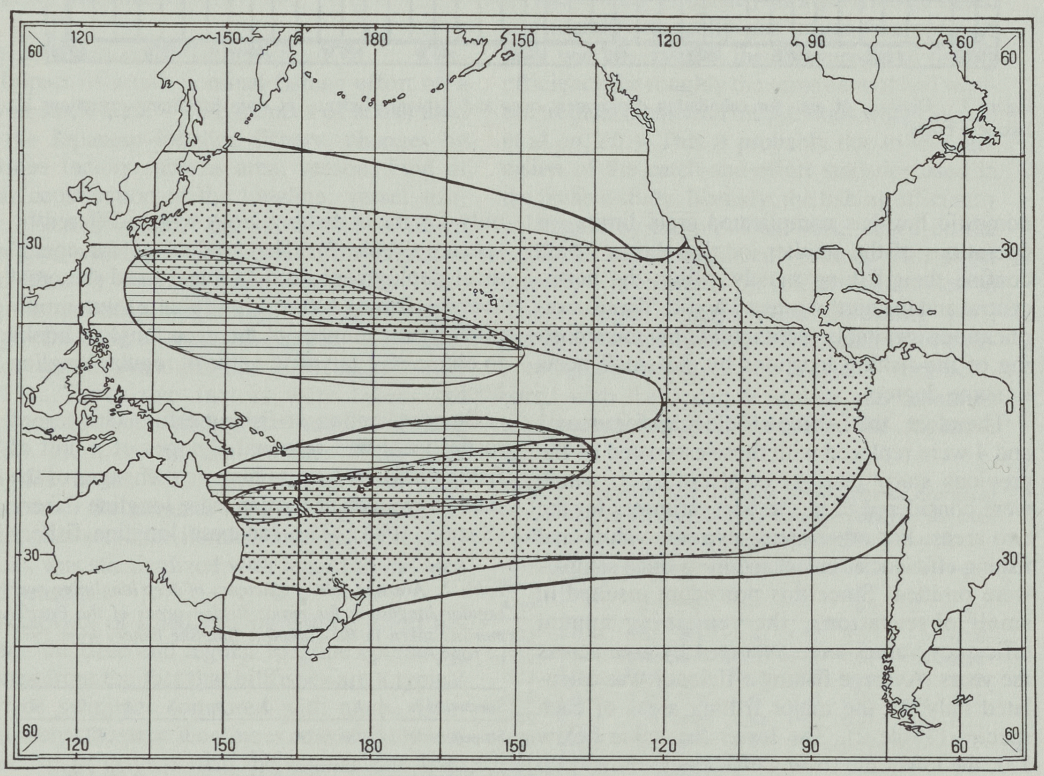

Figure 2. Schematic presentation of distribution and spawning grounds of Pacific striped marlin. Thick lines and dotted area show limits of distribution and high catch rate areas inferred from the Japanese longline statistics. Striated areas denote spawning grounds, verified by occurrence of larvae.

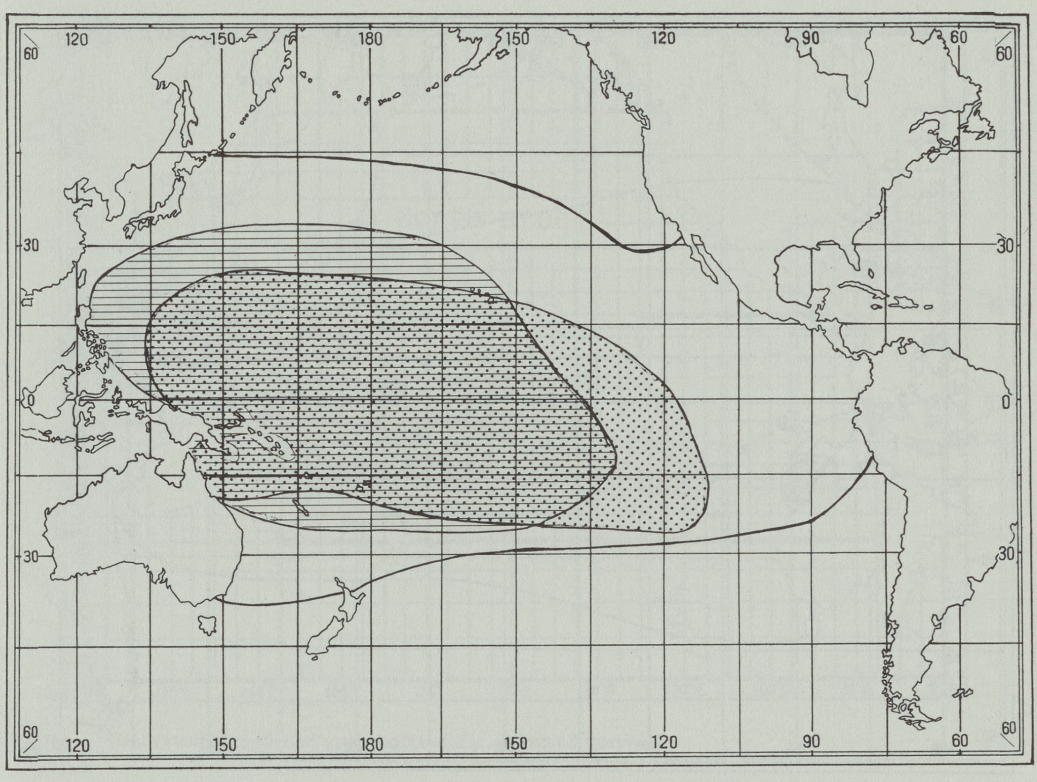

Figure 3. Schematic presentation of distribution and spawning ground of Pacific blue marlin. Legends same as in Fig. 2.

and abundance distribution area were inferred from the CPUE data of the Japanese longline fishery. The spawning areas that have been confirmed by larval occurrence (Nishikawa et al 1985) were used for schematic presentation.

A two-stock assumption was adopted for striped marlin, one in the north Pacific and the other in the south Pacific (Fig. 5). This assumption was made on the basis of a morphometric study by Honma and Kamimura (1958), an absence of striped marlin in the south Pacific that have been contaminated by radioactivity at the Bikini area (Suda 1956), and the rather distinct north-south separation of spawning grounds (Fig. 2). A single blue marlin stock in the whole Pacific (Fig. 6) was hypothesized from the homogeneous distributions of larvae and adult fish (Fig. 3). The stock structure of black marlin might be the least known among the billfishes. Abundance distribution areas are located far apart (Fig. 4). However, only one confirmed spawning area, off the north-east coast of Australia, in the Pacific, and tag recovery off the north-east coast of Australia, released off Baja California, led to a single stock assumption of this species for the whole Pacific (Fig. 6) in this paper. A possibility remains, however, of a mixture of black marlin in the Indian Ocean and the western Pacific Ocean. All cases of unit-stock assumptions made in this paper were covered by the previous work (Suzuki and Honma *op. cit.)* except for the single-stock assumption for black marlin in the whole Pacific.

Results and Discussion

Striped Marlin: North Stock

The north Pacific stock of striped marlin was being exploited dominantly by the Japanese longline fishery by the middle of the 1970s (Table 3). After that period, however, relative importance of the Japanese longline fishery decreased significantly due to a decrease of the fishing intensity by the Japanese longline fishery. Development of other fisheries, such as the Japanese gillnet fishery and Taiwanese and Korean longline fisheries, were also important. The decreased fishing intensity on the north stock by the Japanese longline fishery after the

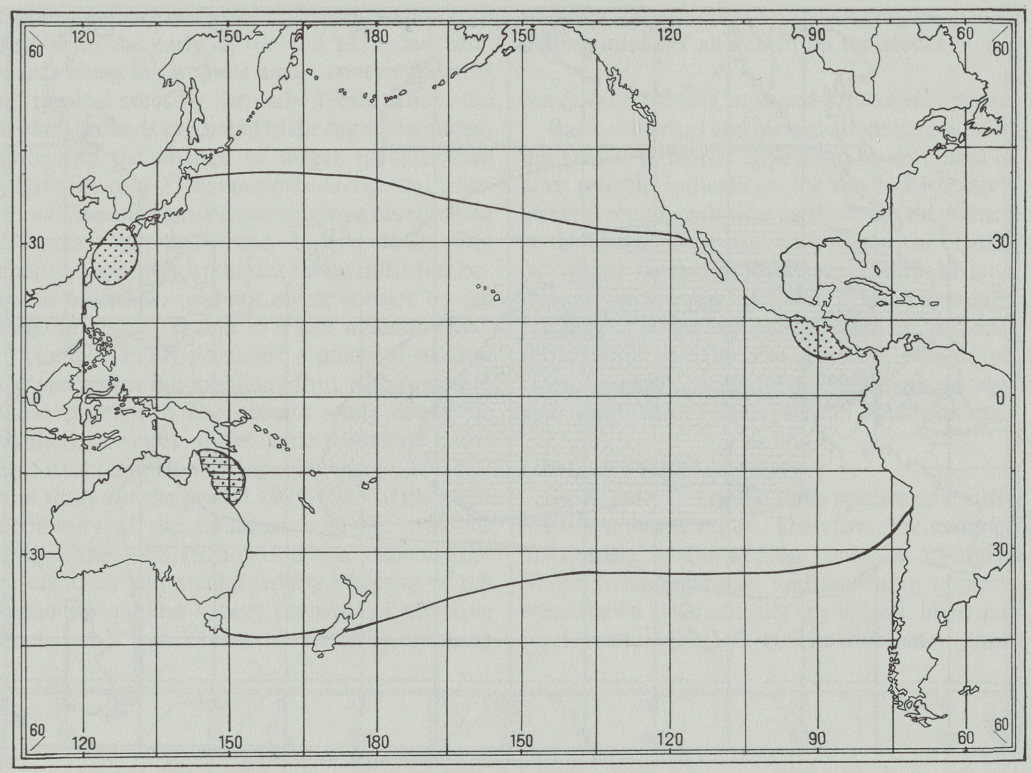

Figure 4. Schematic presentation of distribution and spawning ground of Pacific black marlin. Legends same as in Fig. 2.

mid-1970s reflects the change of target species to bigeye tuna with the use of the deep longlining. Total fishing intensity on the north stock, on the other hand, remained at a high level even after the middle of the 1970s, and peaked in 1978 (Table 3). This fact implies that the development of the other fisheries has had a larger effect on the stock, beyond offsetting the decrease in fishing intensity by the Japanese longline fishery. The total fishing intensity has decreased considerably in the 1980s, however, primarily due to decline of the fishing intensity in the other fisheries. Total catch from the north stock peaked in 1968, at about 21,000 tons, then showed a decreasing trend up to the end of the 1970s despite the increased total fishing intensity during the same period. In the 1980s, the total catch showed a slight decreasing trend. CPUE measured through the Japanese longline data showed a wide fluctuation without a clearly increasing or decreasing trend during the whole 1952-1985 period.

The relationship between total catch and fishing effort is shown in Figure 7. The catch has been sustained over a wide range of fishing intensity, which does not yield useful information on the MSY and the optimum fishing effort. Judging from a wide fluctuation in the CPUE, without any trend, however, it is inferred that the fishing impact on the north stock may not be high enough to be a dominant factor in changing stock size. However, it is noted, as inferred in the previous billfish stock assessment workshop summary (Shomura *op. cit.)* that increased fishing effort beyond the 1975 level resulted in no further increase in catch.

Striped Marlin: South Stock

The south Pacific stock has been exploited mostly by the Japanese longline fishery throughout the entire period from 1952 to 1985 (Table 4). Therefore, the trends of catch and fishing intensity of the Japanese longline fishery are similar to that of total catch and total fishing intensity. The fishing intensity of the total fishery showed an increasing trend from 1952 to 1980. A significant reduction of the total fishing intensity occurred after 1980. This change

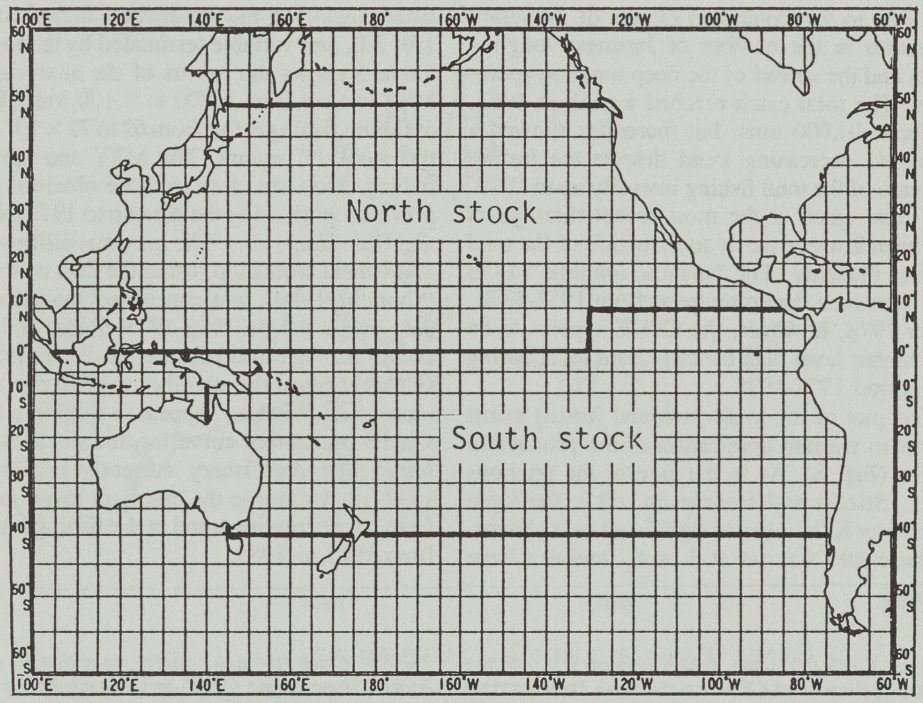

Figure 5. Areal extent of north and south stocks of Pacific striped marlin.

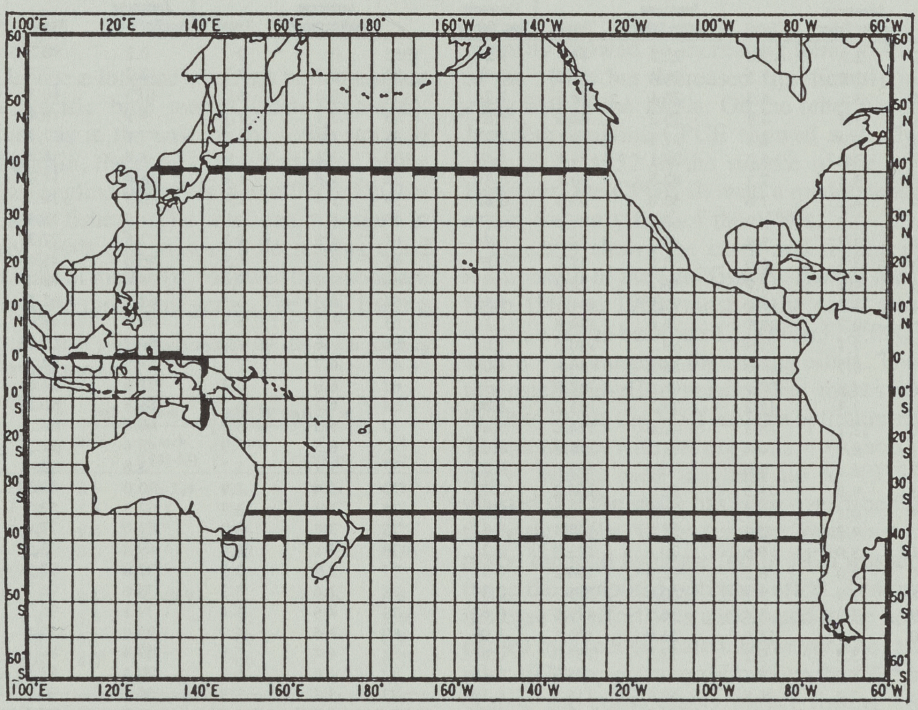

Figure 6. Areal extent of Pacific blue marlin (straight lines) and black marlin (dotted lines) stocks.

was due to the combined effects of voluntary reduction in the number of Japanese longline boats and the spread of the deep longline operations. The total catch reached a peak in 1963, at about 10,000 tons, but thereafter showed a moderate decreasing trend despite the further increase of the total fishing intensity up to 1980. The total catch in the most recent three years has been low due partly to reduction of the total fishing intensity. The Japanese longline CPUE has been on a declining trend from 1952-1978. After 1978, however, the CPUE appears to be at a higher level than the minimum level during the period 1977-1978.

The plot of the total catch and fishing effort seems to warrant application of the production model (Fig. 8). As in the case of the previous work (Suzuki and Honma *op. cit.),* the input parameter K (number of significant year classes, in the catch) was set at 3 or 4,. and m (shape determinator of the production curve) at 0.0, 1.0, 2.0, and variable (estimated by the model). Table 5 shows the results of the analysis. The MSY ranged from 5,700 to 9,100 tons and the optimum fishing effort from 62 to 72 $\times 10^4$ effective hooks/5° square. The MSY and optimum fishing effort are close to those obtained in the previous work using the data up to 1975 (Suzuki and Honma *op. cit.).* The previous billfish stock assessment workshop, using the data up to 1975 (Shomura 1980), was concerned about aberrant data points for the 1973-1975 cluster at the optimum fishing effort because the cluster fell considerably below the equilibrium yield curve. The recent data, however, appear to support a dome-shaped production curve for this stock. It is inferred that the fishery currently exploits the south stock close to the optimum level, judging from the decreasing trend in the fishing intensity from 1981 to 1985.

Table 3. Catch (10^3 tons), fishing intensity (10^4 effective hooks/5° square) and CPUE on the north Pacific striped marlin stock, 1952-1985.

	Catch		Fishing intensity		CPUE $\times 10^{-1}$
	Japanese longline fishery	Total	Japanese longline fishery	Total	Japanese long. fishery
1952	2.7	5.0	22.3	41.1	1.21
53	2.1	3.1	21.4	31.2	0.98
54	3.1	4.3	25.1	34.5	1.24
55	3.7	4.9	35.2	46.5	1.05
56	3.9	6.1	31.9	50.1	1.22
57	3.2	6.0	29.1	54.1	1.10
58	3.8	7.2	42.5	80.7	0.89
59	4.1	7.6	50.0	93.3	0.82
60	3.7	5.9	67.5	106.4	0.56
61	3.7	5.8	49.7	78.3	0.74
62	4.5	6.9	50.8	77.2	0.89
63	4.4	7.0	46.2	73.0	0.95
64	14.2	17.2	91.9	111.1	1.55
65	10.7	17.7	96.6	159.8	1.11
66	7.1	13.3	69.7	130.0	1.02
67	9.7	15.0	88.8	136.8	1.09
68	14.8	20.7	106.1	148.9	1.39
69	7.3	15.2	73.2	151.2	1.00
70	12.1	18.3	82.6	124.6	1.46
71	9.6	17.4	71.3	128.8	1.35
72	6.1	8.9	70.5	103.0	0.87
73	6.0	11.5	82.1	156.2	0.73
74	6.1	10.9	75.8	136.1	0.80
75	4.3	12.4	51.7	150.4	0.83
76	5.0	9.6	70.1	133.9	0.71
77	2.0	8.8	42.3	190.2	0.47
78	1.9	9.7	50.8	255.3	0.37
79	3.8	8.4	56.5	125.5	0.67
80	5.4	11.1	51.0	106.1	1.06
81	3.6	9.2	53.8	137.3	0.67
82	4.7	8.7	57.1	105.0	0.45
83	2.9	6.8	50.1	116.3	0.58
84	3.1	8.0	46.1	120.7	0.67
85	3.1	8.1	39.6	103.0	0.78

Table 4. Catch (10^3 tons), fishing intensity (10^4 effective hooks/5° square) and CPUE on the south Pacific striped marlin stock, 1952-1985.

	Catch		Fishing intensity		CPUE $\times 10^{-1}$
	Japanese longline fishery	Total	Japanese longline fishery	Total	Japanese long. fishery
1952	0	0	0.2	0.2	—
53	0.7	0.7	2.2	2.2	3.18
54	3.0	3.0	10.3	10.3	2.91
55	2.1	2.1	9.9	9.9	2.12
56	1.6	1.6	7.4	7.4	2.16
57	1.2	1.2	8.8	8.8	1.36
58	1.8	1.8	14.4	14.4	1.25
59	1.4	1.4	10.3	10.3	1.36
60	1.5	1.5	11.4	11.4	1.32
61	4.3	4.3	27.8	27.8	1.55
62	6.8	6.8	46.0	46.0	1.48
63	9.9	9.9	78.4	78.4	1.26
64	6.3	6.3	62.5	62.5	1.01
65	6.3	6.3	48.9	48.9	1.29
66	7.6	7.7	66.2	66.8	1.15
67	6.7	7.1	51.5	54.2	1.30
68	6.0	6.4	51.6	54.6	1.16
69	6.2	6.5	81.8	86.3	0.76
70	5.5	5.9	60.0	64.3	0.92
71	6.5	6.9	48.4	51.3	1.34
72	5.1	5.7	53.8	60.4	0.95
73	3.4	3.9	70.0	81.3	0.49
74	3.3	3.7	52.5	59.5	0.63
75	3.4	3.9	69.0	77.6	0.49
76	4.1	4.4	69.3	75.5	0.59
77	2.9	3.5	82.8	97.7	0.35
78	2.6	3.3	78.6	96.7	0.33
79	4.5	5.4	79.1	95.7	0.57
80	3.6	4.7	92.0	119.5	0.39
81	4.4	5.6	69.4	88.1	0.63
82	4.6	5.5	70.4	83.8	0.65
83	3.4	3.9	80.0	92.8	0.43
84	2.2	2.6	49.6	60.6	0.44
85	2.2	3.0	45.9	60.1	0.47

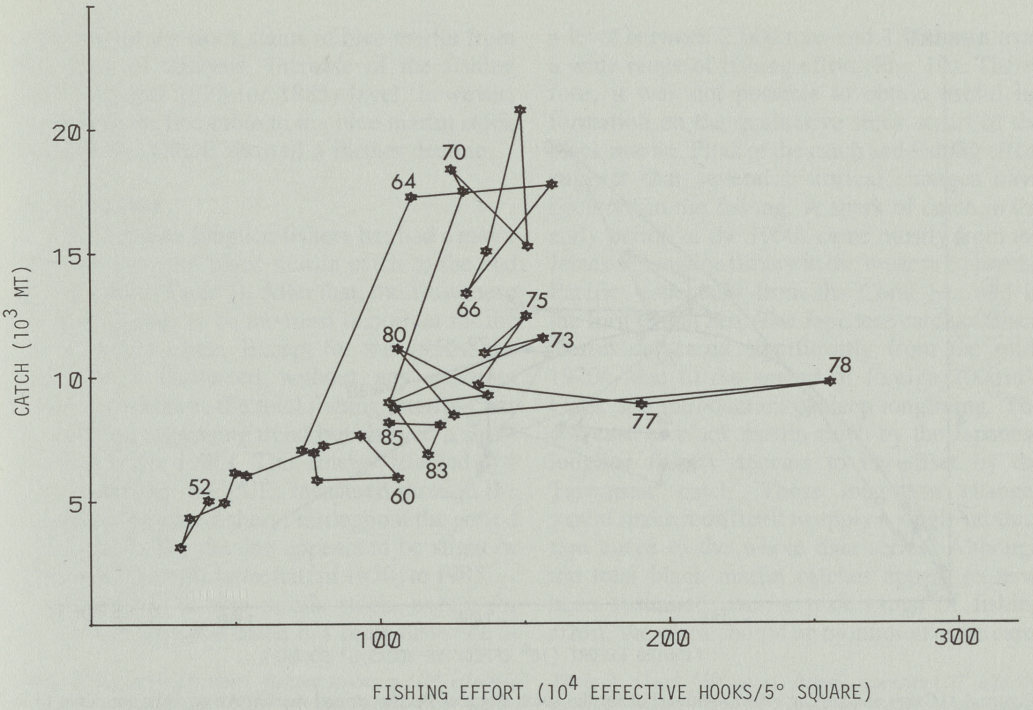

Figure 7. Catch and fishing effort relationship for the north stock of Pacific striped marlin. Numbers in the Figure denote the last two digits of various calendar years.

Blue Marlin

The Japanese longline catch has been dominant for the Pacific blue marlin catch (Table 6). Therefore, as in the case of the south stock of striped marlin, the catch-and-effort trend of the Japanese longline fishery is well reflected in that of the total fishery. The total catch peaked in the early 1960s and showed a decreasing trend to the middle of the 1970s, followed by a moderate increase up to the recent years. The total fishing intensity showed an increasing trend to the end of the 1980s but decreased significantly in the early half of the 1980s. On the other hand, the Japanese longline CPUE showed a steady decline from 1952 to the middle of the 1970s. However, the CPUE showed a moderate recovery in the early half of the 1980s.

Table 5. Result of production model for the south stock of Pacific striped marlin.

	unit: 10^3 tons		unit: 10^4 hooks/5° sq.		
	MSY	Catch (1983-85)	f(opt)	f (1983-85)	fit index
K = 3 m = 0.0	8.5	2.6-3.9	—	61-93	0.71
m = 1.0	5.8	"	65	"	0.75
m = 2.0	6.4	"	66	"	0.74
m = Var. (1.42)	6.0	"	62	"	0.76
K = 4 m = 0.0	9.1	2.6-3.9	—	61-93	0.63
m = 1.0	5.7	"	72	"	0.69
m = 2.0	6.1	"	68	"	0.71
m = Var. (1.6)	6.0	"	66	"	0.71

N.B.: K and m are parameters used in the analysis that define number of significant year classes in the catch and shape of the production curve.

Figure 9 shows the catch and fishing effort relationship of the total fishery. Except for plots from 1961 to 1963, most of the catch remains within a range between 12,000 and 24,000 tons over a wide range of the fishing effort. The flat top catch-and-effort relationship makes it difficult to locate the MSY and the optimum effort. This contrasts with the previous workshop summary, which used the data up to 1975 and warned that the stock has been overfished since the early 1960s. In the previous workshop summary, the total fishing effort in 1975 was almost twice the computed optimum effort, and further increase of effort was anticipated to be accompanied by a reduced catch. However, the catches after 1975 appear to remain above the 1975 level despite the considerably higher fishing effort. Under these circumstances, little information is

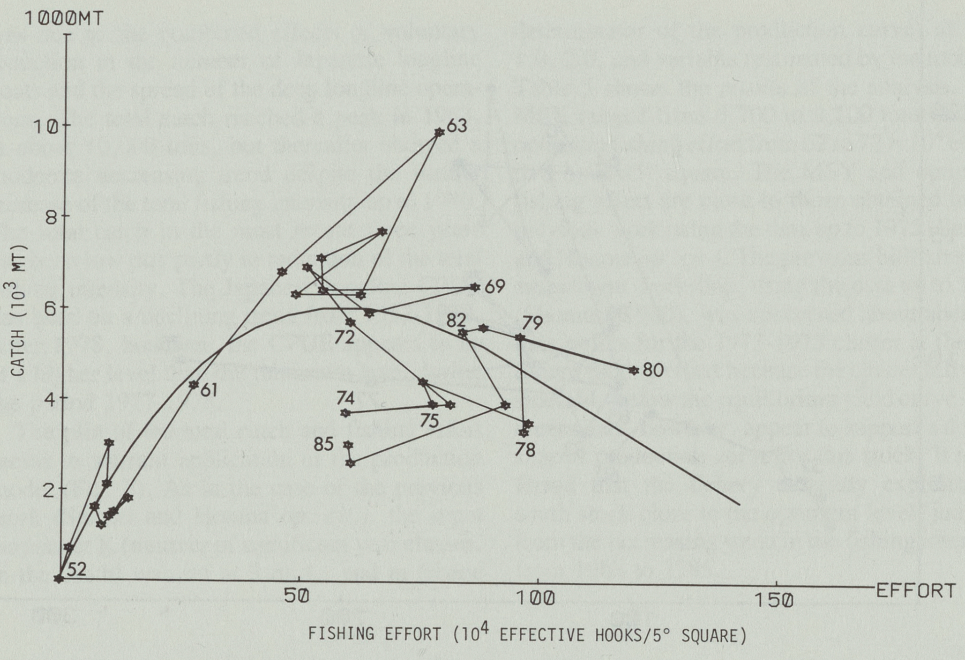

Figure 8. Catch and fishing effort relationship for the south stock of Pacific striped marlin. An equilibrium curve fit in the case of k = 3 and m = variable (1.42) is shown.

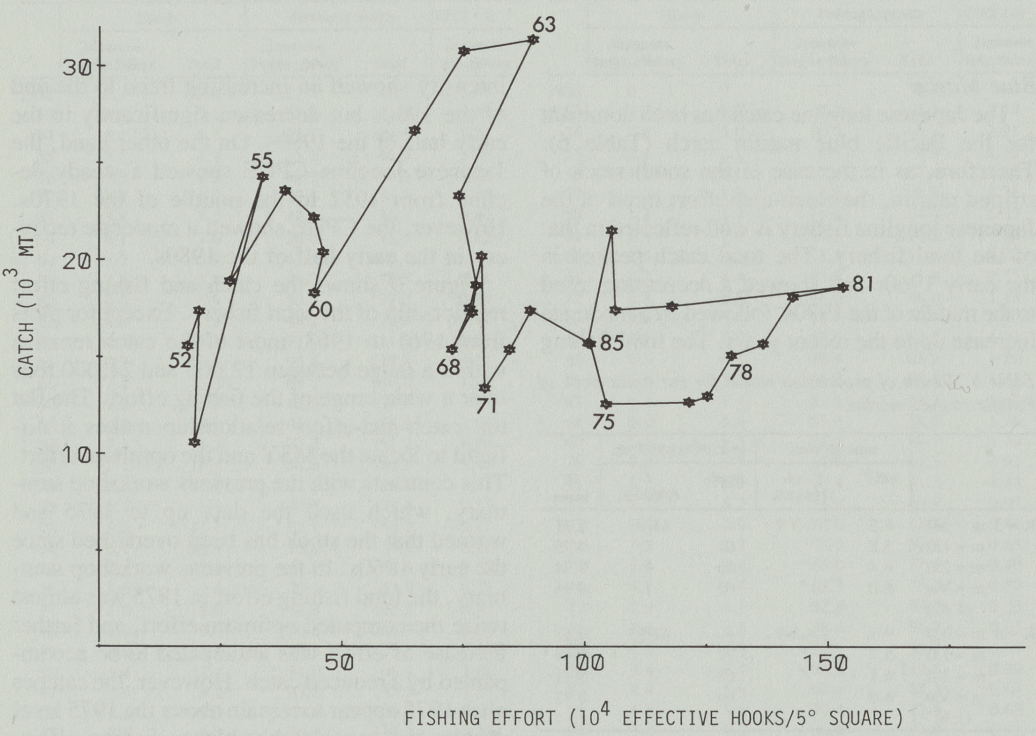

Figure 9. Catch and fishing effort relationship for the Pacific blue marlin stock.

obtained on the stock status of blue marlin from this type of analysis. Increase of the fishing effort beyond 1975 (or 1985) level, however, would not be favorable to the blue marlin stock because the CPUE showed a further decline.

Black Marlin

The Japanese longline fishery has had a major share in the total black marlin catch to the end of the 1960s (Table 7). After that, the Taiwanese fishery appears to be the most important for the black marlin catch. Except for the 1950s, the total catch fluctuated without any apparent trend. In contrast, the total fishing intensity has been on an increasing trend but showed a sharp decline in the 1980s. This change resulted in a steady decline in CPUE, measured through the Japanese longline fishery, throughout the period 1952-1985. The decline appears to be slight or stabilized from the latter half of 1970s to 1985.

Similar to the blue marlin stock, except for the 1950s, the total catch has been sustained at a level between 2,000 tons and 4,000 tons over a wide range of fishing effort (Fig. 10). Therefore, it was not possible to obtain useful information on the qualitative stock status of the black marlin. Plots of the catch and fishing effort suggest that several historical changes have occurred in the fishing. A spark of catch in the early period of the 1950s came mostly from the Japanese longline fishery in the western equatorial Pacific, especially from the Coral Sea and in the East China Sea. The Japanese catch of black marlin decreased significantly from the mid-1970s, due to the spread of foreign 200-mile FCZs and introduction of deep longlining. The decrease of black marlin catch by the Japanese longline fishery appears to be offset by the Taiwanese catch. These long-term changes would make it difficult to apply a single production curve to the whole data series. Although the total black marlin catches appear to have been sustained over a wide range of fishing effort, the stock should be monitored more care-

Table 6. Catch (10^3 tons), fishing intensity (10^4 effective hooks/5° square) and CPUE on the Pacific blue marlin stock, 1952-1985.

	Catch		Fishing intensity		CPUE × 10^{-1}
	Japanese longline fishery	Total	Japanese longline fishery	Total	Japanese long. fishery
1952	15.4	15.5	18.4	18.6	8.37
53	17.2	17.3	20.8	20.9	8.27
54	10.2	10.5	19.4	20.0	5.26
55	23.6	24.2	33.0	33.9	7.15
56	18.1	18.8	26.3	27.2	6.88
57	22.9	23.5	37.6	38.5	6.09
58	21.6	22.1	43.5	44.4	4.97
59	19.8	20.3	45.2	46.3	4.38
60	17.7	18.2	43.5	44.5	4.07
61	26.2	26.6	63.9	64.9	4.10
62	29.9	30.7	73.1	75.1	4.09
63	29.4	31.3	83.5	89.2	3.52
64	21.2	23.2	67.5	74.0	3.14
65	16.6	18.6	69.4	77.6	2.39
66	16.0	18.6	66.8	77.6	2.40
67	13.8	17.2	61.5	76.8	2.24
68	12.2	15.3	58.2	72.7	2.10
69	14.1	17.4	61.7	76.3	2.29
70	16.8	20.1	65.6	78.7	2.56
71	9.8	13.3	58.1	79.5	1.69
72	11.5	15.3	63.4	84.5	1.81
73	12.6	17.3	64.7	88.7	1.95
74	11.8	15.6	76.3	101.0	1.55
75	8.2	12.5	68.4	104.2	1.20
76	7.6	12.6	73.0	121.2	1.04
77	7.4	12.9	71.8	124.9	1.03
78	8.3	15.0	71.8	129.9	1.16
79	8.9	15.6	78.0	136.4	1.14
80	9.8	18.0	77.8	142.4	1.26
81	9.6	18.5	79.5	152.7	1.21
82	10.3	17.5	69.2	117.7	1.49
83	9.4	17.3	57.7	106.1	1.63
84	11.6	21.4	57.2	105.3	2.03
85	8.8	15.6	56.4	100.5	1.56

Table 7. Catch (10^3 tons), fishing intensity (10^4 effective hooks/5° square) and CPUE on the Pacific black marlin stock, 1952-1985.

	Catch		Fishing intensity		CPUE × 10^{-2}
	Japanese longline fishery	Total	Japanese longline fishery	Total	Japanese long. fishery
1952	1.8	1.8	25.8	25.8	6.98
53	3.2	3.2	30.6	30.6	10.46
54	4.7	5.4	49.7	56.7	9.46
55	3.7	5.4	25.6	37.3	14.45
56	4.4	6.5	39.6	57.8	11.11
57	5.1	6.4	91.5	114.4	5.57
58	2.6	4.5	67.0	117.9	3.88
59	1.9	3.1	50.0	81.1	3.80
60	1.9	2.7	53.1	74.4	3.58
61	2.3	3.2	64.9	88.9	3.54
62	2.9	4.1	88.8	127.0	3.27
63	2.6	3.2	105.4	129.7	2.47
64	2.2	2.8	83.0	105.4	2.65
65	3.4	4.0	110.8	129.7	3.07
66	3.2	3.7	130.3	151.1	2.46
67	2.0	2.8	75.0	104.3	2.67
68	1.6	2.4	74.2	110.6	2.16
69	2.1	2.5	81.7	101.3	2.57
70	1.6	2.2	75.4	101.0	2.12
71	1.8	2.7	67.7	102.2	2.66
72	1.4	3.4	55.7	133.6	2.51
73	1.6	3.7	76.1	174.9	2.10
74	1.2	3.0	76.2	197.2	1.57
75	1.0	2.8	68.1	198.2	1.47
76	0.7	2.5	58.1	266.9	1.20
77	0.8	2.7	69.7	222.3	1.15
78	0.9	3.6	73.8	289.3	1.22
79	1.0	4.3	81.0	340.1	1.23
80	1.0	3.1	99.7	307.1	1.00
81	0.9	3.0	110.1	371.0	0.82
82	0.9	2.6	96.3	284.2	0.93
83	0.7	2.9	68.4	276.2	1.02
84	0.7	2.3	65.2	196.2	1.07
85	0.7	2.3	60.8	200.1	1.15

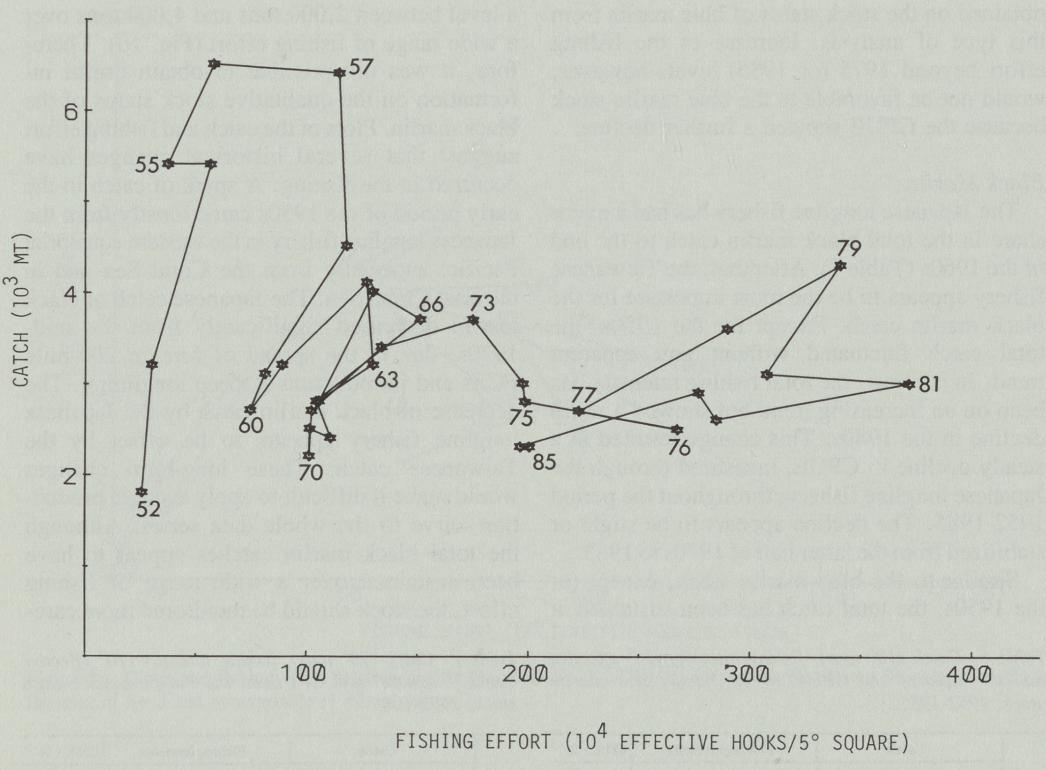

Figure 10. Catch and fishing effort relationship for the Pacific black marlin stock.

fully in view of the consistent decline of the CPUE.

Summary

Status of the stocks of striped, blue, and black marlins in the Pacific was briefly assessed by analyzing overall catch and fishing effort relationship, using Japanese longline statistics as a base of the calculations. The present study updated, for the period from 1976 to 1985 for three species, the basic overall catch and fishing effort statistics used in the previous work (Shomura 1980).

Effective fishing effort was calculated by the Honma method (Honma 1974), with minor modification so as to take into account differences in fishing efficiency between deep and regular longline operations. A Pacific-wide unit stock was assumed for blue and black marlins while north and south stocks, separated approximately by the equator, were hypothesized for striped marlin. Effective fishing effort for the three species showed a more or less similar trend of further increase from 1975 to the 1980-81 period, followed by a decrease to the 1984-1985 period, returning to the level of 1974-1975 period. This reduction of effective fishing effort was accelerated by the spread of deep longlining.

As anticipated in the previous study, further increases of fishing effort beyond the 1974-1975 level did not increase the catches for all stocks under consideration. The present study revealed, however, that the catches of the 1974-1975 period appeared still sustained under the highest effort level attained around the 1980-1981 period.

The north and south stocks of Pacific striped marlin appear healthy. There is more uncertainty about the stock status of the blue and black marlins. The catches from the two stocks are sustained over a wide range of fishing effort, except for an early period of the exploitation. These circumstances imply that the stocks are able to support a sophisticated level of fishery exploitation. However, more careful monitoring of these two stocks is necessary since the catch rate showed a steady declining trend although it is stable or recovering in recent years.

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Status of Pacific Billfish Stocks

Robert A. Skillman

With the increasing worldwide importance of recreational fishing for billfishes, interest in the biological status of billfish populations has heightened. The first attempt at assessing their status on a Pacific-wide basis occurred at a workshop held in Honolulu, Hawaii, U.S.A., in 1977 (Shomura 1980). Indian Ocean billfish stocks were included in a 1979 stock assessment workshop held in Shimizu, Japan (FAO 1980).

This chapter updates the assessments of Pacific billfish by including both more recent data and logbook data from Korea and Taiwan. Additional objectives include determining whether Korean and Taiwanese data can be used to extend the assessment beyond 1980, when Japanese logbook data ceased being published, identifying gaps in the data, and pinpointing other shortcomings in the analyses of individual species. Species included in the study are Indo-Pacific blue marlin *(Makaira mazara),* black marlin *(M. indica),* striped marlin *Tetrapturus audax),* Indo-Pacific sailfish *(Istiophorus platypterus),* shortbill spearfish *(T. angustirostris),* and swordfish *(Xiphias gladius).*

The present assessments are based on a generalized production model (Pella and Tomlinson 1969), analysis of catch rates derived from logbooks, and total catch estimates from volumes of the *Yearbook of Fishery Statistics* published by the FAO (1947-). Steps in the analysis involve (1) selection of probable stock boundaries; (2) selection of index areas for computing estimates of abundance; (3) computation and comparison of these catch rates based on Japanese, Korean, and Taiwanese logbook data; (4) estimation of effective fishing effort; and (5) computation and evaluation of surplus production model estimates of maximum sustainable yield (MSY) and optimum fishing effort at MSY (f_{opt}). The following sections describe the data sources and the steps listed above.

Data Sources

Two basic types of data are used in this study, namely catch-and-effort statistics and estimates of total catch. The former is derived from logbooks and includes estimates of nominal fishing effort and the resulting number of billfishes caught by the Japanese, Korean, and Taiwanese tuna longline fisheries. Unpublished Japanese data for 1952-1961 were provided by the Far Seas Fisheries Research Laboratory (7-1, 5 Chō me Orido, Shimizu 424, Japan) in 1977, whereas data for 1962-1980 are based on logbook statistics published by the Fisheries Agency of Japan, Research Division. Korean data for 1966-1970 and 1975-1982 are based on statistics published by the National Fisheries Research & Development Agency. Lastly, Taiwanese data for 1967-1979 and 1983-1984 were taken from computer listings provided by the Institute of Oceanography, National Taiwan University (P.O. Box 23-13, Taipei, Taiwan, Republic of China).

The second type of data, namely total catch data in metric tons (t), is derived from volumes of the *Yearbook of Fishery Statistics* published by the FAO. These data are the official, total catch statistics submitted by the nations for their flag vessels. Statistics for the early years used in this study are actually modifications of the FAO statistics made during the 1977 workshop (Shomura 1980). Participants agreed upon species estimates of total Pacific catch for 1952-1963, when FAO statistics were not presented by ocean, and also of separate estimates for blue and black marlins for a few years when FAO published only combined statistics. The total

catch data used in this study appear in Table 1 and include updates from recent FAO yearbooks.

Stock Structure

To determine stock structure and to select index areas for computing stock abundance, basic information on the distribution and stock structure of each of these billfishes was extracted from Nakamura (1974) and Shomura (1980). This information was supplemented with annual and quarterly plots of the geographical distribution (5° rectangles) of Japanese catch, fishing effort, and catch rates (simple ratios of annual catches and fishing effort) (unpubl. data).

Indo-Pacific Blue Marlin

In the Pacific Ocean, blue marlin appear to consist of a single stock centered about the Equator, with the poleward extent of its distribution varying seasonally (Shomura 1980). The highest catch rates typically occur along the Equator; high catch rates also occur with varying degrees of regularity in subtropical waters. Thus, I selected five potential index areas (Fig. 1): area 1 has the longest history of higher catch rates and substantial fishing effort, area 4 has a less consistent temporal distribution of fishing effort, and areas 2, 3, and 5 have substantial catches and catch rates in some years. Based on catch rates by index areas (Fig. 2), I selected area 1 for computing indices of stock abundance, although areas 3 or 4 could also have been used. Catch rates for the entire Pacific and area 2 (not shown in Figure 2 to remove clutter) are low throughout the time series and show little or no trend.

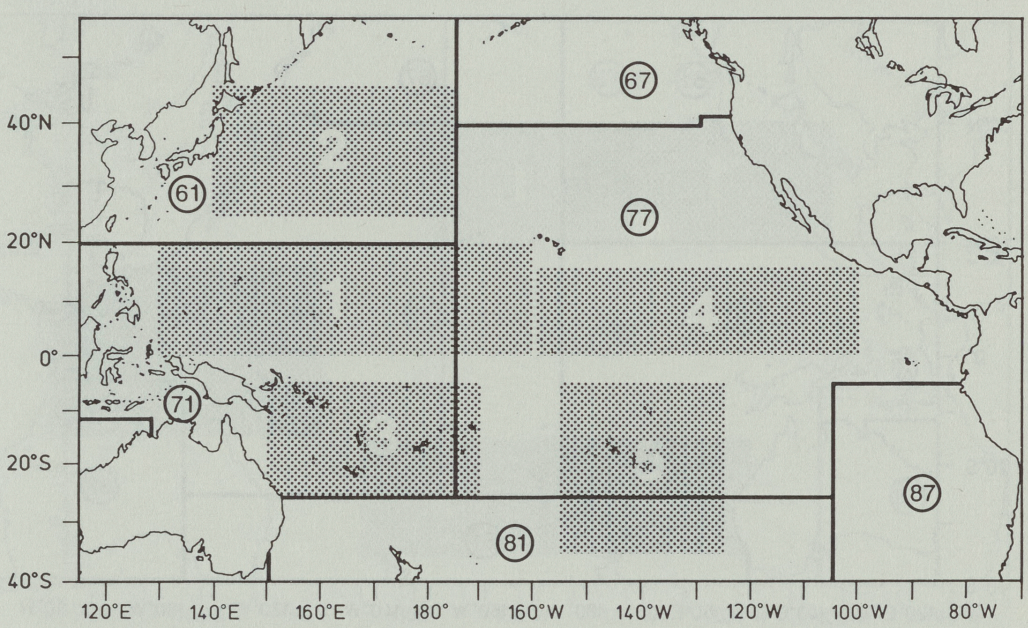
Black Marlin

The stock structure of black marlin is not known but may comprise several stocks on the eastern and western rims of the Pacific (Shomura 1980), and there may be exchange between Pacific and Indian Ocean stocks (FAO 1980). The distribution of catch rates suggest a single stock centered off Australia, with the species being widely distributed but not consistently abundant elsewhere. Hence, I set up four potential index areas (Fig. 1) and compared their catch rates (Fig. 2). Based on these results, and for lack of clear evidence to the contrary, I assume a single, Pacific-wide stock for the remainder of this analysis and use area 2 as the stock index area.

Table 1. Total Pacific billfish catch (in metric tons) by species and FAO statistical areas, 1952-85. Data were derived from Shomura (1980) and volumes of the Yearbook of Fishery Statistics *published by the Food and Agriculture Organization of the United Nations.*

			Striped Marlin						Sailfish–Shortbill Spearfish					
Year	Blue marlin	Black marlin	61	71	77	81+87	All	Swordfish	61+67	71	77	81	87	All
1952	15,525	1,806					4,992	11,339						2,000
1953	17,250	3,188					3,789	11,689						3,300
1954	10,519	5,370					7,256	13,392						2,400
1955	24,190	5,379					7,075	16,485						3,300
1956	18,770	6,466					7,724	12,584						3,200
1957	23,500	6,376					7,150	16,243						2,800
1958	22,106	4,548					8,999	21,341						3,400
1959	20,275	3,081					8,986	19,663						3,400
1960	18,155	2,721					7,362	23,409						5,000
1961	26,581	3,170					10,084	24,286						4,800
1962	30,743	4,066					13,685	14,604						6,800
1963	31,344	3,180					16,944	14,113						7,900
1964	23,233	2,805					23,480	10,112	3,700		2,100	300	0	6,100
1965	18,885	4,039	12,700		11,700	1,600	26,000	12,949	3,600		9,100	0	100	12,800
1966	18,588	3,729	9,600	1,900	9,500	3,500	24,500	14,601	3,800	1,200	5,900	0	100	11,000
1967	17,233	2,836	8,300	1,700	10,800	1,600	22,400	15,649	3,300	1,400	6,900	0	100	11,700
1968	15,283	2,362	10,200	1,200	11,400	2,700	25,500	15,230	4,800	400	6,100	0	1,200	12,500
1969	17,427	2,546	11,900	900	8,900	2,900	24,600	18,934	4,900	300	6,900	0	700	12,800
1970	20,115	2,207	11,000	1,300	11,100	2,400	25,800	15,727	3,700	300	4,900	0	200	9,100
1971	13,342	2,674	12,300	700	11,200	2,100	26,300	11,037	2,500	500	4,900	200	200	8,300
1972	15,300	3,424	3,800	800	7,600	2,000	14,200	11,029	2,000	800	5,700	0	100	8,600
1973	17,285	3,400	6,600	1,000	5,900	1,700	15,200	15,100	2,800	900	4,900	0	100	8,700
1974	15,594	2,665	6,287	591	5,846	2,176	14,900	14,622	1,959	539	5,153	57	29	7,737
1975	12,546	3,613	9,258	560	5,426	1,959	17,203	16,409	3,373	362	3,620	117	32	7,504
1976	12,611	3,086	5,676	328	5,961	2,034	13,999	19,322	2,708	614	10,187	92	69	13,670
1977	13,819	2,737	7,420	207	3,353	1,312	12,292	18,318	5,079	346	5,797	119	50	11,391
1978	15,998	3,796	8,472	691	2,507	1,263	12,933	18,032	3,778	851	5,425	40	31	10,125
1979	16,656	3,530	5,749	717	4,776	2,541	13,783	19,179	2,805	322	4,351	87	40	7,605
1980	19,029	2,120	7,454	904	5,134	2,292	15,784	16,616	5,209	499	1,525	78	66	7,377
1981	19,378	2,136	6,748	901	3,715	3,493	14,857	18,937	3,760	566	566	139	26	5,057
1982	15,398	1,712	4,822	1,194	5,193	2,964	14,173	18,649	2,603	507	2,259	241	58	5,668
1983	14,317	2,216	4,355	664	3,949	1,715	10,683	18,770	3,687	436	1,828	116	78	6,145
1984	16,149	1,527	5,980	589	3,141	980	10,690	18,161	2,988	382	1,270	108	42	4,790
1985	12,609	1,572	6,766	1,108	2,307	850	11,031	19,468	3,050	493	704	13	14	4,274

BLUE MARLIN



BLACK MARLIN

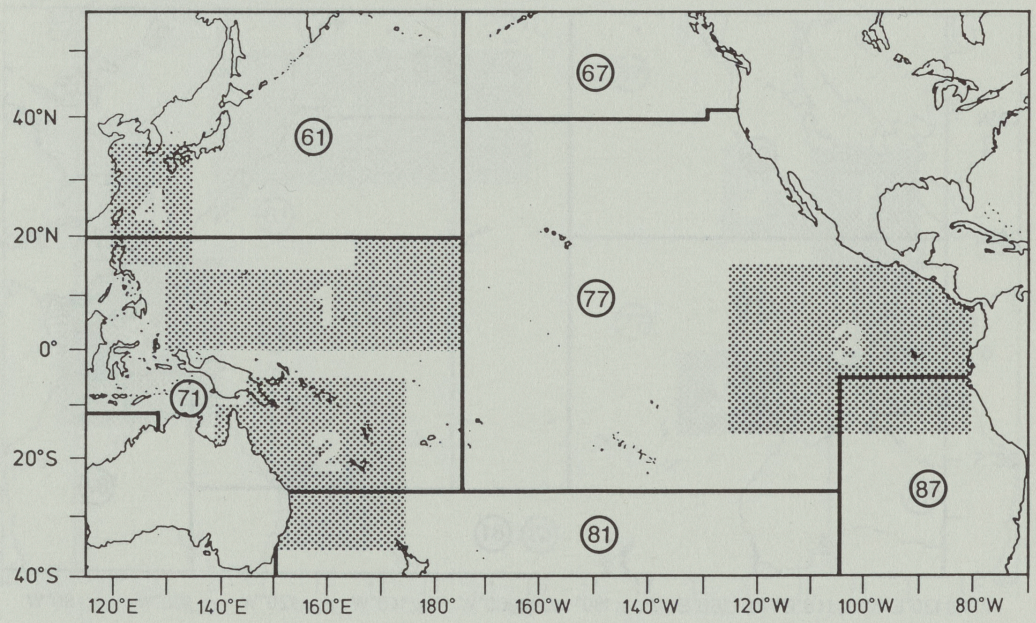
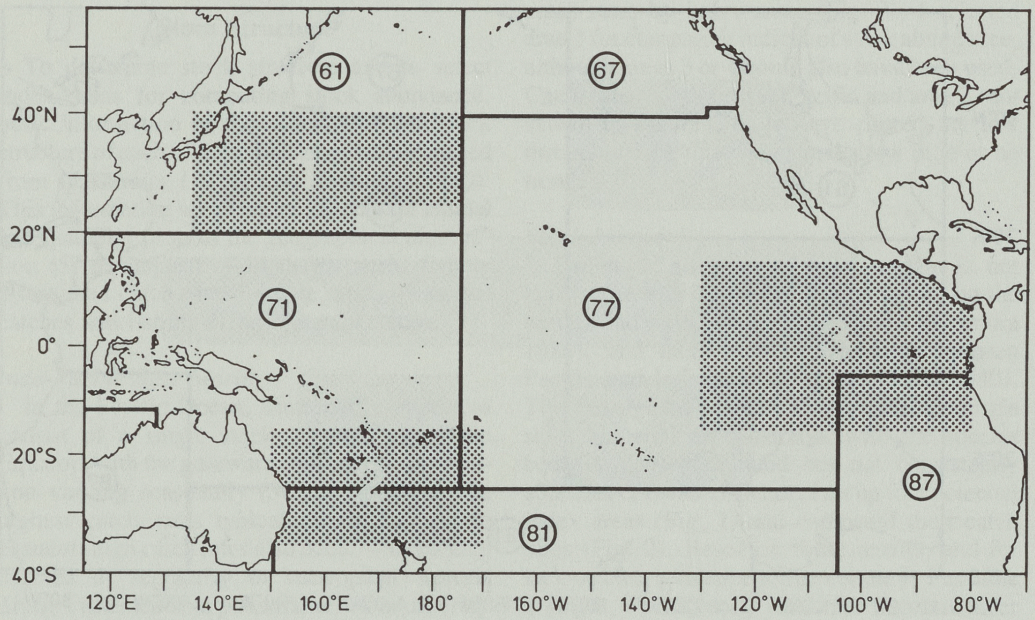
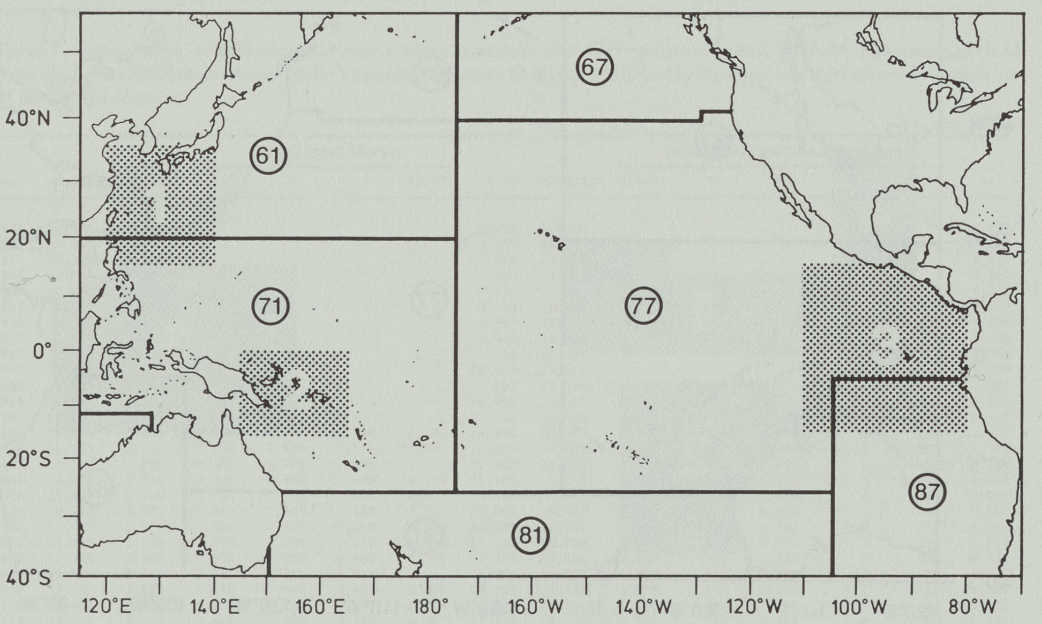


Figure 1. Index areas and Food and Agriculture Organization of the United Nations statistical areas.

STRIPED MARLIN



SAILFISH



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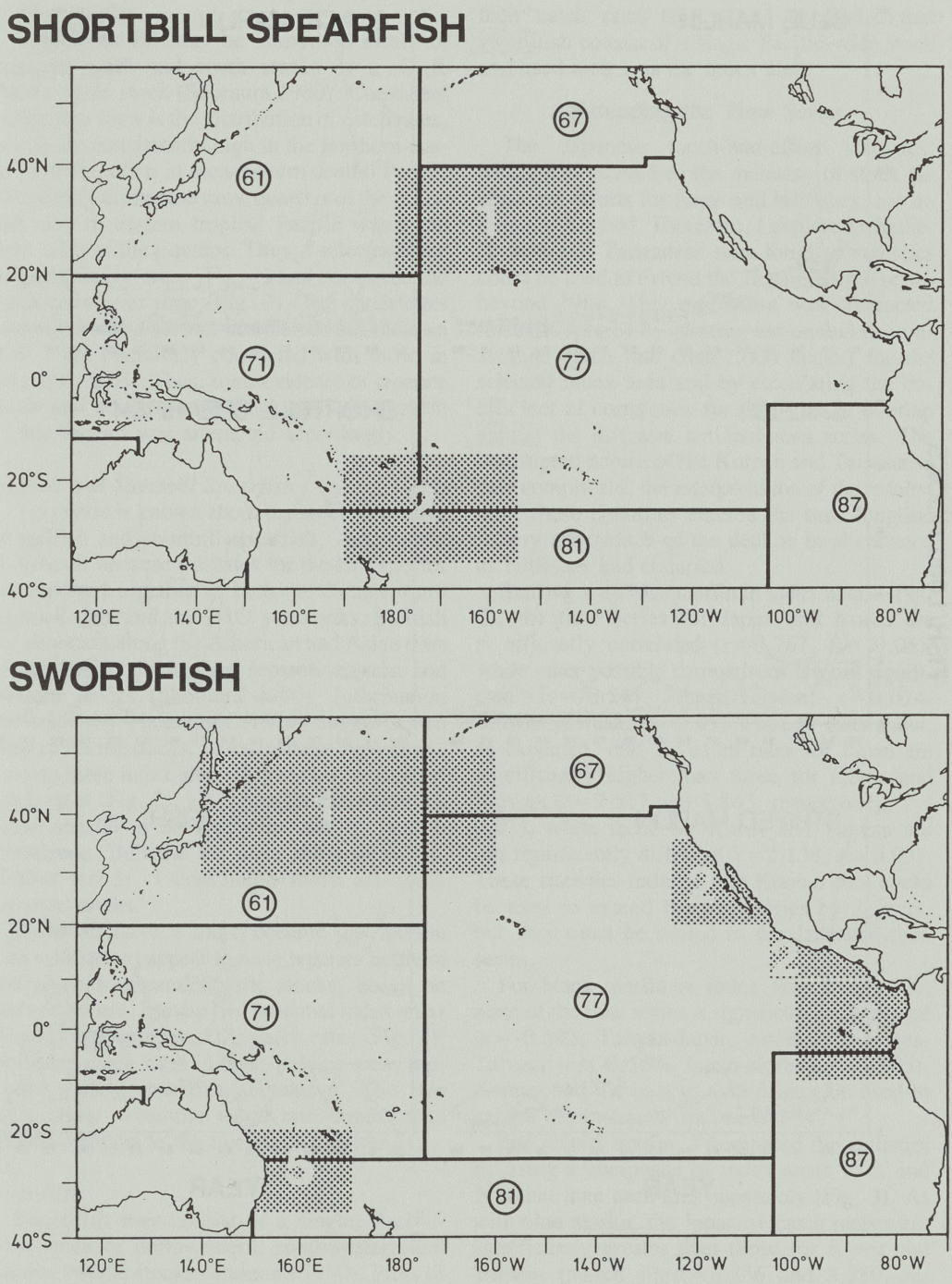

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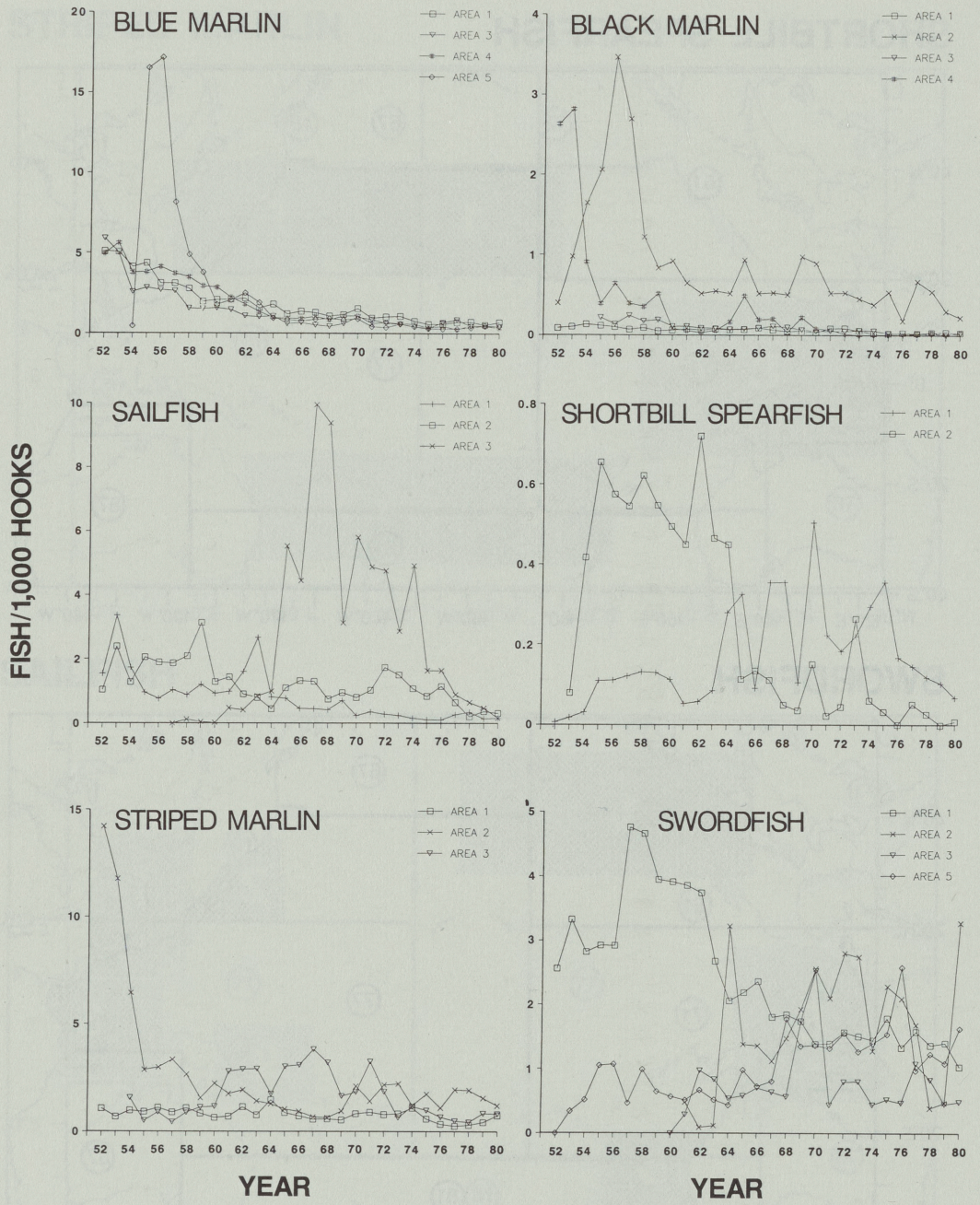

Figure 2. Historical trends in billfish catch rates by index areas.

Striped Marlin

Striped marlin may be composed either of separate north and south stocks or a single Pacific-wide stock (Shomura 1980). Consistent with either view is the distribution of catch rates, which are consistently high in the northern central Pacific, often in the southern central Pacific (frequently during the same quarters of the year), and also in eastern tropical Pacific waters on both sides of the Equator. Thus, I selected three potential index areas (Fig. 1) and compared the catch rates over time (Fig. 2). The catch rates in areas 1 and 2 are not correlated, but those in area 3 are negatively correlated with those in area 2 ($P < 0.05$). Thus, some evidence of separate north and south stocks exists, and assessment of this species was attempted accordingly.

Sailfish and Shortbill Spearfish

Very little is known about the stock structures of sailfish and shortbill spearfish. Assessment is difficult because statistics for the two species are reported together in both the distant-water logbook data and the FAO yearbooks. Sailfish are abundant along the American and Asian rims of the Pacific, indicating separate eastern and western stocks (Shomura 1980). Information presented by Nakamura (1974) suggests two western Pacific stocks. Based on these hypotheses, I set up three index areas (Fig. 1) and compared catch rates (Fig. 2), assuming the catch rates in these coastal areas represent mostly sailfish abundance. Because the three areas show dissimilar trends, I concluded there are three separate stocks.

Spearfish have a more oceanic distribution than sailfish and appear to have separate northern and southern central Pacific stocks. Based on this conjecture, I set up two potential index areas (Fig. 1) and compared the catch rates (Fig. 2), assuming catch rates in these pelagic areas represent mostly spearfish abundance. The two areas show dissimilar catch rate trends, thus lending support to the two-stock hypothesis.

Swordfish

Swordfish may consist of a single, Pacific-wide stock or northwestern, southwestern and eastern Pacific stocks (Shomura 1980). Plots of catch-rate data suggest a single stock centered in the northwest Pacific that extends over the entire Pacific at lower densities; higher catches occur in some coastal fisheries. After setting up four potential index areas (Fig. 1) and comparing their catch rates (Fig. 2), I concluded that swordfish consist of a single Pacific-wide stock and used area 1 as the index area.

Extending the Time Series

The Japanese catch-and-effort statistics, which have served as the mainstay of stock assessment efforts for tunas and billfishes, are no longer published. Therefore, I explored whether Korean and Taiwanese tuna longline statistics could be used to extend the Japanese time series beyond 1980. This evaluation was conducted for each species by plotting the annual ratio of average catch rate (fish/1,000 hooks) for the selected index area and by calculating the coefficient of correlation for the years of overlap among the different national data series. The interrupted nature of the Korean and Taiwanese data complicates the interpretation of the results; also, these countries entered the tuna longline fishery after much of the decline in abundance of billfishes had occurred.

Starting with blue marlin in index area 1 (Fig. 3), the time series for Japan and Korea are significantly correlated ($r = 0.767$, $P < 0.05$), while other possible comparisons are not significant ($r = -0.241$, Japan-Taiwan; $r = 0.024$, Taiwan-Korean; $P > 0.05$). Paired *t*-tests show, as expected, that the catch rates for Japan are significantly higher than those for Korea and Taiwan ($t = 7.517$ and 3.863, respectively; $P < 0.01$), while those for Korea and Taiwan are not significantly different ($t = 2.138$, $P > 0.05$). These statistics indicate that Korean data could be used to extend the time series by 2 years, but they must be scaled to the Japanese time series.

For black marlin in index area 2 (Fig. 3), none of the time series is significantly correlated ($r = -0.502$, Taiwan-Japan; $r = -0.756$, Korea-Taiwan; $r = -0.568$, Japan-Korea; $P > 0.05$). Korean and Taiwanese data cannot be used to extend the Japanese time series.

For striped marlin, I compared the statistics by using a composite of index areas 1, 2, and 3, rather than each area separately (Fig. 3). As with blue marlin, the Japanese catch rates were significantly greater than those for Korea and Taiwan (paired *t*-test = 6.836 and 8.289, respectively; $P < 0.01$), but were correlated with those for Taiwan ($r = 0.654$, $P < 0.05$) rather than Korea ($r = 0.040$, $P > 0.05$). Thus, the Taiwanese data could, once scaled, be used to extend the time series; however, a 3-year gap

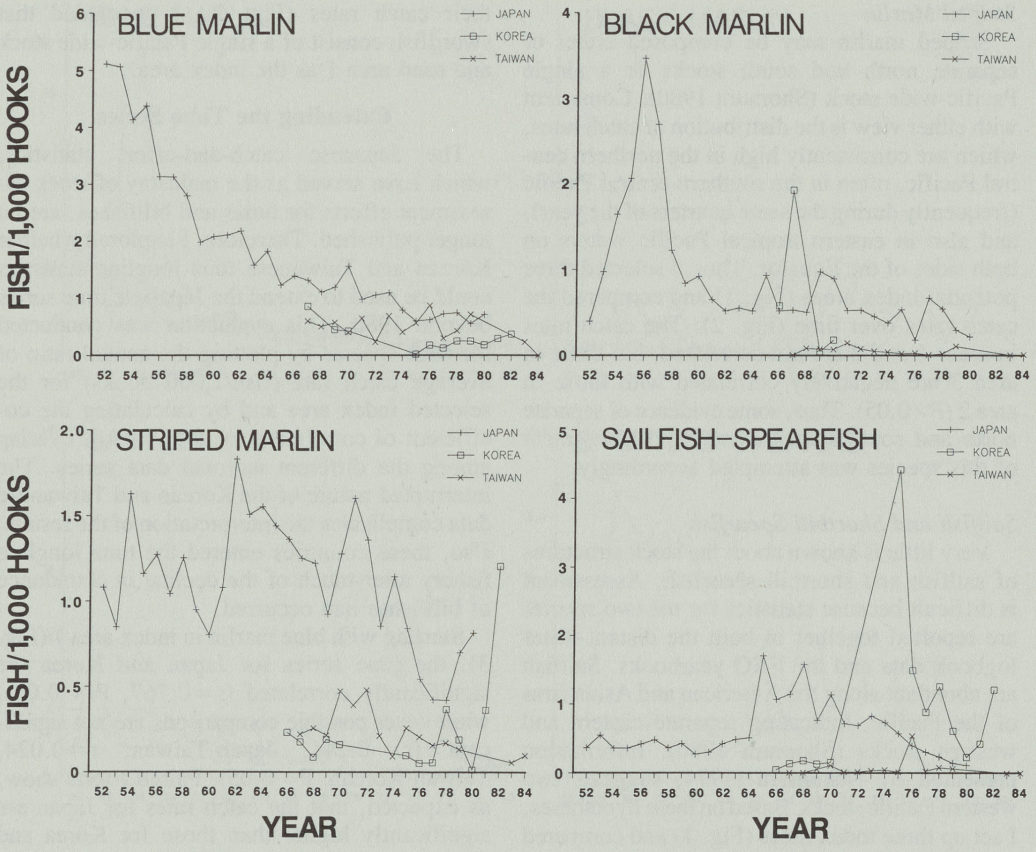

Figure 3. Comparison of Japanese, Korean, and Taiwanese catch rates of blue marlin (index area 1), black marlin (index area 2), striped marlin (index areas 1, 2, and 3 combined), and sailfish-shortbill spearfish (entire Pacific).

exists between the end of the Japanese time series and the last two Taiwanese data points.

For sailfish and spearfish combined, the catch rate trends are quite dissimilar (Fig. 3), indicating that neither Korean nor Taiwanese data can be used to extend the Japanese time series.

For swordfish in index area 1, Taiwan reported catches for only 1 year, and the Japanese and low Korean catch rates are quite dissimilar. For a composite of all the potential index areas, none of the time series is correlated ($r = 0.377$, Japan-Korea; $r = 0.211$, Japan-Taiwan; $r = 0.654$, Korea-Taiwan; $P > 0.05$). Thus, Korean and Taiwanese data cannot be used to extend the time series.

Based on these results, the Korean and Taiwanese data for billfishes are not of sufficient quality to extend the published Japanese time series. A couple of significant correlations out of 16 comparisons is not sufficient to convince me that these data can be used to assess the status of any of the billfish stock.

Some Conversions Before Fitting the Production Model

The most straightforward situation in fitting the surplus production model is when one has a complete time series of estimates of fishing effort and the resultant weight of fish caught. This situation rarely, if ever, exists. While reasonably good estimates of the weight of the various billfishes caught are available, catch-and-effort statistics are available for only the generally predominant fishing method (tuna longline) and then effectively for only one of the nations (Japan). Thus, I followed the common procedure of computing catch rates from available catch-and-effort statistics, dividing

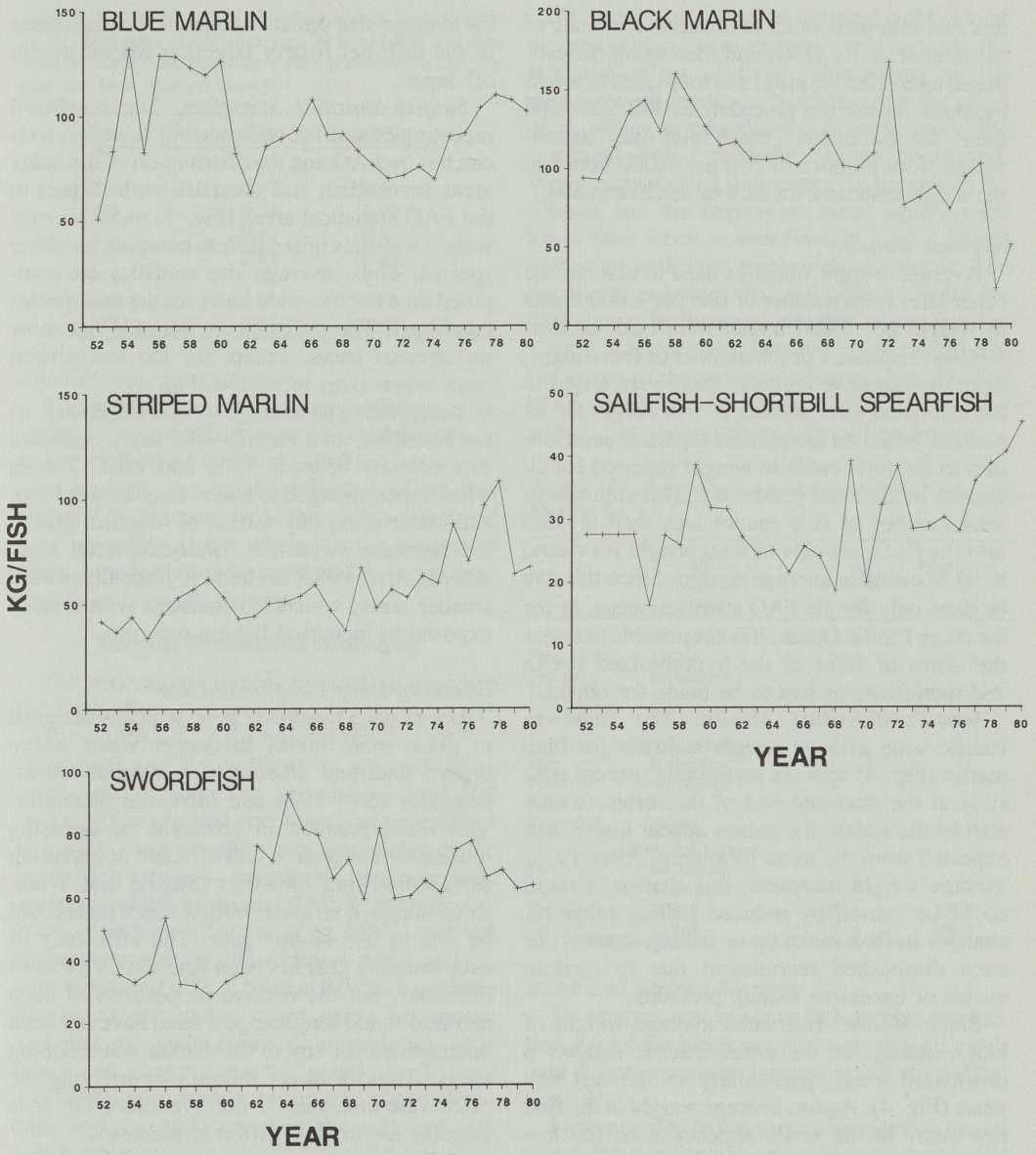

Figure 4. Billfish average weight statistics.

this rate into total catch to obtain an estimate of the total effective effort and then using the estimated total effective effort and total catch to assess the stock. To use this procedure for billfishes (and tunas, for that matter), catch rates must be converted from number of fish per 1,000 hooks to the weight units used for the total catch estimates.

Average Weights

Average weight statistics used to convert the catch rates from number of fish per 1,000 hooks to weight per 1,000 hooks were calculated as follows. Estimates of the number of fish caught, from the Japanese logbook data, were raised to the estimated total number of fish caught for all nations, based on the percent Japanese contribution to the total catch in weight reported for all nations in the FAO yearbooks. This estimate of total number of fish caught was then divided into the FAO estimate of total weight (in metric tons) to estimate average weight. Since this can be done only for the FAO statistical areas, or for the entire Pacific Ocean, it is not possible to assess the status of some of the hypothesized stocks and modifications had to be made for others.

Indo-Pacific Blue Marlin. The trend in Pacific-wide average weight statistics for blue marlin (Fig. 4) appears reasonable, except possibly at the start and end of the series. At the start of the series, the values appear lower than expected from the trend following. After 1975, average weight increases; this change in trend could be caused by reduced fishing pressure, changes in fleet make up or fishing strategy, or even diminished recruitment due to random events or excessive fishing pressure.

Black Marlin. Estimated average weight of black marlin for the entire Pacific follows a downward trend, particularly in the last few years (Fig. 4). Again, average weight in the first few years in the series appears to be too low given the remainder of the series.

Striped Marlin. For striped marlin, the average size statistics using Pacific-wide data (Fig. 4) show an increasing trend throughout the history of the fishery. Since this trend is the opposite of that expected for heavily exploited stocks, the reliability of the statistics and the validity of any production model fit to the data are suspect. Such a trend might be due to changes in fleet make up or fishing strategy, mismatching (in time) of the logbook and total catch data, or underreporting of tuna longline logbook data. Suzuki (pers. commun.) notes that changes in the average size statistics coincide with increases in the drift-net fishery targeting striped marlin off Japan.

Sailfish-Shortbill Spearfish. The combined reporting of sailfish and shortbill spearfish total catches by FAO and the distribution of the index areas for sailfish and spearfish with respect to the FAO statistical areas (Fig. 1) make average weight statistics impossible to compute for either species. Thus, average size statistics are computed on a Pacific-wide basis for the two species combined. The statistics are variable but show no obvious trend, except for the last several years when sizes increased (Fig. 4).

Swordfish. The average weight trend (Fig. 4) for swordfish on a Pacific-wide basis exhibits a discontinuity between 1961 and 1962. This is when Japan changed to a new statistical system, and about when day setting of longline gear in the Japanese swordfish fishery replaced night setting. After 1962, the trend is gradually toward smaller sizes, which is consistent with a stock exposed to increased fishing pressure.

Effects of Deep Longlining Gear

Use of deep longlining gear, which is designed to place more hooks in deeper water where bigeye tuna and albacore are most abundant, began in about 1974 and increased thereafter. This trend resulted in problems in assessing billfishes. The gear is less efficient at capturing surface-dwelling billfishes (Suzuki and Warashina unpub.), so lower billfish catch rates could be due to use of this gear. The efficiency of deep longling gear has been determined for most billfishes, but the relative proportions of deep and traditional longline gear used have not been documented for any of the distant-water fishing fleets. Thus, a direct means of correcting the catch rate statistics is not available, but it is possible to simulate different scenarios.

Assuming that deep longlining gear was first introduced into the fishery in 1974, and that its use increased slowly at first and then more rapidly by 1980, I examined two hypothetical situations. In the first, the efficiency of the total longline fishery for catching billfish was reduced by 25% by 1980 and, in the second, by 50% (Table 2). These relative efficiency factors were divided into the annual catch rate statistics, and then these adjusted abundance estimates were used, along with the corresponding adjusted estimates of effective effort, to fit the surplus production model.

Table 2. Two scenarios for the effect of deep longline gear on the catch rates of billfishes; i.e., 25% and 50% less than what the catch rates would have been if traditional longline gear had been used exclusively.

Year	25%	50%
1973	1.0	1.0
1974	0.97	0.95
1975	0.94	0.90
1976	0.91	0.85
1977	0.88	0.80
1978	0.84	0.70
1979	0.80	0.60
1980	0.75	0.50

Equilibrium Approximation

To approximate equilibrium conditions, estimated effective effort was adjusted according to the method of Gulland (1969). That is, for each species, the annual effective effort was replaced by the average of that year's effort and k - 1 preceding years, where k is the number of years a year-class was reckoned to contribute significantly to the fishery.

Surplus Production Modeling

The generalized surplus production model in the form of

$$Y/EF = (MSY/f_{opt})\ [m + (1\text{-}m)\ (EF/f_{opt})]^{\,1/(m-1)}$$

(Wetherall and Yong 1984) — where Y/EF = catch rate or index of abundance (kg/1,000 hooks), EF = adjusted effective effort (in millions of hooks), and m = the shape parameter of the production curve — was fit by nonlinear least squares to obtain estimates of MSY, the optimum level of fishing effort at (f_{opt}) MSY, and the shape parameter (m). In addition, MSY and f_{opt} were estimated with m fixed at 0 (which assumes that catch rate versus effort curve is concave and that the yield curve is asymptotic), at 1 (since m cannot exactly equal 1, I used 1.0000001; the catch rate curve is slightly concave and the yield curve is skewed) and at 2 (catch rate curve is a straight line and the production curve is symmetrical).

Indo-Pacific Blue Marlin

For blue marlin, I used running averages of 2, 3, and 4 years on the effective effort statistics to approximate equilibrium conditions. Duplicate effort values were added to the beginning of the time series to preserve the number of years used in the assessment. However, since the results differed little, only that for the 3-year effort averaging is presented (Table 3). Although the gear effectiveness adjustments shifted the post-1974 data points from the extreme right side of the production curve progressively more to the left, the effect of these adjustments on the parameter estimates was much less than the effect of m. When m was allowed to vary freely, the nonlinear fitting procedure rarely converged. When convergence did occur, the parameter estimates and the regression mean square were lower than when m was fixed at 1 or 2. When m was set at 0, convergence did not occur. The parameter estimates differed little (‹1,900 t for 25% gear effectiveness) whether m was fixed at 1 or 2, undoubtedly because of the relatively flat shape of the production curve (Fig. 5). The MSY appears to be about 20,000 to 24,000 t with f_{opt} at about 100 to 140 million hooks.

Table 3. Surplus production model parameter estimates for blue marlin, $k = 3$.

m	MSY (in metric tons)	f_{opt} (in millions of hooks)	Regression mean square
	Unadjusted		
Free 0.3	19,246	70.9	240.9
Fixed 0.0	No solution		
Fixed 1.0	21,734	105.6	361.2
Fixed 2.0	23,757	141.4	360.6
	25% Gear Efficiency		
Free	No solution		
Fixed 0.0	No solution		
Fixed 1.0	21,589	103.0	365.6
Fixed 2.0	23,468	134.6	365.0
	50% Gear Efficiency		
Free	No solution		
Fixed 0.0	No solution		
Fixed 1.0	21,478	103.1	370.6
Fixed 2.0	23,265	133.5	370.1

Black and Striped Marlins

No attempt was made to fit a surplus production model for black marlin because total catch data did not vary with increasing effective effort (Fig. 6).

I attempted to fit the surplus production model ($k = 4$ for equilibrium averaging) to the striped marlin data, but no solution could be found for any of the shape parameter or gear efficiency adjustments. The production data are too linear for the model to be successfully fit (Fig. 6).

Sailfish-Shortbill Spearfish

Effort was smoothed over 2 years to approximate equilibrium conditions. The gear efficiency adjustments have a substantial effect on the parameter estimates, increasing both the estimates of MSY and f_{opt} (Table 4). The production curve (Fig. 5) suggests that the composite

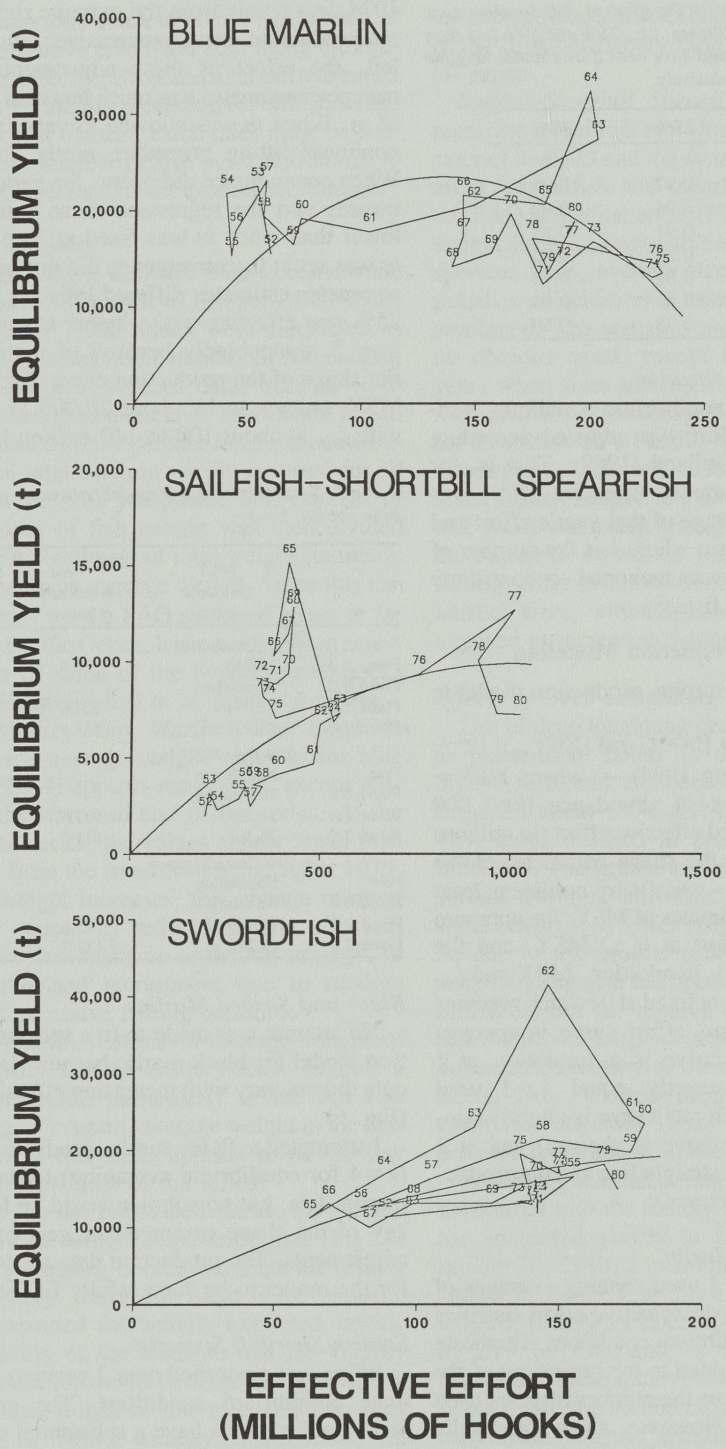

Figure 5. Surplus production using 25% gear efficiency model curves with observed (smoothed and adjusted data for blue marlin ($k=3$, $m=2$), sailfish-shortbill spearfish ($k=2$, $m=2$), and swordfish $k=1$ and 4, $m=2$).

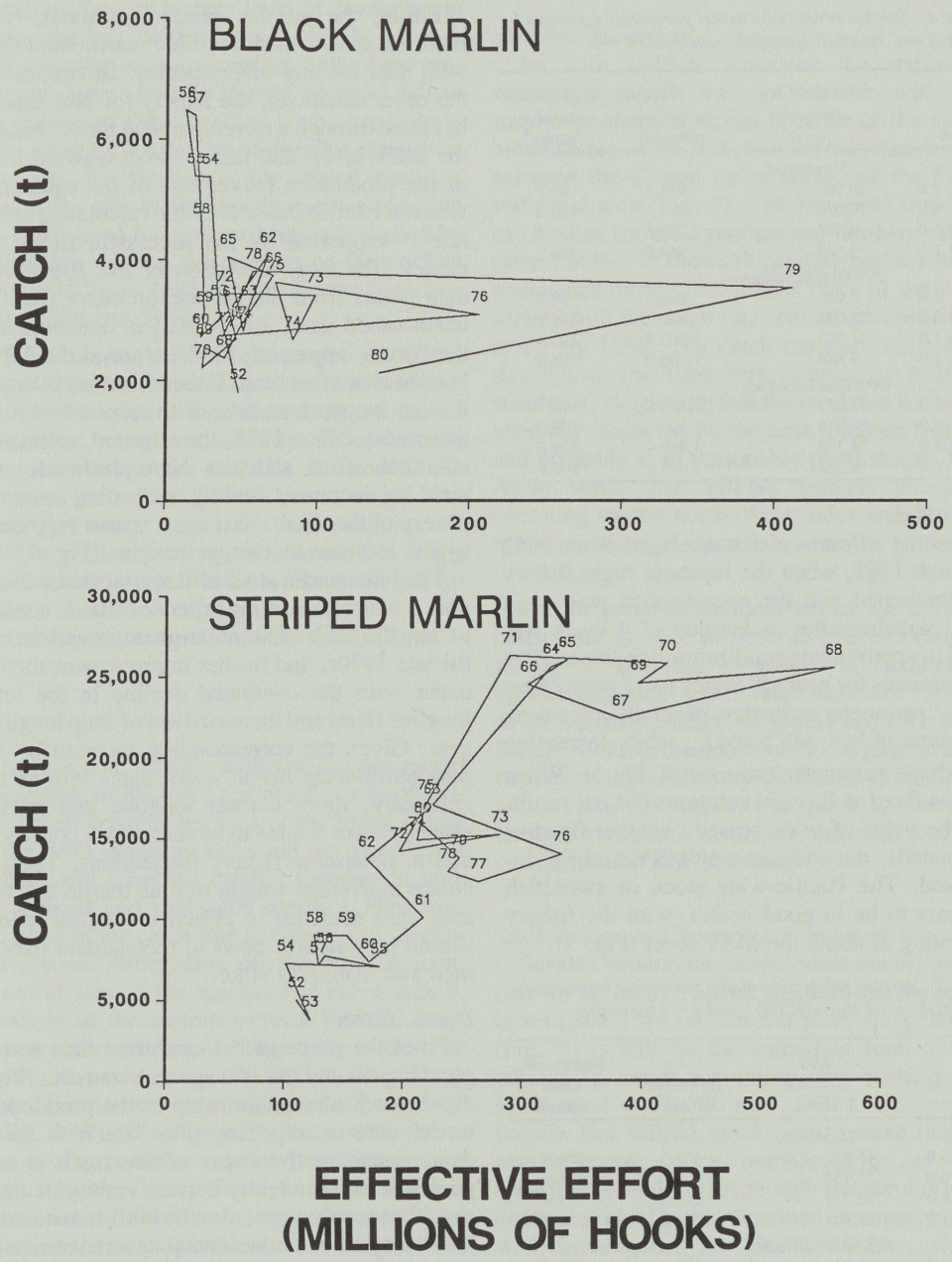

Figure 6. Production model data for black and striped marlins, assuming 25% gear efficiency.

fishery for these two species is still on the ascending limb.

Table 4. Surplus production model parameter estimates for sailfish and shortbill spearfish combined, k=2.

m	MSY (in metric tons)	f_{opt} (in millions of hooks)	Regression mean square
	Unadjusted		
Free 3.0	10,361	954.7	69.5
Fixed 0.0	19,010	∞	104.0
Fixed 1.0	9,903	1,253.6	104.1
Fixed 2.0	9,608	954.8	104.2
	25% Gear Efficiency		
Free 3.0	9,686	876.3	70.9
Fixed 0.0	26,091	∞	106.3
Fixed 1.0	11,585	1,562.3	106.3
Fixed 2.0	9,884	1,000.0	106.4
	50% Gear Efficiency		
Free 3.0	13,492	1,322.9	72.7
Fixed 0.0	68,919	∞	109.0
Fixed 1.0	24,708	3,860.4	109.0
Fixed 2.0	16,762	1,907.5	109.0

Swordfish

Fishing effort was not averaged from 1952 through 1961, when the Japanese night fishery predominated and the average size was small (Fig. 4); thereafter, a k value of 4 years was used to approximate equilibrium conditions. The adjustments for gear efficiency had a large effect on the parameter estimates, generally increasing estimates of both MSY and f_{opt} while decreasing the shape parameter estimate (Table 5). When m was fixed at 0, valid solutions did not result. As the value of m decreased (whether fixed or estimated), the estimates of MSY and f_{opt} increased. The Pacific-wide stock of swordfish appears to be in good health, with the fishery operating at about the MSY level (Fig. 5).

Table 5. Surplus production model parameter estimates for swordfish, k=1 through 1961 and k=4 thereafter.

m	MSY (in metric tons)	f_{opt} (in millions of hooks)	Regression mean square
	Unadjusted		
Free 3.0	17,852	167.5	224.0
Fixed 0.0	27,952	∞	335.9
Fixed 1.0	18,219	219.5	335.9
Fixed 2.0	17,703	176.8	336.0
	25% Gear Efficiency		
Free 0.3	24,274	588.9	227.0
Fixed 0.0	34,677	∞	340.6
Fixed 1.0	20,583	274.4	340.6
Fixed 2.0	19,266	206.7	340.6
	50% Gear Efficiency		
Free 0.4	27,217	574.8	230.6
Fixed 0.0	43,126	∞	345.8
Fixed 1.0	23,765	335.6	345.8
Fixed 2.0	21,543	239.1	345.8

Discussion

Indo-Pacific Blue Marlin

Fitting the surplus production model was more successful with the blue marlin data than with data for any other species. In contrast to the other situations, the fishery for blue marlin has gone through a developmental phase, passed the MSY level, and tested the downward limb of the production curve. Use of the equatorial western Pacific index area for calculating catch rate is supported by the successful fit of the model. The large deviation of the 1963-1964 data points from the production curve (for the unsmoothed data, 1962-1963) is notable since the fishery apparently first exceeded the MSY level at about that time. If these data are in error, it is an inopportune time with respect to fitting the model. Since 1975, the adjusted, estimated effective effort statistics have declined, and yield has increased slightly, indicating some recovery of the stock. This view is also supported by the increase in average weights (Fig. 4).

The blue marlin stock still appears to be overfished, with more effort expended than is needed to take the MSY. The situation improved during the late 1970s, and further improvement should occur with the continued decline in the tuna longline fleets and increased use of deep longline gear. Given the corresponding increase in the tuna purse-seine fleets, which catch billfish incidentally, more current longline and purse-seine data are needed to monitor stock condition and to determine fishery interactions. The increase in average weight of blue marlin and the estimated decrease in effective longline effort should be welcome news to recreational fishermen and managers alike.

Black Marlin

From the shape of the catch-rate time series plot (Fig. 2) and the average size statistics (Fig. 4), the lack of a relationship in the production model data is surprising (Fig. 6). With these data, assessing the status of the stock is not possible. Independently derived catch-rate data should be sought since, even by billfish standards, black marlin are an incidental or rare species in the tuna longline fisheries, and catch rate computed from these statistics may not be a good index of abundance. In addition, total catch statistics may be underestimates because of continuing problems in the separation of black and blue marlins in the statistics submitted to FAO (Suzuki pers. commun.).

Striped Marlin

The fishery, assuming a single Pacific-wide stock, reached its highest level of development during the late 1960s and early 1970s, but it is still operating on the ascending limb of the production curve. Post-1974 data seem to fall in the middle of the ascending limb, particularly after adjusting for the use of deep longline gear. Thus, the Pacific fishery for striped marlin is apparently still in the development stage, and the MSY level has not yet been approached by the fishery. In fact, the pressure on the stock in the late 1970s to 1980 appears to have been less than in the late 1960s.

The increasing trend in the average size statistics (Fig. 4) casts doubt on the quality of the statistics and may have led to the failure to fit the surplus production model successfully. Independently obtained average-size statistics are needed both to assess the resource under the assumption of north and south stocks and to investigate the validity of the assessment assuming a single Pacific-wide stock. Data on the drift gill-net fishery conducted off Japan need to be made available and incorporated into the analysis.

Sailfish

As indicated above, surplus production model assessment of the three presumed stocks of sailfish is not possible because of the broad nature of the FAO statistical areas and the reporting of sailfish and spearfish catches together in both the logbook and total catch statistics. However, the trend in the catch-rate statistics (Fig. 2) provides some information on the probable condition of one of the stocks. For index area 3, which is in the eastern tropical Pacific, catch rates were low during the beginning of the time series, increased drastically in 1966, suggesting that the resource was "discovered" commercially, then declined possibly because of excessive fishing pressure in prior years or a loss of interest by the fishing fleets. If the decline was due to fishing, then the fishery had a substantial effect on the density of the stock during the last 10 to 15 years of the time series, resulting in the stock now being at a much reduced level. The catch-rate trends for the other stocks do not show much variation over time and probably would not result in valid surplus production model estimates even if the data were available. If these sailfish stocks are to be assessed, fishery statistics specific to this species and these stocks must be obtained.

Shortbill Spearfish

As with sailfish, assessing the status of shortbill spearfish was not possible with the surplus production model because of the combined nature of the statistics and the relationship between the chosen index areas and the FAO statistical area (Fig. 1). The historical trend of catch rates for the hypothesized northern stock (area 1 in Fig. 2) shows fluctuating but increased abundance during the middle years of the time series, with the catch rate returning to previous levels by 1980. The catch rates are quite low throughout the time series, even by billfish standards, suggesting that the stock has not been seriously impacted by the tuna longline fishery and probably is in reasonably good shape. The Asian squid drift gill-net fishery, although operating mostly north of the index area for the northern stock of spearfish, may be of some concern.

For the assumed southern stocks, the trend in catch rates is more difficult to interpret (area 2 in Fig. 2) but may be related to changes in species targeting. Catch rates increased rapidly as the Japanese entered the south Pacific longline fishery for albacore and remained high until they began leaving the fishery (Skillman 1975), after which catch rate dropped precipitously. The real trend in abundance of this assumed stock is not clear from the available statistics.

Sailfish-Shortbill Spearfish Combined

Surplus production model assessment, using data for the entire Pacific, suggests that the combined fishery for sailfish and shortbill spearfish (Fig. 5) is still on the ascending limb of the production curve but closely approaching the MSY level of 10,000 to 12,000 t. This result implies that sailfish stocks are to some degree overharvested, since overharvesting of the spearfish is doubtful. Although the surplus production model fits the combined data reasonably well, investigating the 1965-1975 data, which deviate in a consistent fashion from the production model curve, might be informative.

Swordfish

The surplus production model assessment of this fishery indicates that the assumed, single Pacific-wide stock is being harvested below

MSY (Fig. 5). As indicated by the average weight statistics (Fig. 4) and the production curve, this fishery apparently has had three phases. First, a night-set longline fishery for small fish predominated from 1952 to 1961, and the fishery expanded, nearly reaching the estimated MSY. With the introduction, in 1962, of the day-set longline fishery, which harvests larger fish, catches exceeded the former production levels even as total effective effort declined through 1965. After that, fishing effort expanded, and the catches moved up the ascending limb of the production curve, but at a level comparable with those in the first period (1956-1961) for smaller fish.

Since deep longline gear has less effect on swordfish catches than any other billfish catches (Suzuki and Warashina unpub.), the production model for unadjusted data may be more appropriate. Since this choice leaves the data for the last few years out on the right limb of the production curve, the estimates of MSY and f_{opt} are reduced to about 18,000 t and 200 million hooks, respectively, and the fishery seems to be at about the point of MSY and f_{opt}. To improve this assessment, detailed information on fleet composition, fishing strategy, and fishing gear, including deep longline gear, must become available.

General

The status of most billfishes in the Pacific seems to have improved from 1975 to 1980, although the blue marlin is still being overharvested and swordfish and sailfish may be approaching that condition.

Japan is ceasing to release its data for use by the international community and is reducing the size of its tuna longline fleet. Korean and Taiwanese data have thus become more important for the assessment of billfish and tuna stocks. Consequently, the quality of Korean and Taiwanese tuna longline statistics must be improved, for example, by increasing fleet coverage and by accurately recording billfish catches. Because assessing some of the billfish stocks seems possible by employing the index area method, I propose that judicious selection of index areas would allow the international fishery community to continue monitoring the status of billfish stocks without compromising Japan's position in international and bilateral management negotiations.

Nations should strive to obtain separate statistics for blue and black marlins as well as for sailfish and shortbill spearfish. Coverage of coastal fisheries for swordfish could also be improved. Statistics from gill-net fisheries, whether billfishes are targeted or incidentally caught, and from purse-seine fisheries need to be made available.

The FAO fishery statistical areas for reporting total catches may be appropriate for coastal pelagic and demersal resources, but must be revised to facilitate assessment of offshore pelagic resources like billfishes and tunas. In the Pacific, area 77 is particularly in need of subdivision into Northern and Southern Hemisphere areas. Also the boundary between areas 61 and 71 in the western Pacific may be too far north for a reasonable division of north and south pelagic stocks.

For all billfish species, size data must be collected directly from landings, compiled, and published. Doing so will place the assessments on much sounder ground and allow evaluation of some of the unexpected trends seen for average weights calculated from total catch and logbook data, for example, for striped marlin.

Modeling of the potential effects of deep longline gear indicates that incorporating data on this development would improve the fit and accuracy of the production models. Hence, the distant-water tuna longline nations should be encouraged to modify their data collection procedures accordingly and to publish the resulting data.

Summary

Surplus production model assessments were completed, using geographic index areas for computation of indices of stock abundance, for Pacific stocks of blue marlin, swordfish, and sailfish-shortbill spearfish combined. No attempt was made to fit the model to black marlin data, nor to sailfish and spearfish separately, because of data problems, and no satisfactory fit could be obtained for striped marlin. Average weight statistics, computed from reported logbook numbers and FAO weight statistics, did not always follow expected trends, particularly for striped marlin for which the computed average weight increased throughout the history of the fishery. The effect of deep longline gear was simulated using assumed 25% and 50% reductions in the effective catch rates for billfishes. In general, the status of billfish stocks seems to have improved in the latter part of the time

series, from the late 1970s to 1980s, as estimated total effective effort declined, particularly under the assumption of declining overall gear effectiveness with the more widespread use of deep tuna longline gear.

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Robert A. Skillman received a B.S. in biology from Bradley University, an M.S. from Iowa State University (fisheries management), and a Ph.D. in 1968 from the University of California at Davis (zoology, specializing in resource management). Joining the Honolulu Laboratory, National Marine Fisheries Service, NOAA (then called the Bureau of Commercial Fisheries, U.S. Fish and Wildlife Service), conducted research on pelagic species, e.g., stock assessment of South Pacific albacore, forecasting skipjack tuna catches in Hawaii, and age and growth of blue and striped marlins. In 1979-80, worked with FAO in the South China Sea Fisheries Development and Coordinating Programme to help establish what is now called the Indo-Pacific Tuna Development and Management Programme. Returning to the National Marine Fisheries Service in 1980, became leader of the Fishery Management Research Program, which is the primary interface with the Western Pacific Regional Fishery Management Council. In 1987, he returned to the area of pelagic species research with the creation of a research program directed at pelagic species under the Magnuson Fishery Conservation and Management Act, namely mahimahi (dolphin), wahoo, billfishes, and sharks.

Panel 2 Discussion

Lawrence Benjamin, Caribbean Fishery Management Council:

I want to ask this question in the most diplomatic way. Has there been any increase in the willingness to supply you with landing figures — the data you need to compute, so that you may be sure the data you get are as accurate and as reliable as possible? Are you confident that the figures you have to work with are the best you can get?

Peter Miyake, International Commission for the Conservation of Atlantic Tunas:

It's a good question, but very difficult to answer. In the case of swordfish, I'm confident that the data base is very solid. When we are talking about billfish in general, however, I'm not too confident. The best available data at present for the Atlantic are in the ICCAT data base, but there's much room for improvement. As Raymon Conser has already mentioned, we recently started a program to get better sampling and better estimates of total catches. As far as we know, the data we are using in the Atlantic are the best estimates we have, though still insufficient.

Norman Bartoo, National Marine Fisheries Service:

As far as the Pacific goes, there are so many different fisheries and so many different countries reporting statistics that you could almost make a case-by-case description of each one. By and large, for the high-seas longline fleets, you have the Japanese data, of the best quality, with the most difficulty perhaps being with the Korean statistics. They are sometimes difficult to interpret. Some coastal nations have no statistics, like Chile for its swordfish fleet. Some coastal nations are reporting excellent data, like the U.S. for its swordfish fishery.

Gordon Broadhead:

All you have to do is look at some of the graphs; the one for blue marlin tells you right away that the data are poor. It's a pretty serious matter, particularly concerning a couple of species that seem to be in need of more critical analyses.

Gregor Cailliet, Moss Landing Marine Laboratories, California:

I have several questions that have to do, first, with the surplus production model. I see it being fit to some data sets and not others. I've looked at a lot of published papers on fishery biology that have been fit to worse data sets. Were there statistical reasons why some data were fit and some weren't?

Robert Skillman, National Marine Fisheries Service:

I didn't attempt to fit the surplus production model to black marlin data, as I indicated. In my opinion it would be a failure; statistically, you just wouldn't be able to do it. I attempted to do it with the striped marlin data, depending on which particular parameters I was using in the model. I used a non-linear fitting procedure. I let m, the shape parameter, vary freely as well as forcing it through 0, 1, or 2. Generally speaking, when the model was allowed to vary freely, or you tried to force it to 0, no solution was possible. The program either blew up or it would estimate some statistics, especially fishing effort, essentially at infinity and give you a maximum sustainable yield for it. It just didn't work.

Gregor Cailliet:

I understand that. My feeling with those models is that all you have to do is get one or two data points that are over the hump and then your model fits fine. I think what happened in your case was that you didn't yet have one that was over the hump, which leads me to my second question. Why aren't there similar curves for species that are already either severely decimated or where the related fishery has already caused

a production or a population decrease? In other words, why don't we see surplus production models for similar or the same species, perhaps in the Atlantic, where you could then compare the two and see where you might want to think about setting MSY, even with a curve that hasn't gone over the hump? Is my question clear?

Ramon Conser:

In actuality, surplus production models have been fitted for Atlantic species. In the period that I described, roughly from the mid-1970s through the early 1980s, they were actually fitted on an annual basis, in this process of the data base evolving. I think the critical question with surplus production models is not so much whether you have data points that are over the hump that will allow you to identify the right side of the curve. I think the critical point is whether you believe that you have a reasonable index of abundance, and that you can measure the effective effort. Lacking confidence in that, I think it's pointless to fit these models, because you can get some very strange results that mean absolutely nothing. So, I'm not sure that it's a question of whether the surplus production model is appropriate for these animals as much as the fact that we just don't have the right data elements to drive it. An awful lot has been done in this area recently and some of the limiting assumptions that were a bit of a problem for billfishes in the past, such as the instantaneous response to recruitment without time lags, no longer need to be assumed. There may be some potential for the future use of these models, especially some of the more advanced models — again, provided that the data sources coming into them can be upgraded.

Gregor Cailliet:

Robert Skillman, I can't tell from looking at your slides whether there really was a significant increase or decrease in the average weight of a fish. Some of those fish are 15 or 20 years old and the variation might be extremely high. When you see a curve going up, is it really going up, or is there enough variation to blow that up?

Robert Skillman:

I guess I glossed over that too much; I do not have variance estimates. I took the available longline logbook estimates of numbers caught and I expanded those where necessary. Some of the Korean and Taiwanese data are not expanded, and ended up as the total estimates of the numbers of whatever species were taken in the Pacific, or in the areas that I was using. I then took the FAO statistics, either for the total Pacific, or for different areas, and simply divided those two numbers into each other. It's a very crude average based on two separate data sets, and estimating total catch, one in number and one in weight.

Gregor Cailliett:

What it suggests to me is that we should look into more detailed data on age and size composition.

Robert Skillman:

We need market sampling to get specifics on that. It's very clear in the case of striped marlin.

Gary Sakagawa, National Marine Fisheries Service:

Peter Miyake, you mentioned that the swordfish data base for the Atlantic seemed to be solid, and I wonder whether we are talking about different levels. You show a growth curve for both sexes combined but, as we know, there's sexual dimorphism in many of the billfishes. That fact confuses again the situation with respect to getting catch by age. Then we get to the question of whether we have information on sex by size, a very important component. Do we have it, or don't we?

Peter Miyake:

You're right, we are talking about two different levels. The first level, for which the data base is rather solid, is the catch, effort, and size — but not by sex. We have some limited data showing the sexual dimorphism, and we recognize that we should separate and analyze these data by sex. We haven't done that because of the inadequacy of the size data by sex.

Gary Sakagawa:

My next question is to all of the panel. Do you feel sincerely that the data base that's available to you is adequate? I bring this point up again and try to emphasize it because you're apparently depending on the Japanese longline data base, all of which ends in 1980. We are here in 1988, which raises the question, why didn't you extend that information further to the current situation? Second, we need sex informa-

tion, length-frequency information, age and growth, perhaps some information on stock, and so on, including information on fishing effort. Some needs are for fishery statistics, and some are for biological information that's collected secondarily to fishing operations. Is it the general opinion that perhaps we're satisfied?

Ramon Conser:

I had very much hoped that the thrust of my talk would be that we are not satisfied. The only real results that I showed today in terms of assessment results were those done in 1982. The reason for that of course is that the data that we have available in order to do what we need to do have actually degraded since that time, this specifically being the information on the depth of fishing. I hope the message is that we're not satisfied.

I think, having said that our available data have degraded a bit, we need to indicate that there has been some progress in some of the areas, at least in the Atlantic. We do have data from the Japanese that is continued beyond 1980 in the Atlantic, but not in the Pacific. We are continuing to get data on a regular basis and, in the case of the marlins, the fact is that the Japanese catch is now such a small percentage of the overall total that we cannot rely on it to the extent that we did, earlier, for such things as indices of abundance. That situation has been further complicated by this deep longlinging effect that makes the index totally impractical based on those data. Overall, if you look at the progress that has been made at ICCAT, for example, since the early 1970s, we're in considerably better shape in some ways in terms of the quality of the catch and effort data. In some other ways, because of changed targetting in the fishery, we're worse off. Matters are moving in both directions. We should recognize that progress has indeed been made in some of these areas.

Edwin Irby, Florida Department of Natural Resources:

What's the quality of data we're getting from the American longline tuna fishery? In some cases it's existed now for about eight years, and I'd hate to come back ten years from now for a billfish symposium and still see only Japanese, Korean, and Taiwanese data being used for stock assessment.

Peter Miyake:

We are getting a good chunk of data from the U.S. longline fisheries. As a matter of fact, they supply a major part of the data base for the swordfish.

Edwin Irby:

What about tuna? We have a substantial longline fishery now in the Atlantic that is directed to tuna. I'm asking specifically relative to tuna, not the swordfish data.

Peter Miyake:

We are getting those data as well. I didn't mention it because it wasn't on billfish, but we have been getting those data for the last two or three years. on a regular basis.

Bradford Brown, Southeast Fisheries Center, National Marine Fisheries Service:

Edwin Irby mentioned that some of the fisheries have existed for eight or ten years. It's only within the last two years that we have gotten rather comprehensive data that apply to the tuna aspect of the fishery. When we look at the billfish aspect of the fishery, then, since many billfish are not landed through standard commercial channels, the data on the billfish are poor for the U.S. longline fishery. We don't know the number of releases and the mortality among them. Also, in some areas the billfish are considered property of the crew and do not enter the normal sales statistics. So, the billfish data are minimal. For swordfish, the data are good for a significant period of years; for tuna, data are good at present, but it's only just beginning.

Jeannette Foster, Audubon Magazine:

I'd like representatives from the Pacific and from the Atlantic to answer this: What specifically are your agencies doing, or what are other agencies doing to get those data?

Peter Miyake:

For the Atlantic, we recognize the fault in the data, particularly for billfish. Last year, we started an Enhanced Billfish Research program, based on private funding. Using this trust fund, we started a comprehensive data search for historical and artisanal catches, and started port sampling where the majority of billfish are landed. We are sending some observers on the boats to look into the make-up of the catches of billfishes, and we started a tagging program.

Ziro Suzuki:

For the Pacific, especially for the Japanese longline fishery, we have been compiling catch and effort statistics on an annual basis, and we have the data up to 1985. As a scientist, this is a personal opinion, the data should be available to all the scientists and other interested people. However, though this is the scientists' wish, the administrators in Japan have a different view, so the publication of data after 1980 has stopped. Nonetheless, we have been compiling the data, both catch and effort statistics, and we also have some size measurement data. We have initiated an improvement of size measurement data, both to increase the measurements and asking the commercial fishermen on board the boats to measure carefully. I know nothing about other longline fleets operating in the Pacific.

Steven Berkeley, South Atlantic Fishery Management Council:

Peter Miyake, considering the dramatic changes that we've seen in fishing gear and methods in the longline fishery, including innovations in electronic and navigation gear and satellite imagery, and all the other recent developments in the ability to locate fish, what if anything is being done to incorporate these changes into a standardized unit of effort?

Peter Miyake:

Some of the catch-per-unit-of-effort data that we use has some adjustment for expansion of the area and time, or season. However, as I understand it, none of these catch-per-unit-of-effort data fully incorporate all these changes, particularly the efficiency of fishing grounds. Attempts have been made to standardize into certain units, but I don't think it's fully incorporated. That's one of the reasons that I have some reservations when using these catch-per-unit-of-effort data in whatever model and seeing the results as conclusive.

Steven Berkeley:

Robert Skillman, considering the general lack of agreement in CPUE trends among the Korean, Taiwanese, and Japanese longline indices, you concluded that you wouldn't want to extend the Japanese data beyond the years you have, using those other indices. To me, it suggests that maybe none of them are adequate indices of abundance, since they don't show the same trends. Why would you assume that one is good and the others are not?

Robert Skillman:

Good question. I guess the only basis for that is that we have used the Japanese statistics for some time in our stock assessment attempts. While there are certainly problems with that, in changing of targetting and the deep longline gear, we have at least some feeling that in the past it's worked pretty well for us. It has yielded assessments that are credible, seem logical, and appeal to us. We compare with other statistics and see if they deviate; they do. It's a question of the reliability of the other statistics. It may well be that in the later years, especially as the Japanese fishing effort has declined in a number of fisheries, that these estimates are also not nearly as good as they used to be and they may not be at all valuable to us. It's a problem that has occurred in the Atlantic, where the Japanese effort is now such a small part of the fishery. That's still not really true in the Pacific, although Japan is moving more and more out of the longline fisheries. So, there will come a time when even those statistics may not do what we want.

John Gulland, England:

I have a few observations and questions. The first one is an observation in relation to FAO statistics, because everyone seems to be using the FAO statistics and then saying their lousy. As somebody who's been associated with FAO a long time, I appreciate both those statements. The fact is that FAO can only publish the statistics that other countries collect. We have a very small staff to prod countries, to try and sort out why the Koreans, for instance, are reporting species from the Atlantic that have never been known to occur in the Atlantic. I think it would be useful to encourage FAO and give it a little bit of backing, because it needs some friends at the moment.

Robert Skillman:

One thing that bothers us to a great extent about the FAO statistics is the statistical areas that are employed. They seem to have no rhyme or reason with respect to any possible stock separations that we can imagine, at least for the pelagic highly migratory species. It is really very difficult to try and do assessments on north and south stocks when you have statistical areas

which stretch from 30 degrees north to 30 degrees south in the eastern Pacific. It makes things very difficult. If that could be divided some way, quality aside, it would prove most useful.

John Gulland:

I think that is really a matter of the FAO areas being sort of coastal looking rather than ocean-wide looking, more for species lilke cod and herring. A point for Robert Skillman is that I ran into a similar problem about average sizes. One of the problems is that the FAO statistics reflect the total landings in Japan, whereas sometimes the logbook statistics do not always reflect the total landings, and there is also some slip between time zones. The logbooks refer to when it's caught and the statistics refer to when it's landed. There might be some problems there. What is useful when looking at mean size is the difference between mean size and the size at recruitment. If the sizes come down from 50 kilos to 40 kilos, and the smallest fish recorded is right about 35 kilos, this means a much bigger signal in terms of changes in mortality, changes in fishing rates, than if it comes down the same from 50 to 40 when the smallest fish recorded is 10 kilos.

A couple of points to Peter Miyake in relation to work that is going to be done, and I appreciate the difficulties he had in making that presentation. In other areas in other fisheries, there have been two big problems. One is in converting from length to age when you haven't got the age, that the growth curve you see is the mean length at age, and it's not the same thing as mean age at length, particularly when there are changes in mortality rates. So you may have some considerable difficulty there and the same with tuning VPAs. A lot there depends on your assumptions and your way of tuning, and you can get into a lot of trouble, particularly for the most recent years. The virtual population analysis is an extremely powerful tool for historical examination of fossilized fisheries, but not what's happening this year.

My final point is offered to the people presenting the production models. What struck me, looking at most of them, was the extent to which runs of years seemed to clump. You had perhaps 20 years data, of which 14 or 15 years kept on one curve and then there was a whole set of 6 years sitting up to one side or down to one side. I wonder if there is any explanation, either in terms of runs of good year classes or changes of fishing practice, that might account for that, so that it doesn't make the pits of the curve that much more hairy.

Donald de Sylva, University of Miami:

I'd like to reinforce what Dr. Gulland said about the species identification. Not only should we be worried about stocks but, in some cases, we don't even know what species we're identifying in the Atlantic. That may not be so much of a problem in the Pacific but, in the Atlantic, "black marlin" have been reported in large numbers in the south, "short-billed spearfish" have been recorded, as well as "striped marlin;" what are these things, where do they occur? I know that Izumi Nakamura has put together an extensive species document. Has there been any attempt in ICCAT to distribute this information to longline captains so they can decide what they're catching? Such action would be very valuable to help improve our data base.

Peter Miyake:

As far as ICCAT studies go, only 2 or 3 tons of black marlin were recorded in the past, in the southernmost Atlantic. Probably what happened is that the Japanese, Korean, and Chinese names are different from the English, and there are errors by statisticians, not by fishermen, in assigning those catches in the different species categories. That's one of the major problems. The second problem is that many countries, such as Korea or Cuba report billfishes together without separating by species. In the Atlantic, the countries are reporting by species. Combining as "billfish" is probably still practiced in some other oceans. Unfortunately, Japanese fishery scientists have combined spearfish and sailfish statistically. The computer can take only 80 digits, and there is no space to record spearfish and sailfish separately. I hope this practice can be changed so that we can have proper records of the two species.

Donald de Sylva:

Robert Skillman, in the 1950s a Japanese scientist named June Nakagome found that the longline catches reflected that the shallow-caught species were males and these were smaller, and that the deep-water marlins were females and these were larger. With the longline practice going into deeper sets, you might be able to plot that and see whether you get larger fish as you go deeper.

Finally, a comment about Raymon Conser's request for information on sexual maturity of billfish. We've been trying to get this for years, and it's very hard to find because small billfish are hard to come by. Our data base is basically from the recreational fishery. Now our data base is being dried up because the Regional Fishery Management Councils want to prohibit the landing of any small fish. This restriction is going to put us out of business, as well as you, unless you have some plan to gather sexes at sea aboard longline vessels. We don't.

John Dean, South Atlantic Fishery Management Council:

In the discussions during the development of the Atlantic billfish plan, it was made very clear all along that it would be easy to get a scientific sampling permit. The National Marine Fisheries Service assured us of that all along; it was a primary concern, and it is simply not an issue. If there is a well-developed and properly organized plan, you'll find that those sampling permits will be made available.

Christopher Weld, National Coalition for Marine Conservation:

I'd like to introduce a caveat, and invite Peter Miyake to comment on it. I caught my first swordfish over 20 years ago and I've had a rather proprietary interest in the species ever since. My feeling, as far as the American catch data are concerned, is that there are many historical influences on those data that make them incomplete in some instances and probably skewed in others. In the old days, when you just had a harpoon fishery, only big fish were being landed. A harpoon is rarely thrown at a fish under 150 pounds. Those landings were probably understated because many fish were being sold direct to restaurants or small jobbers and the only historical data came from the weigh-out sheets. The landing data for the 1960s were probably never collected or sorted until the 1970s, at the very earliest, and it's just hard to believe that those data were complete. Mind you, I'm suggesting here that the number of large fish in the early years of the fishery is understated.

Now, conversely, it is my very strong belief that the number of small fish being caught in recent years is also being understated. Then you have a middle period when the fishery went underground on account of the FDA mercury restrictions, when landings were being disguised and weren't being reported. They were taken off the docks and trucked up and down the country, but they never went through the counting process. This circumstance is particularly bad because this was when the fishery was expanding very rapidly, when the longline was being introduced. The population of large fish fell so rapidly that you could notice it from year to year in the sport fishery in the northeast.

In modern times, you have a relatively small number of operators, all of whom are pretty sophisticated people. They have a history of subversion, they know what fish counting is going to do to them managerially, and there is absolutely no incentive for them to report the real number of small fish being caught. So, my caveat to you is, any data you are getting out of this side of the Atlantic should be looked at very carefully before being accepted.

Gregory McIntosh, South Alantic Fishery Management Council:

Peter Miyake, as you are aware, the South Atlantic Council and its four sister councils are responsible for fisheries management within the U.S. EEZ, and have prepared a fishery management plan for swordfish. One of the primary objectives of that plan is to prevent growth overfishing, defined in the plan as fishing occurring at Fmax. Based upon the two-stock hypothesis that ICCAT has been operating under for the last several years, would you consider the eastern stock of swordfish in a state of growth overfishing?

Peter Miyake:

Are you asking my personal opinion or the official ICCAT opinion? The official ICCAT opinion cannot be expressed until after the September workshop. The ICCAT scientists have decided to handle the total north Atlantic population as a single management unit, not as two units — east and west. If any hypothesis of two units, east and west, is adopted, then some mechanism to account for the high exchange of fish between the east and west would be needed. As for the official opinion of ICCAT, it's very difficult to separate the western Atlantic from the eastern Atlantic. In my personal view, it's true that when you are fishing and you're putting any intensive effort of exploitation onto any stocks, the stocks start declining and the size of the fish will decline, and then the fishing

grounds will expand, and so on and so forth. That's the history of a whole fishery. Overexploiting is very difficult to define and, in this case, in my opinion, the fish are now extensively exploited throughout the north Atlantic, but not as extensively as some tuna species. When we look at the statistics, we know that the Atlantic catch is about 10,000 to 15,000 while the Mediterranean catch is 10,000. The Mediterranean catch comes mostly from a very small area between Sicily and the Spanish coast. I believe that there is a very high risk of overexploitation in the Mediterranean. Considering this, and the management of the stocks in the north Atlantic, I doubt that there is the risk of exploitation at the current level. We must study and monitor the fisheries very carefully so that whatever measures are taken shouldn't be too late. That's my personal opinion.

Gregory McIntosh:

You're aware that the U.S. councils define the stock that we manage under our process as out to 40 degrees west, and that we have along with the NMFS determined that that stock of fish is well beyond Fmax at this juncture. The second issue is that the NMFS has provided the councils with a rather extensive stock assessment or catch-per-unit-of-effort analysis. Will those data be made a part of the work that will be done in September by ICCAT? Will they be considered in that stock assessment work?

Peter Miyake:

All the data the NMFS is working on will be a part of our data base. We are getting 1986 and 19876 catch and effort data from the United States, Canada, Japan, Spain, and Taiwan, which are the major players in swordfish catches. Therefore, I believe that the coming workshop results will be based on the most recent and updated data base. Also, each nation's scientists are working to produce the catch-per-unit-of-effort series, standardized for their fisheries, updated to 1987.

Gregory McIntosh:

If I may belabor the point, that the South Atlantic Council has been presented with a document by the Southeast Fisheries Center of the NMFS which we will use as the best scientific data available. We will use that for management purposes in developing a forthcoming amendment. Will the data incorporated in that document be presented to you in September? Perhaps Bradford Brown would like to respond to that?

Bradford Brown, Southeast Fisheries Center, National Marine Fisheries Center:

The document provided to the South Atlantic Fishery Management Council was an analysis of the U.S. fishery within the U.S. EEZ. All of those data will be available to the scientists at ICCAT. It is unlikely that the document would be presented as an ICCAT document, but the data will be available to use for the analysis of the stocks done at ICCAT.

Richard Shomura, National Marine Fisheries Service:

A number of questions have been raised regarding the amount and quality of data. I was interested in the comment that Christopher Weld made, since my comments were that the data that are available to the scientists on billfish are really relative. I think everyone agrees on that. I kept on looking at the Atlantic data base and considering that as being fairly good. When you look at the Pacific, it's in pretty bad shape. My personal opinion is that the data that are available to the scientists for billfish assessment purposes are lousy. The Atlantic is in much better shape than the Pacific because the Atlantic does have an international organization whereby member countries are providing data to a common pool to be analyzed. That does not exist in the Pacific. Also, the recreational catch, which I think is substantial, is never accounted for in these analyses. Since 1980, the Japanese have not made available detailed catch and effort statistics, simply as national policy. The lack of an international organization is one of the reasons why these data do not become available. I think the data available to scientists in general have deteriorated since the FCMA extended jurisidiction in the mid-1970s. You can see it clearly in the Pacific. As John Gulland said, the FAO data are dependent upon the countries that submit them. For this meeting, I had encouraged Robert Skillman to do an assessment of the marlins in the Pacific with the view that we had a data base that was independent of what the Japanese had, and that it would be valuable for comparative purposes. Because billfish are a by-catch, however, the data were inadequate that Bob took from the log books that we get voluntarily from Korea an Taiwan. When he compared the Japanese longline data with the Korean and

Taiwanese, there should have been a much better correlation than he mentioned. Adjustments for deep longlining and area had no effect, which to me suggests that the data are inadequate in one or all of the data sets.

James McHugh, Mid-Atlantic Fishery Management Council:

The bottom line to what proceeded on swordfish is whether the stock assessment coming out of ICCAT in September will be a single-stock or two-stock assessment?

Peter Miyake:

Since ICCAT scientists decided at the last workshop session to adopt a one-stock hypothesis, I think the results will be in terms of one stock. There may be some comments on the case of two stocks, as well, but that's what I expect.

James McHugh:

Doesn't ICCAT still recognize the potential for two stocks? I thought that's what I read in the report.

Peter Miyake:

As far as I know, they are inclined to adopt the one-stock theory. In any case, if a two-stock theory is to be adopted, the substantial mixture of fish between the east and west should be considered. That's the conclusion at the last workshop.

Gregory McIntosh:

Peter Miyake, you talk about substantial mixing between the two stocks, yet the tag return data I saw indicated no mixing. Could you please explain that inconsistency?

Peter Miyake:

This issue has been a point of discussion. I'm not defending what the scientists decided, I'm just tracking what the discussion was. They agreed to manage this as a single management unit.

Gordon Broadhead:

I think the stock aspect is perhaps a little misunderstood here, in that what we're really talking about in the international arena of ICCAT is a mangement unit, and the fact that most of the fish are caught by three nations overlapping in the central north Atlantic. From a management point of view, and on an international basis, the scientists pretty well had to consider that aspect. That doesn't preclude a separate analysis for the west upon which an individual nation could act if they think it's in their best interest.

Panel 3

Biological and Statistical Requirements for Management

David Grobecker, Chairman

Stock Identification and Billfish Management

Robert A. Skillman

While economic and social evaluations of fisheries are today recognized as important elements in managing fisheries, determining the biological status of fish exposed to a fishery and to a management regime remains a basic and important element in management. For the status of a stock to be assessed, boundaries must be set. If the boundaries actually encompass more than one stock and management is carried out as if there were only one stock, the management scheme may perform satisfactorily on average for the two stocks. However, the more that population parameters, such as growth and mortality, differ among individual stocks, the more likely it is that the management regime will adversely impact one of the stocks. If the boundaries do not completely encompass a stock, then events external to the management area can significantly affect the stock.

This chapter reviews stock identification methods as they relate to fisheries management and, in particular, to billfish management. The stock concept, itself, will be discussed before reviewing the various methods used to study stock structure. Then, what is known about billfish stock structure will be reviewed, followed by recommendations regarding the most likely productive research strategies to follow for billfishes in the future.

The Stock Concept

Setting boundaries and identifying stocks is, in effect, determining what part of the total species population is going to be assessed and managed. Thus, the term stock or unit stock is used, ". . . to connote as well as circumscribe the basic grouping on which management needs to focus attention" (Kutkuhn 1981). This initial step in assessment has led to many reviews of the unit stock concept, with many authors proposing new or modified definitions. Providing a historical perspective might be appropriate at this time.

Fishery biologists first defined a stock in terms of the various tools employed in conducting an assessment. For example, Cushing (1968) said, ". . . a stock may be defined as a population in which the vital parameters of recruitment, growth, and mortality are homogeneous." In practice, fishery biologists frequently identified stocks based on where the fish were found as larvae, as adults in the fisheries, or while spawning, as well as by how the fish looked (meristics and morphometrics). Then, the existence of these putative stocks was evaluated by using estimates of vital (or population) parameters. With the development of population genetics, the fishery biologists' definition of a stock was viewed as vague and not quantitatively rigorous compared with the geneticists' definition of a population or a subpopulation. Thus, fishery biologists began incorporating genetic concepts, and new definitions were proposed. For example, ". . . a unit fish stock is one consisting of randomly interbreeding members whose genetic integrity persists whether they remain spatially and temporally isolated as a group, or whether they alternately segregate for breeding and otherwise mix freely with members of other unit stocks of the same species" (Kutkuhn 1981). Along with this definition came numerous attempts to identify stocks by using various genetic techniques.

The debate on the utility of genetic techniques in fisheries stock assessment and fisheries management continues today. One problem is whether a population determined to be genetically homogeneous meets the needs of fishery biolo-

gists to conduct stock assessments; namely, the unit stock must be homogeneous with respect to recruitment, growth, and mortality. A second problem is whether genetic techniques can resolve the structure of a large population inhabiting an extensive area having vague and changing environmental boundaries when biological (fishery) information suggests some degree of stock structuring. While all the evidence is certainly not in, the genetic and fishery biological definitions apparently coincide reasonably well for demersal species and stocks with well-defined physical or environmental boundaries. On the other hand, they apparently do not coincide well for species inhabiting, as adults or larvae, the pelagic ecosystem with poorly defined physical and environmental boundaries.

Stock Identification Methods

As indicated above, the study of population structure in fisheries consists of two basic approaches. The traditional biological approach consists of a number of alternative techniques for identifying stocks. These stocks meet the fishery biologists' stock asessment needs but may not be the same as genetic subpopulations. The newer genetic approach consists of a few but growing number of techniques for identifying subpopulations that may or may not be helpful for stock assessment and management purposes.

Biological

Distribution. Probably the first method employed was to examine the geographical distribution of fishery catches, which often consist of adults. Thus, this method has direct applicability to defining the boundaries of a fishery, and possibly the boundaries of management action, but it may not be satisfactory for determining the boundaries of a stock unless the distribution of fishing effort is extensive. For example, if the fishing effort is directed at the species being examined, it is not likely to occur beyond the region where the species is commercially or recreationally important. In such cases, stocks may be distributed more extensively than indicated. Compiling the distribution of catches by size classes may help substantiate the existence of putative stocks when recruitment can be shown to vary.

Determining the distribution of spawning sites may result in more reliable identification of stocks. The existence of geographically or temporally separate spawning sites, with no exchange of individuals among the sites, is necessary for genetic separation and could contribute to differences in vital parameters. The distribution of larvae and juveniles may also be used to identify stocks, particularly when the samples are collected independently from any fishery. Thus, using juveniles collected from the stomachs of commercially-landed predatory fishes should be done with care.

Population Parameters. Estimates of population parameters, such as growth, recruitment, and mortality, are used to separate stocks. In addition, they are commonly used to characterize putative stocks and evaluate whether their existence seems plausible; that is, whether the parameters are homogeneous over the range of the reputed stock. While demonstrating that parameter estimates are different among potentially separate stocks does not necessarily prove the existence of separate stocks, stock structuring is supported when geographical clumping or clinal variation of parameters occurs. Such results are consistent with a lack of genetic mixing (subpopulation formation) and a lack of exchange of fish among fishing grounds or mixing of individuals in nursery areas (stock formation) because separation, from either perspective, could lead to different population parameters. Given the poor ability to estimate mortality even for well-studied stocks, however, estimates of billfish mortality are not likely to provide as much information as growth estimates. On the technical side, comparison of the growth estimates is complicated because the commonly used von Bertalanffy growth parameters, maximum size (L_{inf}) and rate of approaching that maximum (k), are correlated. Simple cluster analysis conducted by plotting L_{inf} versus k for samples from different areas has proven productive in the identification of stocks. Other population parameters (e.g., the age at first maturity and gonadal index) are also used. Age at first maturity is strongly affected by stock size, which is, in turn, affected by the size of the fishery. Gonadal development is seasonal but may differ among stocks.

Parasites. Using the occurrence of fish parasites as a means of studying stock structure is based on the concept that parasites are naturally occurring "tags"; that is, the incidence of parasitic species varies geographically and these natural tags are not lost. The method is not applied frequently to large pelagic species for a number of reasons. Fishery biologists recognize

that parasitology is not a tool in the sense that morphometric and multivariate statistical methods are, but is an additional level of biological complexity requiring research itself. This complexity involves the identification of relatively bizarre animals; use of different sampling, preservation, and preparation techniques; and, most importantly, familiarity with a different set of life-history strategies involving host-parasite relationships. Parasitologists have tended to work more in freshwater and coastal marine habitats where fish stock sizes and parasite-to-host linkages are more amenable to reseach. Consequently, the life histories of parasites occurring on large pelagic species and the effect of environmental changes on infestation are not well known, and interpretation of results has been open to question. Research is needed on the possibility of tag loss (selective or differential loss of parasitic species or parasite size classes) with movement of fish into areas having different environments, and then reinfestation by other parasitic species. Also, application of the method to date has assumed that each natural tag (each parasitic species) is made up of one population, but I see no reason why they could not be divided into subpopulations as well. Nonetheless, such studies can provide a fishery-independent determination of stock structure, and additional long-term work on the basic biology of pelagic fish parasites is likely to improve the utility of the method as a stock identification tool.

Tagging. Tagging fish for the study of stock structure is very popular because it provides direct, if not irrefutable, evidence of fish movement and the lack of stock separation. Movement is the mechanism for exchange of individuals and the mixing of genetic products. However, the method has several problems, and care must be taken in analyzing the results (Hilborn and Sibert 1988). First, the method is expensive if large numbers of tagged fish are to be released, and this is certainly desirable if not a requirement with the large populations that exist for billfishes and other pelagic species. Also, a great deal of international promotion and cooperation are required to conduct such experiments successfully. Second, results are meaningful only if fisheries exist that have the potential of recapturing the tagged fish. Third, fishing effort statistics from these fisheries are required for quantitative evaluations of the recaptures. Fourth, without additional information about the biology of the fish and such specifics as the size and maturity of the fish when released and retaken, recaptures may indicate movement but provide little information on stock structuring.

Morphometrics and Meristics

Fish exhibit greater observable (phenotypic) variation than other vertebrates, apparently because they are poikilothermic (cold-blooded) and have a capacity for indeterminate growth (e.g., Allendorf et al 1987). Thus, early workers were able to recognize stocks on the basis of appearance, and later workers built on this by analyzing measured characters (morphometrics) or analyzing counted characters (meristics). With the development of analytical tools in the fields of taxonomy and statistics, this approach flourished and provided a means for rigorously identifying stocks. However, morphometric and meristic characters were shown to be strongly influenced by the environment, and their use fell into disfavor with the development of electrophoresis for studying population genetics. Experience has shown that stocks identified by using morphometrics or meristics are in general agreement with subpopulations identified genetically (e.g., see Ihssen et al 1981). However, a greater degree of stock structuring is often found by using morphometric and meristic methods than by using genetic procedures, because of the superior power of the statistical tests associated with the former methods and the use of environmentally influenced characters.

Thus, among many biologists, morphometric and meristic methods are still viable means of investigating stock structuring. With the development of new techniques for studying shape, the statistical power of the methods has increased even more. Truss analysis (e.g., see Winans 1987) makes use of recently developed powerful multivariate analysis techniques. Showing great promise is the use of planar shape analysis, first used in the study of the evolution of ostracods (e.g., see Benson 1967) and recently making its way into fisheries (Bird et al 1986). This method is based on pattern recognition techniques using mathematical tools such as Fourier analysis and discriminant analysis. The collection of data for analysis using the truss and planar shape methods can be performed on microcomputer-based image processing systems, thus reducing the cost of collecting data in the field.

Genetics

The following historical perspective is drawn in part from Utter et al (1987). Although great strides in the inheritance of observable characters have been made from the time of the pioneering work of Mendel (1866) up to the 1930s, this work was not transferable to fish because of the magnitude of environmental influences on their observable characters. About this time, the inheritance of blood groups had been resolved, and attempts were made later to use the technique on tunas (Cushing 1956, Sprague et al 1963, Fujino 1970). This technique was unproductive because of the fragility of fish erythrocytes and problems in making and preserving the discriminating antisera. Lundstrom (1987) indicates that the use of monoclonal antibodies shows promise, but other genetic procedures probably show more potential for success with billfishes.

The determination of the structure of the DNA molecule by Watson and Crick (1953) led quickly to the determination of the relationship between genes and intracellular, enzymatic proteins, called isoenzymes or isozymes for short. By 1955, electrophoretic techniques were developed that allowed easy examination of the variation (polymorphism) of these proteins and, thereby, the genes that make them. Thus was born the most powerful and productive technique to date for studying population genetics, dominating since the mid-1960s. Examples even in the fisheries literature are too numerous to mention. A serious problem with the technique is that separation of stocks depends on statistically testing of what are called the Castle-Hardy-Weinberg gene proportions. This test is statistically weak and, with the typical genotypic ratios involved, requires large sample sizes to obtain meaningful results. After many years of work on skipjack tuna *(Katsuwonus pelamis)* in the Pacific Ocean (Fujino and Kang 1968, Argue et al 1986), some degree of population structuring is indicated, but distinct subpopulations have not been resolved. Grant et al (1987) state that marine fish, in general, exhibit little genetic population structuring because of the passive dispersal of larvae and active movement of adults (Ryman et al 1984; Shaklee 1984). Given the life history of most billfishes, electrophoretic study of isozyme variability is not likely to be very productive.

Recently, two additional DNA-based techniques have been developed. As the name suggests, DNA sequence determination involves the resolution of genes directly on the DNA molecule, which is located in the cell nucleus. The method is sufficiently sensitive that relatedness of progeny and ancestors of a generation or two can be detected; beyond this, variability becomes so great that all individuals appear to be different (Wetton et al 1987). Thus, the name "DNA fingerprinting" has been used to describe this method. It is not likely to be of much benefit for the study of billfish stock structuring, although it may be the genetic "marker" so long sought for hatchery-reared fish released into the wild.

The second technique involves the analysis of DNA occurring in mitochondria located in the cell cytoplasm. Because mitochondrial DNA (mtDNA) is maternally inherited, each individual has an exact copy (except for rare mutations) of the mtDNA genotype from its mother. Therefore, the operational taxonomic unit is the individual rather than the population, as with nuclear gene analytical techniques such as electrophoresis. Thus, in practical terms, the statistical requirements are quite different, and sample sizes can be substantially less than with electrophoretic work (Ferris and Berg 1987). For example, reported sample lot sizes per species have varied from 1 to 12 (Avise et al 1979, Berg and Ferris 1984, Graves et al 1984, Wilson et al 1985, 1987) with species totals in 2 studies reaching 36 (Avise et al 1979) and 87 (Lansman et al 1981). This contrasts with sample lot sizes of 50 to 100 (Fujino and Kang 1968) or even 200 (IATTC 1978) and total sample sizes in the thousands for electrophoretic studies of fish. Although the technique apparently holds great promise for resolving stock structuring (Avise et al 1979), little experience has been gained with pelagic species. Avise (1987) could not find any evidence of stock structuring in the American eel *(Anguilla rostrata)* which spawns in the pelagic environment, whereas stock structuring was evident for several demersal or estuarine species. Graves et al (1984) did not find any difference between Atlantic and Pacific samples of skipjack tuna; however, the specimens were frozen, which considerably reduces the amount of mtDNA recovered for analysis (Lansman et al 1981; Ferris and Berg 1987).

Billfish Stock Structure

In the following sections, information on the stock structure of billfishes is summarized from a variety of sources. Papers presented at the first billfish symposium in 1972 (Shomura and

Williams 1974) discuss, for Atlantic, Indian, and Pacific oceans, the distribution of adults based on tuna longline catches, the distribution of larvae and ostensible spawning areas based on research data, and results from tagging. For the Atlantic Ocean, I am not aware of any single source summarizing information on billfish stock structure, so I have used the way billfish stocks are assessed and reported in the biennial reports of the International Commission for the Conservation of Atlantic Tunas (ICCAT) as an indication of the state of knowledge (e.g., see ICCAT 1987). For the Indian Ocean, participants at a 1979 tuna and billfish stock assessment workshop summarized the state of knowledge for billfish stock structure (FAO 1980). Likewise, for the Pacific Ocean, participants at the 1977 billfish stock assessment workshop (Shomura 1980) summarized what was known about the stock structure of billfishes as a prerequisite to assessing the status of the presumed stocks.

Atlantic Ocean

Among the several billfishes occurring in the Atlantic Ocean, the ICCAT biennial reports contain material on separate stocks only for sailfish *(Istiophorus platypterus),* namely eastern and western stocks. The basis for this separation seems to be the distribution of longline catches and tagging results (Mather, Tabb, Mason, and Clark 1974). While tagging results support the existence of separate northern and southern stocks of the Atlantic blue marlin *(Makaira nigricans;* Mather, Mason, and Clark 1974), the ICCAT reports contain discussions of stock assessment results for the entire Atlantic Ocean but present figures showing surplus production models for separate stocks. White marlin *(Tetrapturus albidus)* assessments are presented for one Atlantic-wide stock. For swordfish *(Xiphias gladius),* researchers (ICCAT 1987) now believe that separate eastern and western stocks exist, as well as a separate Mediterranean stock, based on longline catch distributions, tagging results, and the distribution of spawning activities and larvae.

Indian Ocean

Information on the stock structure of five billfishes is available for the Indian Ocean (FAO 1980). The distribution of longline catches and information on spawning suggest that there is a single stock of Indo-Pacific blue marlin *(M. mazara)* in the Indian Ocean. Similar kinds of data for striped marlin *(T. audax),* swordfish, sailfish, and black marlin *(M. indica)* suggest multiple stocks. In addition, the workshop participants (FAO 1980) believed that movement of the latter species could occur between the Pacific and Indian Oceans although no tag recaptures had been made to support the contention.

Pacific Ocean

For the Pacific Ocean, stock structure information is available for six billfishes (Shomura and Williams 1974, Shomura 1980). Based on the distribution of tuna longline catches, tagging returns, and the distribution of spawning, the Indo-Pacific blue marlin is believed to consist of a single Pacific-wide stock (Shomura 1980), whereas the other billfishes exhibit some evidence of stock structuring. In an electrophoretic survey of blue marlin captured in Hawaii, sufficient polymorphism to conduct a population genetic study was found (Shaklee et al 1983). The only suggestion of population structuring (mixing of subpopulations) in this small sample collected at one site in 1 month, however, was a deficiency of heterozygotes for one of seven polymorphic gene systems surveyed. For black marlin, participants at the 1977 stock assessment workshop (Shomura 1980) indicated that separate eastern Pacific and two western Pacific stocks probably exist. Skillman (1989) assumed one Pacific-wide stock centered off Australia, based on the distribution of tuna longline catches. Nakamura (1983) indicates two spawning areas, one off Australia and a second in the north Pacific between the Caroline and Marshall Islands. Northern and southern stocks of striped marlin may exist, but the evidence is contradictory or inconclusive. For striped marlin, the area of high tuna longline catches in the eastern tropical Pacific appears to join or merge seasonally in many years with high catch areas in the middle latitudes of both the north and south Pacific. In contrast, the annual distribution of spawning stretches from comparable northern and southern central Pacific areas across the Equator in the western tropical Pacific (Nakamura 1983). Swordfish population is generally believed to consist of a single Pacific-wide stock, but may consist of separate stocks in the northwest, southwest, and eastern Pacific. Spawning grounds are located in warm, tropical waters in the western and central Pacific (Nakamura 1983). Sailfish are believed to be divided into eastern and western stocks based on tuna longline catch rates and distribution of spawning

sites. Distribution of tuna longline catches suggests separate northern and southern stocks of shortbill spearfish *(T. angustirostris),* and the distribution of spawning activity supports this conclusion.

Recommendations

The following research recommendations would, in my opinion, most likely contribute to our understanding of the stock structure of billfishes.

1. Tag-and-release programs, particularly for young fish, should be continued and extended to other tournaments and fisheries. Recaptures provide valuable information on movement and the relationship among fisheries, information not easily gotten by any other means. Although the number of billfish that could be released from most fisheries is small, and indeed probably smaller than desirable for estimating such parameters as fishing mortality, growth rate, and rate of exchange between fisheries, qualitative information on movement is still useful. Returning viable billfish to the sea without tagging them, or retaining all nontrophy or nonpoint-contributing billfish for tournaments, is, in effect, throwing away a valuable research opportunity. Support of tagging operations is particularly amenable to cooperative arrangements among national fishery agencies and recreational interests and, indeed, could provide the basis for further cooperation.
2. More effort should be expended on shape analysis, especially the newer truss and planar shape methods, but possibly on traditional morphometric and meristic methods as well. Although the newer methods require or would benefit from access to microcomputer-based image processing equipment and some specialized computer software (though not very sophisticated or costly), the traditional methods can be used by small fisheries offices with measuring devices, a microcomputer, and standard statistical software. Such studies would benefit from intergovernmental cooperation and, of course, collaboration with fishermen, tournament organizers, and fish processors.
3. Studies should be conducted to estimate vital parameters, such as growth, age at first maturity, recruitment, and mortality, to ensure that valid stocks are identified and that models used to assess the status of stocks are applied correctly.
4. Billfish larval surveys should be designed and implemented. Results from ichthyoplankton tows, taken by different kinds of gear, at different depths, in different seasons, and, for the most part, without any experimental design (along with charts of the distribution of billfish catches by tuna longline gear), have been the most commonly used means of identifying stocks. Enough is now known, however, about the location of spawning grounds and seasonal occurrence of spawning for most billfishes, to formulate testable hypotheses about their stock structure. Because of the large areas involved, such experimentation would benefit from international collaboration among national fisheries agencies and universities.
5. Selected genetic studies using mtDNA or electrophoresis should be continued but not on a large scale. I suggest that selecting species such as sailfish, generally believed to consist of multiple stocks, would be more productive than choosing a species thought to consist of one panmictic stock. Also, regarding mtDNA analysis, the development of standard tissue collection and preservation procedures for situations where the samples cannot be immediately processed would benefit billfish research.

Summary

The identification of separate biological units or stocks is required for determining the status of the resources and for conserving them via fisheries management. A number of biologically based methods for separating stocks are available; using such methods on billfishes is likely to be more productive than using population genetic methods. The stock structures of billfishes are, in general, poorly known. The largest billfishes, blue and black marlins, appear to consist of single ocean-wide stocks, while there is some evidence for east and west or north and south stocks of the smaller striped marlin and swordfish. Evidence for multiple stocks for the smallest species (spearfish and sailfish) is stronger.

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The Adequacy of Current Billfish Fisheries Statistics for Stock Assessment and Management Purposes

Richard S. Farman

Arising from the concern over declining catch rates and expanding fisheries, the adequacy of billfish fisheries statistics for stock assessment and, hence, management purposes has long been questioned. Earlier consultations have concluded that the detailed information required to understand the effects of fishing on billfish stocks had not been acquired (Anon 1981a, Anon 1981b, Shomura 1980, Shomura and Williams 1974). With the advent of this new symposium, it is pertinent to review what progress has been made to date and to assess the current situation. It is the object of this chapter to identify existing and potential sources of data that can be used for stock assessment and management purposes and to determine the extent of their availability. It will also look at the adequacy of the current data holdings with respect to current management questions.

Existing and Potential Sources

Since billfishes are principally harvested by commercial longline operations, the bulk of the data is comprised of catch statistics. These data are routinely collected by vessel operators and compiled by the fishing nations, mainly Asian countries (Japan, Korea, and Taiwan), or regional organizations involved with pelagic fisheries (e.g., International Commission for the Conservation of Atlantic Tunas, Inter-American Tropical Tuna Commission, South Pacific Commission, Indo-Pacific Tuna Programme). The standardized longline logsheet adopted for the western Pacific Ocean (Fig. 1) has been translated in the various languages of the flag vessels operating in the region. Different log sheets are used elsewhere, but the current move is toward the adoption of a single format (for each gear), which is now being discussed at meetings on global tuna statistics. These data are often published, albeit in a variety of summary formats and covering different periods, which makes them theoretically accessible.

These statistics, however, concern only information on the location and amount of the catch and effort. Finer ancillary data such as individual lengths and weights, and other biological samples, are being collected during unloading. These collections are by marketing authorities, fishing associations, or research groups and their outputs depend greatly on the reasons for which they are made. Because of its economic nature, the information is often regarded as confidential; as such, it is seldom if at all available in raw format. Furthermore, sampling practices for non-scientific purposes may not be rigorous and a variety of measures are often employed for the same parameters (e.g., dressed/whole weight, round/flat length).

Finally, there is a growing body of data generated by recreational fisheries which include both types of information mentioned above. These fisheries generate catch statistics and provide specimens for biological sampling. With the growing popularity of catch-and-release competitions, recreational fisheries have also provided an excellent medium for opportunistic tagging. The catch records are kept by fishing groups, clubs, or association, but these data have not until recently, still in only a few areas, been centralized or published, and are not easily tracked. In addition, these data are seldom standardized and provide information of varying quality.

LONGLINE VESSEL - CATCH REPORT FOR THE WATERS OF .....

VESSEL NAME _____
COUNTRY OF REGISTRATION _____
REGISTRATION NUMBER _____
GROSS REGISTERED TONNAGE _____
LICENCE/PERMIT NUMBER _____
NAME OF CAPTAIN _____

NUMBER OF HOOKS/BASKETS _____
DISTANCE BETWEEN FLOATS (M) _____
LENGTH OF FLOAT LINE (M) _____
LENGTH OF BRANCH LINES (M) _____

BAIT USED (Species)	1	2

	NAME		YYMMDD
DEPARTURE FROM PORT		DATE	
ARRIVAL AT PORT		DATE	
NUMBER OF CREW			

YEAR _____ MONTH _____ LICENCE/PERMIT HOLDER'S SIGNATURE _____

Comments Code
1. Days not fishing
2. In port

DAY	NOON POSITION				NUMBER OF HOOKS	SEA SURFACE TEMPERATURE	Albacore		Bigeye		Yellowfin		Bluefin		Striped marlin		Blue marlin		Black marlin		B.B. Sword fish		Sailfish		Shark		OTHER SPECIES		DISCARDS		COMMENTS CODE
	LAT		LONG				NO.	TOT. WT. (KG)	NO.	TOT. WT. (KG)	NO.	TOT. WT. (KG)	NO.	TOT. WT. (KG)	NO.	TOT. WT. (KG)	NO.	TOT. WT. (KG)	NO.	TOT. WT. (KG)	NO.	TOT. WT. (KG)	NO.	TOT. WT. (KG)	NO.	TOT. WT. (KG)	NO.	TOT. WT. (KG)	TUNA (KG)	OTHERS (KG)	
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TOTAL																														

Figure 1. Standardized log sheet to report longline catches in the western Pacific.

Adequacy of These Data for Stock Assessment and Management Purposes

Previous Evaluations

The conclusions of earlier symposia and workshops, concerning billfish stocks in the three major oceans, noted that, except for catch-and-effort statistics from some segments of the longline fishery, data required for the purpose of stock assessment were virtually nonexistent (Anon 1981a, Anon 1981b, Shomura 1980, Shomura and Williams 1974), thereby precluding but the coarsest analyses of catch trends or surplus production described by Shaefer (1954). In addition, the available catch-and-effort data were found limiting because of incomplete coverage, virtual absence in some sectors, nondiscrimination of some species [notably sailfish *(Istiophorus platypterus)* and shortbill spearfish *(Tetrapturus angustirostris)*] and nonstandardized reporting practices for catch data. These reflections were based on the needs for basic biological information and adequate statistics such as: size, sex and age composition, total catch, and catch-and-effort over several years. It was thus recommended that all nations with billfish fisheries establish sampling programs and procedures to insure the collection of statistics on total catch by species, gear, type of operation, and ocean region; total nominal effort for the same categories; catch per unit of effort (CPUE) by small area-time strata, gear, and type of fishing operations; and size and sex composition of the catches by species and by small area-time strata (Shomura 1980). During the last ten years, significant changes in the tropical pelagic fisheries have accompanied the redeployment and redirecting of longline effort concurrent with the advent of large-scale industrial purse seining. Have there been corollary changes in the way and extent that data are collected? What progress has been made over the last ten years in implementing the recommendations of international fora?

Current Needs

The objectives of stock assessment or management will obviously have a bearing on what data and methods are needed for the analysis of the data and the evaluation of proposed strategies. Let's thus first review what the current concerns are and see which data are not available to address them. Our reflection is necessarily based on earlier assessments, which estimated that most billfish fisheries were fully exploited or overfished (Anon, 1981a, 1981b). These circumstances imply that we should be concerned whether and how effort should be expanded or reduced and what expected impact these changes will have on the stocks and the fisheries. We should thus be addressing the ancillary questions of whether current yields are sustainable and how to maximize yield per recruit by looking both at the trends in abundance and recruitment and at what is happening to the spatial distribution of the catch. The techniques available to answer these questions are determined by the type of data we need.

Common Techniques. In principle, there is no way to evaluate how a population responds to exploitation without measuring relative changes in stock size over time. The common approach is to look at the evolution of catch per unit of effort as the fishery progresses, assuming that the unit of effort takes a catch proportional to the stock present in the fishing area. Tagging studies are also used to estimate abundance and exploitation rates, giving point estimates.

Recruitment may be inferred from the age composition of the catch, by back-calculating the recruitment rate from the catch history of an age class (cohort), or by fitting an average catch curve through the same data and finding the number of fish alive at the beginning. Ancillary techniques have evolved to use the same methods with length-frequency data, assuming that growth is uniform among cohorts.

Finally, there are several techniques to estimate the relationships between catch and the exploitation rate. One such method is to assume that all natural processes combine to produce a net positive rate of biomass (tonnage) growth, called surplus production, which is the amount that should ultimately be harvested by the fishery. Another approach is the yield-per-recruit analysis, which predicts how the cumulative catch from one age class varies in relation to exploitation.

It is beyond the scope of this discussion to cover these methods in more detail. Suffice it to say that they all make a certain number of assumptions which are often difficult to sustain.

Data Requirements. The afore-mentioned techniques to estimate abundance, especially tagging studies, rely on complete catch-and-effort statistics, including an estimate of total catch. The definition of effort is particularly important for the analysis of catch-per-effort

trends and it needs to be standardized for the various gears and techniques. To do so requires information on gear configuration that is available only from log sheets or through extensive observer programs. The spatial distribution of catch (abundance), which is also used for this purpose, requires complete statistical coverage of the various fisheries.

The other methods for estimating various parameters, such as recruitment, can be estimated from age composition data. Yield-per-recruit analysis also requires weight at age and the catch at age. Finally, the estimation of mortality may be obtained from length frequencies, age distribution of the catch, or tagging data.

From this short discussion, it is apparent that our data needs have not changed. Basically, unless there has been a significant improvement in data collection and coverage, we are still confronted with the same problems today as 10 years ago.

Today's Situation

The problems associated with the assessment of billfish stocks can be classified in two categories, one inherent to the nature of the fishery and the other to the availability of the data. The problem with the nature of the fishery is the fact that, except for recreational fisheries and some species like striped marlin *(Tetrapturus audax)* and swordfish *(Xyphias gladius),* billfishes are mostly non-target species. The greatest part of the catch is incidental to the tuna longline fishery and to a lesser extent to the purse-seine and gillnet fisheries. It is therefore difficult to determine which part of the fishing effort is being applied to billfish stocks and to interpret variations in apparent catchability. The competition between the different species of billfish for longline hooks compounds the problem, further confounding the interpretation of catch-per-effort statistics.

The adequacy of longline statistics to measure relative abundance in itself can also be questioned. One study suggested that, for bigeye tuna *(Thunnus obesus),* areas of higher catch rates corresponded to areas where the hook depths coincided with layers of optimum temperature and dissolved oxygen content above the requirements of that species, and therefore that they were not necessarily representative of areas of greater fish concentration (Hanamoto 1987). This problem is even more acute for billfishes, which are seldom the targeted species; we cannot or should not infer relative distribution or abundance from longline statistics alone. We need independent evidence from tagging and biological studies to identify stock structures, habitat preferences, and possible migration patterns before we can determine which sections of the different populations are vulnerable to various gears and thus compute the effective effort. In most cases, this information is not available or is poorly documented.

There has also been a shift to deeper longline gear since the late 1970s, which places most hooks below the mixed layer depth where most billfish occur (Sakagawa 1987, Yang and Gong 1986). These latest statistics are even less likely to be representative of the effective effort exerted on billfishes. The existing methods to adjust and standardize fishing effort require more detailed analysis based on the knowledge of gear configuration and target species. Such data have been available for subsets of a particular fishery and have allowed the estimation of relative efficiency between gear configurations (Yang and Gong 1986; Gong et al 1986; Honma 1974). They have been found deficient, however, when attempting a complete stock assessment analysis, and it was recommended that all fishing nations collect them in a systematic fashion, and report to a single agency (Conser et al 1985).

We now come to the problem of data availability. Complete catch statistics, notably total catch, are often not collected. The purse-seine catch form currently in use in the western Pacific (Fig. 2) contains no provision for recording billfish bycatch. A more detailed form (Fig. 3), that has yet to be implemented, will record billfishes only as a group. Even for longline catch forms, a recurring problem has been the nondiscrimination among some species, more often sailfish and spearfishes but sometimes also blue marlin *(Makaira nigricans)* and black marlin *(Makaira indica),* because these species are often lumped under the same category. Data from specialized fisheries like those for swordfish or recreational fisheries may not be collected regularly or rigorously and, as such, may not be available or be of little use to scientific analysis.

Incomplete statistical coverage of the fleets, particularly in the high seas areas, is a major obstacle to a full analysis of the spatial distribution of the fishery which, in turn, precludes the computation of effective effort and thus the es-

PURSE SEINE VESSEL - CATCH REPORT FOR WATERS OF .....

	NAME		YYMMDD
DEPARTURE FROM PORT		DATE	
ARRIVAL AT PORT		DATE	

VESSEL NAME _____ LICENSE/PERMIT NUMBER _____

COUNTRY OF REGISTRATION _____ NAME OF CAPTAIN _____

REGISTRATION NUMBER _____ LICENSE/PERMIT HOLDER'S SIGNATURE _____

GROSS REGISTERED TONNAGE _____

NAME(S) OF FISH CARRIER(S) FOR GROUP PURSE-SEINER _____ YEAR _____ MONTH _____

NUMBER OF CREW	

DAY	NOON OR SET POSITION				SCHOOL TYPE	TIME SET	SKIPJACK		YELLOWFIN		OTHER SPECIES			COMMENTS	DISCARDS		
	LAT		LONG				CATCH (mt)	AV. SIZE (kg)	CATCH (mt)	AV. SIZE (kg)	SPECIES NAME	CATCH (mt)	AV. SIZE (kg)		TUNA (mt)	OTHERS (mt)	REASON FOR DISCARD
	DDMM	N S	DDDMM	E W													
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					( )									( )			( )
TOTAL																	

NUMERICAL EXPRESSION OF SCHOOL TYPE, COMMENTS, AND REASON FOR DISCARD

****

SCHOOL TYPE

1 Log
2 Surface
3 Whale
4 Porpoise
5 Raft
6 Other

COMMENTS

1 A full day in transit between fishing grounds or to or from fishing grounds.
2 A full day not fishing due to breakdown.
3 A full day not fishing due to bad weather.
4 A full day searching for fish but no sets made.
5 Part of day searching for fish but no sets made.
6 Set unsuccessful for any reason, e.g. fish dive, roll up.

REASON FOR DISCARD

1 Undesirable species
2 Fish too small
3 Vessel completely loaded
4 Other reason - please specify

.....

Figure 2. Standardized log sheet to report purse-seine catches in the western Pacific.

PURSE SEINE VESSEL

CATCH REPORT FOR THE WATERS OF _____ YEAR_____ LOGSHEET #

Vessel Name : _____
Country of Registration : _____
Vessel Registration Number : _____
Gross Registered Tonnage : _____
Length of Net : _____ Depth of Net : _____
Number of Crew : _____
For Group Seiner,
Name(s) of Fish Carrier(s) : _____

Licence/Permit No : _____
Name of Captain : _____
Name of Fishing Master : _____
Licence/Permit
Holders Signature : _____

Aerial Assistance ☐ Helicopter ☐ Airplane ☐ None

FISH WEIGHT UNITS Tick (✓) one box

	Size Range	CATCH Wt
	lbs	short tons
	kg	metric tonnes

DATE

	PORT NAME	YY	MM	DD
DEPARTURE PORT				
UNLOADING PORT(S)				
ARRIVAL PORT				

NOTE : Please record all sets, even for no catch

DATE MM DD	Beaufort Scale	Sea Surface Temp.	Vessel Search Time hrs.	Aerial Search Time	Activity (code)	SET No.	Set or Noon Position: Latitude DD MM M N S	Longitude DDD MM M E W	School Type (code)	Time Set (local)	SKIPJACK: CATCH Wt	SKIPJACK: Size Range (Wt)	YELLOWFIN: CATCH Wt	YELLOWFIN: Size Range (Wt)	BIGEYE: CATCH Wt	BIGEYE: Size Range (Wt)	OTHER SPECIES: Species Codes	OTHER SPECIES: CATCH Wt	WELL NOS.	DISCARDS: TUNAS Species	DISCARDS: TUNAS Wt	DISCARDS: Billfish No.	DISCARDS: Others Wt
						1 or noon																	
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						1 or noon																	
						2																	
						3																	
						TOTAL CATCH																	

ACTIVITY CODES :

0 – A day in which a set was made.
1 – A full day in transit.
2 – A full day not fishing due to breakdown.
3 – A full day not fishing due to bad weather.
4 – A full day searching for fish but no sets made.
5 – Partial day searching but no sets made.
6 – Any other reason for no sets.

SCHOOL TYPE CODES

1 – Foamer/Boiler
2 – Rippler/Breezer
3 – Birds only
4 – Natural log/debris
5 – Free floating raft/payao
6 – Anchored raft/payao
7 – Animals (whales, shark)
8 – Other

SPECIES CODES FOR "OTHERS" AND "DISCARDS"

KAW – Kawakawa, Mackerel Tuna
FRZ – Frigate Tuna, Bullet Tuna
DOT – Dogtooth tuna
ALB – Albacore
RRU – Rainbow Runner
DLF – Dolphinfish, Mahimahi
WAH – Wahoo
SHK – Shark
YFT – Yellowfin Tuna
SKJ – Skipjack
BET – Bigeye
BIL – Billfish
OTH – Other Species

Figure 3. Proposed log sheet to report purse-seine catches in the western Pacific.

timation of abundance indices. In the western Pacific for instance, the regional longline database compiled at the SPC is mostly comprised of statistics from Japan, alone, and covers only about 50 to 60% of the total activity (Anon 1986). If we consider the total catch figures published by FAO for statistical areas 61, 71, 77, 81 (minus Philippines and Indonesia) (Anon 1985) as indicative of the total catch for the entire Pacific, SPC holdings for 1984, which provided fairly representative coverage, comprised only between 1 and 23% of the billfish statistics depending on the species. Since few agencies may have reciprocal arrangements to obtain raw data from other sources, and since most fishing nations have discontinued publishing their statistics after 1981 except for total catch figures, it is unlikely that any one organization can have a complete coverage or time series. A cursory look at the literature seems to indicate similar situations in other areas, maybe better in the Atlantic ocean under the auspices of the long established ICCAT but probably worse in the Indian ocean where the centralization of data has only just begun. We are thus faced with the assessment of a resource, billfishes as a group, for which the data may be collected but are not often centralized.

These limitations have confined the assessment of billfish stocks to the analysis of catch rate trends and production models, based on subsets of the longline fishery and estimates of oceanwide catches (Anon 1981b, Shomura 1980, Wetherall et al 1979, Joseph et al 1974). These procedures, however, rely on computed estimates of total catch and effective effort, and the results depend on the extent to which assumptions about relative mortalities can be sustained. Their applicability, particularly to nontarget species, may thus be questioned.

More powerful techniques such as virtual population and yield-per-recruit analyses require estimates of growth and mortality that can be computed from length-frequency data coupled with complete catch data. This latter analysis is probably the most useful technique available to evaluate management options. It has been used successfully for the Atlantic swordfish fishery (Conser et al 1985), making a strong case for the extensive collection of length measurements. It is particularly important to monitor the harvest of small individuals as it may occur in the purse-seine or gillnet fisheries. Indeed, traditionally only the larger (older) fish have been harvested and, although it may be argued that catches were not optimized, the stocks were not then, at least in the biological sense, in any danger of collapsing. If a significant proportion of the younger fish were to be removed, it could conceivably reduce the recruitment to larger sizes, as is feared for the yellowfin tuna *(Thunnus albacares)* and bigeye tuna, which would not be apparent with the methods currently employed. Furthermore, the direct implications of different management strategies that may be implemented in that case can be evaluated only through yield-per-recruit analysis. The availability of length frequencies more than the lack thereof and the incomplete statistical coverage have prevented the systematic use of this method so far.

Still, the best techniques available cannot be applied indiscriminantly and further knowledge of stock structure is a prerequisite to the identification of the unit stocks to be managed. The limitations of catch statistics to represent the spatial distribution of the population have already been presented, and it can only be repeated that they should not be used alone. Tagging studies that have otherwise provided too few recaptures for stock assessment purposes would be instrumental in that respect.

Conclusions

Although there has been some progress in data coverage and acquisition over the last ten years, principally with respect to the biology of the species, it appears that for most species the data requirements for in-depth analyses are still not met. The current evaluations based on trends in catch rates and surplus production analyses can provide only the roughest estimates of the statuses of the different billfish stocks and warrant further efforts in the systematic collection of length frequencies for application in more robust methods. Considering that most of the information is likely to be available from various sources, the situation may not be as bleak as it seems. It does however ascertain the need for consultation between research agencies and other data holders for a more comprehensive inventory of the data, arguing for the need to perform joint analyses of complementary sets.

Summary

Drawing on the example of the south Pacific Ocean, this chapter first reviewed the extent of statistics typically collected in a billfish fishery, their sources, and their availability. Catch-and-

effort statistics have been collected as part of longline fisheries data for many years. They are processed and often published by the fishing nation and/or regional or research organizations and, as such, should be accessible. Because of the nature of the longline fishery, unloading records have been kept in many areas, often coupled with port sampling. These data concerning total catch and length frequencies are generally in the custody of fishing associations or research organizations but are seldom available in raw format. In addition, there is a growing body of catch statistics generated by recreational fisheries.

In the past, data have been found limiting because of their incomplete coverage, lack of standardization, nondiscrimination among some species, or simply because they were not available. In order to evaluate the adequacy of the current statistics, it is necessary to determine which management questions have to be answered, which stock assessment methods are appropriate, and what are their respective data needs.

Assuming (from previous assessments) that the billfish fisheries are fully exploited to overfished, the question, whether effort should be expanded/reduced (and how), was addressed. The primary stock assessment concerns are, therefore, whether current yields are sustainable, what are the trends in abundance and recruitment (is yield per recruit maximized?), and what is happening to the spatial distribution of the catch. The common techniques applied to estimate the necessary parameters rely on catch-and-effort statistics, length distribution, and length at age information.

There are some inherent problems with the information collected to date that have precluded all but the coarsest estimations. Foremost is the fact that billfish are mostly non-target species in longline and other fisheries and that complete catch statistics, notably total catch, are seldom collected. Also, the interpretation of billfish catch per unit of effort is confounded by the fact that effort is targeted at other species, certainly resulting in unpredictable variations in apparent catchability. The existing methods to adjust these statistics require more detailed information than is readily available. Incomplete statistical coverage of the fleets, particularly in the high-seas areas, is a major obstacle to a full analysis of the spatial distribution of the fishery. In the Pacific, for instance, regional longline statistics, the majority of which come from a single flag, cover only about 50 to 65% of the total activity, thereby rendering a biased picture of the fishery. Length-frequency data collected on a regular basis, coupled with complete catch data, would if available provide powerful tools for the estimation of mortality and, ultimately, yield per recruit.

Although there has been some progress in data coverage over the last ten years, principally with respect to the biology of the species, most of the data needed for stock assessment and management purposes thus remain unavailable, precluding in-depth analyses. This situation therefore highlights the need for consultation among research agencies for the joint analysis of complementary data.

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Vital Rate Statistics for Billfish Stock Assessment

Christofer H. Boggs

Growth, mortality, recruitment, and migration rates are sometimes called "vital" statistics because they are "life" history parameters used in population dynamics models. Since the previous symposium (Shomura and Williams 1974, 1975) and the Pacific billfish workshop in 1977 (Shomura 1980), many studies have been conducted on billfish vital rates, concentrating mostly on age and growth rates. Analysis of hardpart markings has advanced growth rate estimation beyond the old method of following length-frequency modes through time. Billfish stock assessments making use of age and growth data have, however, been limited to western Atlantic stocks of swordfish *(Xiphias gladius)* and Atlantic sailfish *(Istiophorus albicans)* (Conser 1984, SEFC 1987). Much of the available data on billfish vital rates have not been utilized. This chapter compares some new vital rate estimates with older ones and examines their adequacy for stock assessment.

Growth Rates

Methods of Estimating Growth

All approaches to estimating growth have major limitations, as applied to billfish. These limitations must be addressed because different approaches (Table 1) have not produced similar results. Analysis of length-frequency modes has been applied to most species. This method is relatively easy, but it depends on assumptions not met for most billfish. Length-frequency modes do not represent age classes unless the spawning season is distinct, no mixing occurs for fish with different growth rates or from different spawning seasons, and the length sampling process is not selective. Each sequential length-frequency sample must be collected over a short time frame, or growth will blur the modes. When these conditions are met, growth rate estimates are specific to the size of the modes analyzed, but actual age is still not known. To construct a growth curve showing growth as a function of age (e.g., Atlantic swordfish, Fig. 1), it is necessary to assume that the mode for the smallest fish represents a given age (in this case, 1 year old). An additional problem with constructing growth models from length-frequency data is that, as growth slows with age, the modes becomes indistinguishable.

The tag-and-recapture method of estimating growth is compromised by the lack of age determinations or precise sizes of billfish at tagging. Estimates of change in size divided by time since tagging and release provide growth rates for specific sizes of fish that can be useful in verifying results from other methods (Conser 1984). Unfortunately, the weight at tagging is often estimated visually, so individual growth estimates are often wrong and frequently negative (SEFC 1987). The justification for the method is that, on average, no systematic bias exists in the estimated weight at release. As more tournaments encourage the tagging and release of billfish, promoting better methods of estimating initial size might be advantageous. Such methods could include the use of measured streamers, slipped onto the leader to trail alongside the fish, and photography. The remaining problem is that age is not known. Fitting an age-specific growth model to tag-and-recapture growth data requires assumptions about age and assumptions about how growth rate changes with age (the form of the model). For example, for Atlantic swordfish (Fig. 1), a model was used that assumed an increasing growth rate phase early in life and a diminishing growth rate phase later in life (Gompertz model; SEFC 1987). It was also assumed that age 0 fish were 1.4 kg (3 lb) dressed weight.

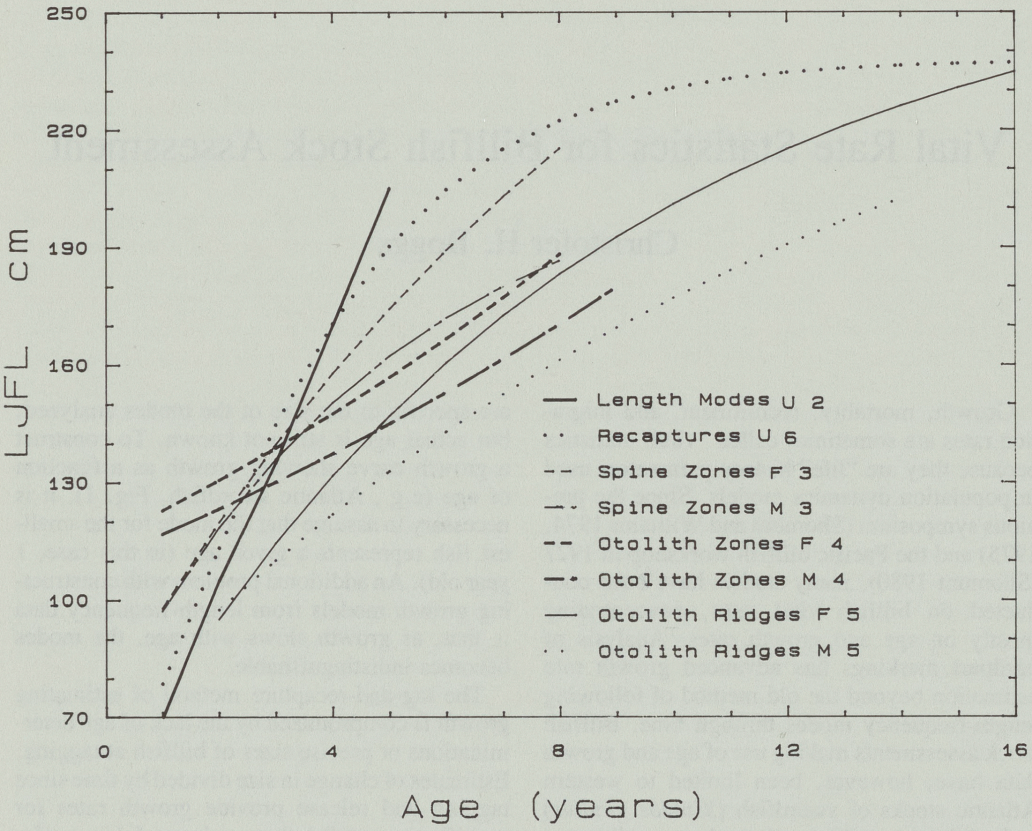

Figure 1. Length (LJFL = lower jaw to fork length) versus age curves for swordfish *(Xiphias gladius)*. Numerals in the key refer to literature in footnote 3 of Table 1. M = male, F = female, and U = unknown or unreported.

Biologists have been reluctant to use age-specific growth rate models based on billfish hardpart studies because of a lack of verification and a near absence of validation. Verification is agreement between age estimates from one method, or source of material (i.e., hard parts), and those from another. Validation is proof that a count of hardpart markings equals the measured passage of time (i.e., time since hatching or since the hard parts were chemically marked). Thorough validation is proof that, throughout the life of the animal, hardpart markings are deposited at regular intervals (i.e., one per day or per year). Marginal increment studies to establish the periodicity of growth mark formation on billfish hard parts have not yet produced definitive results (Berkeley and Houde 1983, Prince et al 1987). Failed attempts to verify billfish hardpart age estimates have usually involved counts of large-scale internal zones observed in spines compared with some other hardpart estimate (Radtke and Hurley 1983, Prince et al 1986, 1987). Spine zone counting is popular because spines are easily removed and cause little damage to marketable fish, but spines contain living tissue that can resorb inner zones. A method of estimating missing zones based on spine diameter appears to resolve this discrepancy (Hill 1986). Verification has been obtained by using fine-scale increment counts across the entire radius of otoliths for two adult swordfish, aged 6 and 9 years old based on external otolith ridge counts (Radtke and Hurley 1983). The daily addition of fine-scale increments in otoliths has been validated in many tropical species, including yellowfin tuna *(Thunnus albacares)* (Wild and Foreman 1980). So, although extremely small and difficult to remove, billfish otoliths are useful indicators of age.

A few good validations of annual marks or daily fine-scale increments in billfish hard parts

could remove much of the skepticism that has kept a large amount of age and growth research (Table 1) from being applied to stock assessment. The reluctance to apply growth curves based on hardpart aging data is not appropriate, considering that growth curves based on other approaches which have been applied are equally unproven. There is a single validation of a billfish age estimate: An Atlantic sailfish recaptured 10.8 years after being tagged as a 2- to 4-year old had 13 external otolith ridges (Prince et al 1986). Validation in billfish hardpart aging

Table 1. Billfish growth and mortality rate estimates. Von Bertalanffy growth parameters were taken directly from the literature or from analyses of data therein (see Shomura 1980). Natural mortality rates (M) were calculated from K using the equation of Murphy and Sakagawa (1977).

Locality	Method	No.	Sex[1]	Size range[2] (cm)	Source[3]	Growth parameters K	t_0	L_∞	M
				Swordfish					
Pacific	Length modes		U	61-245	1	0.124	-1.169	309 cm	0.22
Atlantic	Length modes and vertebrae		U	50-260	2	[4]0.230		[4]365 cm	0.43
	Anal spine	275	M	70-270	3	0.19	-2.04	217 cm	0.35
	internal zones	164	F			0.09	-2.59	340 cm	0.15
	Otolith	39	M	79-209	4				
	internal zones	39	F	102-290					
	Otolith ridges	73	M	88-208	5	0.07	-3.94	277 cm	0.12
		195	F	80-270		0.12	-1.68	267 cm	0.21
	Tag recapture	66	U	100-270	6				
				Pacific sailfish					
Pacific	Length modes	51,000	U	140-210	7	0.472		232 cm	0.90
				Atlantic sailfish					
Atlantic	Length modes	8,630	U	1-201	8	0.901	-0.496	243 cm	1.73
	Otolith ridges	64	U	102-184	9				
	Dorsal spine	259	M	80-186	10	0.301	-1.959	184 cm	0.56
	internal zones	310	F	86-198		0.159	-3.212	230 cm	0.29
	Tag recapture	59	U	100-180	11	Same as dorsal spines.[5]			
				Striped marlin					
Pacific	Length modes		U	120-235	12	0.264		275 cm	0.49
	Length modes	16,898	M	108-171	13	0.417	-0.521	206 cm	0.79
		13,532	F	108-175		0.696	0.136	186 cm	1.33
				Pacific blue marlin					
Pacific	Length modes	1,327	M	93-212	13	0.285	0.106	276 cm	0.53
		1,757	F	78-289		0.116	-0.161	505 cm	0.21
	Otolith ridges	7	M	165-191	14				
		7	F	217-294					
				Atlantic blue marlin					
Atlantic	Otolith ridges	8		87-136	15				
	Otolith and	10	M	82-157	16				
	dorsal spine	4	F	110-133					
	internal zones	6	U	82-140					
				Black marlin					
Pacific	Length modes		U	150-250	17	0.474		282 cm	0.90

[1] M = male, F = female, and U = unknown or unreported.

[2] Atlantic swordfish and Atlantic sailfish data are given in lower jaw fork length. All other data are given in eye to fork length. Transformations between size measurements are in Royce (1957) for Pacific marlin, Lenarz and Nakamura (1974) for Atlantic marlin, and Jolley (1977) for Atlantic sailfish.

[3] Sources: 1. Yabe et al. (1959), 2. Caddy (1976, 1977), 3. Berkeley and Houde (1983), 4. Wilson and Dean (1983), 5. Radtke and Hurley (1983), 6. SEFC (1987), 7. Koto and Kodama (1962a), 8. de Silva (1957), 9. Radtke and Dean (1981), 10. Hedgepeth and Jolley (1983), 11. Conser (1984), 12. Koto (1963), 13. Skillman and Yong (1976; all age groups, model 1), 14. Radtke (1983), 15. Radtke et al. (1982), 16. Prince et al. (1987), 17. Koto and Kodama (1962b).

[4] These estimates of K and L_∞ from Caddy (1977) do not match the size at age groups given in Caddy (1976). Midpoints of the age groups in Caddy (1976) were used to plot the curve in Figure 1.

[5] Conser (1984) refit the data of Hedgepeth and Jolley (1983) using nonlinear regression, and the results were much more similar between males ($K = 0.1947$, $t_0 = -3.168$, $L_\infty = 199.4$ cm, $M = 0.358$), and females ($K = 0.1967$, $t_0 = -2.842$, $L_\infty = 210.4$ cm, $M = 0.362$).

studies is extremely difficult because maintaining billfish of any age in the laboratory is not possible and injecting chemicals for marking hard parts is difficult during tagging. Newly available methods for injecting chemical markers into billfish from a distance with dart guns or syringes on the ends of sticks should help solve this problem.

Comparison of Growth Estimates

A difference in billfish growth rate by sex is usually seen when both sex and age are determined. Unfortunately, a lack of sex data for the catches makes it impossible to apply sex-specific growth curves in stock assessments (Conser 1984, SEFC 1987). The faster growth of females compared with males is clear in hardpart estimates for swordfish (Fig. 1) and Pacific blue marlin *(Makaira mazara)* (Fig. 2) but less distinct in Atlantic sailfish and in length-frequency mode estimates for Pacific blue marlin and striped marlin *(Tetrapturus audax)* (Table 1).

Growth rate differences between stocks within a species are not evident in a casual comparison of swordfish growth curves estimated from length-frequency mode data. After eye to fork length curves from the Pacific (Yabe et al 1959) and tropical Atlantic (Ovchinnikov et al 1980) are converted to lower jaw to fork length curves, they appear similiar to the data from the western Atlantic (Caddy 1976). Blue marlin age data from the Pacific, based on otolith ridge counts, barely overlap with data from the Atlantic (Fig. 2). Making comparisons between single growth parameters such as *K, to* and *Loo* can be misleading since they are not independent. The parameters are listed (Table 1) to update a previous summary (Shomura 1980), but comparisons are made between actual length at age estimates from the models (i.e., Figs. 1 and 2).

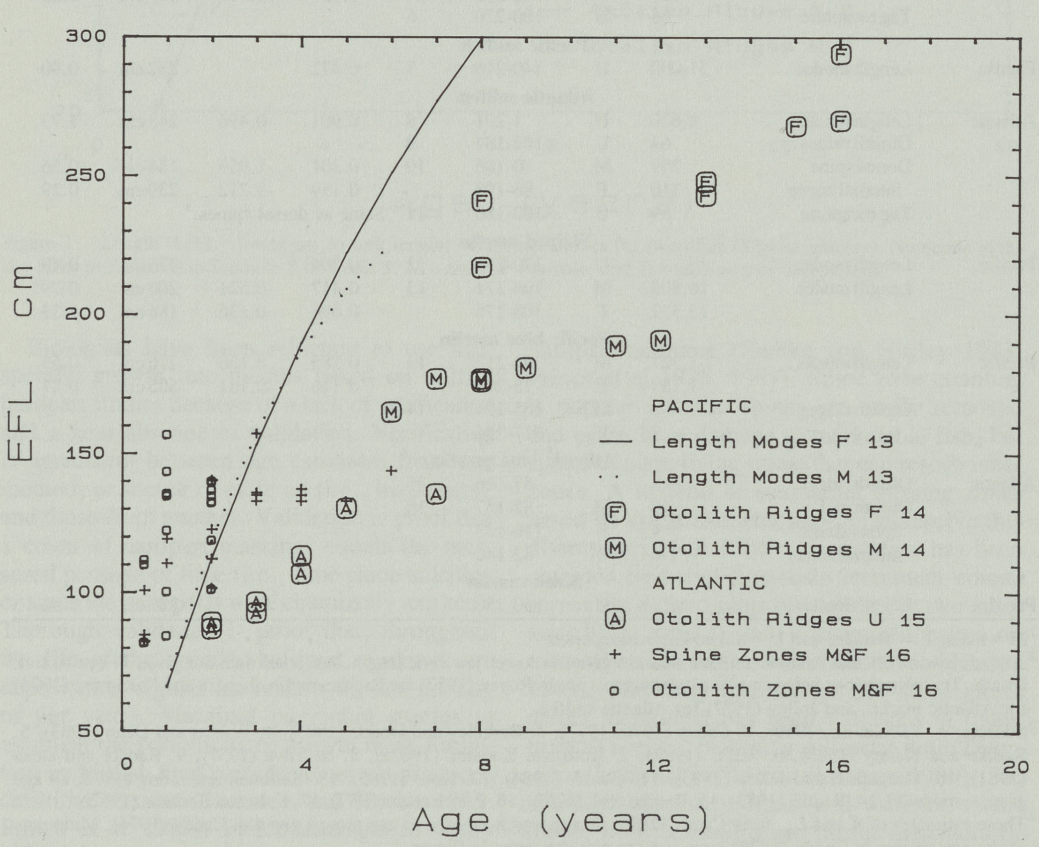

Figure 2. Length (EFL = eye to fork length) versus age data for Pacific blue marlin *(Makaira mazara)* and Atlantic blue marlin *(M. nigricans)*. Numerals in the key refer to literature in footnote 3 of Table 1. M = male, F = female, and U = unknown or unreported.

A comparison between Atlantic blue marlin *(M. nigricans)* and Pacific blue marlin is not a "stock" comparison since two separate species are now recognized (Nakamura 1985). Age-at-size estimates from Atlantic blue marlin otolith ridge counts barely overlap with those from Pacific blue marlin (Fig. 2).

Some of the discrepancies resulting from different approaches to estimating growth are too consistent to be due to true variation in the growth of the species caused by environmental and physiological variables (e.g., feeding, temperature, activity). Adult growth rates estimated from length-frequency mode analysis are always the fastest, and those from hard parts are always the slowest (Table 1), with tag-and-recapture estimates matching the length-frequency estimates in one case (swordfish; Fig. 1) and matching the hardpart estimates in another (Atlantic sailfish; Conser 1984). The slowest growth rates in adult swordfish (Fig. 1), Atlantic sailfish (Table 1), and Pacific blue marlin (Fig. 2) have been estimated from hard parts. The only validated datum (an Atlantic sailfish; Prince et al 1986) and the only study verified with complete fine-scale otolith increment counts (swordfish; Radtke and Hurley 1983) indicate that adult billfish are much older than estimated from other methods. In contrast to the slow growth in adult billfish indicated by hardpart studies, hardpart age estimates suggest that very young billfish grow much faster than indicated by other methods (Figs. 1 and 2).

Mortality Rates

Using Age and Growth Data

With growth curves (age-length relationships) and population length-frequency distributions, age-structured models can be used to estimate the proportion of fish being harvested, the annual variation in this proportion, and the effect on yield of changing the size of fish caught. However, even if growth curves are available, the inadequacy of data on length frequency, catch, and effort can prevent adequate stock assessments. Without vital rate statistics, analysis of catch and effort data can indicate only the level at which increasing fishing effort begins to produce a decrease in catch.

The most important application of growth models is the estimation of mortality rates which, in turn, are useful in determining sustainable yield. Total mortality *(Z)*, which is the rate of removal of fish from a population through fishing mortality *(F)* and natural mortality *(M)* combined *($F+M=Z$)*, can be estimated from the age distribution in the population, as determined from the length-frequency distribution and a growth curve. With additional data on the catch, or with independent estimates of *M*, it is possible to separate *F* from *M* (Gulland 1983). As a rule of thumb,the level of catch may be sustainable if *$F<M$*, but the stock may be overexploited if *F* is *$\gg M$*. Together or individually, fishing and natural mortality can remove more fish from the population in a year than are present at any given time. *(F, M,* or *Z* can be *>1.0)* if the population is constantly replacing biomass through recruitment and growth. In other words, a *Z* estimate of 1.5 means that 1.5 times the standing stock of fish die or are caught each year (under certain equilibrium conditions).

Estimating the average age of fish in the population is the simplest way to estimate *Z*, because the older all the fish are, the lower the mortality rate must be. The average age can be estimated from average age of the catch, adjusted by the age at first capture. Thus, *Z* can be estimated from the average length caught, adjusted by the size at first capture, using a growth curve to translate length into age. Other more complex procedures for estimating *Z* are based on the same idea (Gulland 1983). It is also possible to estimate *Z* from length-specific growth curves obtained from tag-recapture data and length-frequency data, without actually knowing true age (Wetherall et al 1987).

Adequate Accuracy and Precision

The accuracy of billfish age-length relationships is in doubt. How accurate do they need to be, and how much random error is acceptable? According to Powers (1983), who simulated the effects of bias and random error in assigning ages to length data, increasing lack of precision (random error) of up to 1 to 5% in assigning ages increases the standard error of *Z* estimates (in simulation), whereas increasing lack of precision in assigning age beyond 1 to 5% has only a slight effect on the standard error of *Z* estimates. Sample size (number of fish aged) has a much greater effect on the standard error of *Z*. Bias (inaccuracy) in assigning ages leads to a roughly equivalent opposite bias in *Z*.

The yield-per-recruit analysis for Atlantic sailfish by Conser (1984) is an example of the state of the art in age-structured billfish stock assessment: His *Z* estimates are from a variety

of analytical methods applied to the same age and size-frequency data and cover a range equal to about 25% of the mean. This suggests biases no larger than those inherent in various analytical methods (25%) may be achieved with biases of up to about 25% in assigning ages, based on simulations in Powers (1983). Unfortunately, the disparity between ages given by various growth curves for billfish is often much greater than 100% (Table 1; Figs. 1 and 2). Thus, it is important to determine which growth models are correct.

Using Deterministic Growth Curves

Using a growth curve to assign ages by size results in assigning a single nonvariable age to a given length whereas, in reality, the ages of fish of a given size always vary. A biased age distribution results (Bartoo and Parker 1983). The worst case results when fish approach the asymptotic size given in the growth curve. In these slow-growing, older fish, size changes very little with age but does vary between individuals, so that many fish are actually larger than the theoretical maximum. These fish cannot be assigned an age by using a deterministic growth curve. Bartoo and Parker (1983) addressed this problem and recommended a stochastic method using estimated probabilities of various lengths at age. Unfortunately, this method was not used for either of the age-structured billfish stock assessments conducted to date.

Estimating Natural Mortality

Natural mortality *(M)* can be estimated from length-frequency data by using growth curves to assign age, as described above, but the length-frequency data must be from an unexploited population, i.e., when F is negligible and Z equals M. It is also possible to estimate F and M from tag-and-recapture data. However, data from unexploited populations or adequate tagging data are rarely available, so that models have been developed to estimate M directly from growth curve parameters (Murphy and Sakagawa 1977, Pauly 1980). The ideas supporting these models are that each species (or population or sex) has evolved growth and reproductive characteristics that balance a given M, providing the maximum possible reproductive success. Faster growth and reproduction have evolved in tandem with a high M. Slower growth and repro duction are more efficient when M is low. One model has included environmental temperature as a factor that increases M (Pauly 1980).

These models are poor substitutes for real information on natural mortality, which is almost completely lacking. However, Conser (1984) used both models (Murphy and Sakagawa 1977, Pauly 1980) and preexploitation length-frequency data on Atlantic sailfish to estimate M and found that all three were remarkably similar. I calculated a model estimate of M for each available von Bertalanffy K estimate (Table 1) using the model of Murphy and Sakagawa (1977). Pauly's (1980) method requires an estimate of asymptotic size (i.e., L_∞). Since length measures are problematic for billfish, the best choice would be asymptotic weight W_∞. Some estimate of the mean environmental temperature for each species would also be required.

Mortality Estimates and Stock Assessment

More age-structured billfish stock assessments are needed, and the two that were done should be reexamined in light of new growth rate estimates. For western Atlantic sailfish, Conser (1984) concluded that fishing mortality ($F = 0.338$), estimated from the difference between Z and M, was moderate and that the exploitation rate was sustainable. His yield-per-recruit analysis demonstrated that the size of fish being caught was larger than necessary to prevent growth overfishing. Conser (1984) used a growth curve based on dorsal spines (Hedgepeth and Jolley 1983) to estimate Z (0.674 from length-frequency distribution of the exploited stock) and M (0.336 from the pre-exploitation length-frequency distribution of the stock). Conser (1984) did not use an available growth curve based on otolith ridge counts (Radtke and Dean 1981). The otolith growth curve was not significantly different from the spine-based growth curve. The implications of the much greater estimate of Prince et al (1986) for sailfish longevity, however, based on a validated otolith ridge count, need to be examined.

Estimates of total mortality *(Z)* from tag recaptures can be used to check estimates derived from growth curves and length-frequency data. Decline in tag recovery rates over elapsed time since tagging is caused by Z. Tag-recovery Z estimates for western Atlantic sailfish (Conser 1984) ranged from 0.688 (corrected for tag shedding) to 1.11 (assuming no tag shedding). The corrected estimate was almost identical to the estimate used in the stock assessment (Conser 1984). Total mortality *(Z)* was estimated from

tag recovery rate data on white marlin *(Tetrapturus albidus)* by Mather et al (1974), but no growth parameter estimates exist for comparison.

Age-structured stock assessments for marlins are nonexistent. Estimates of Z and M for striped marlin were given in Shomura (1980), who estimated $Z = 1.94$ (males) and $Z = 1.38$ (females) based on growth curves from Skillman and Yong (1976) and size-frequency data from the Hawaii longline fishery (Yoshida 1974). Assuming theoretical values for M (Table 1), I calculated F values of 1.15 (males) and 0.05 (females). These values seem unrealistic. The only mortality estimates for black marlin *(Makaira indica),* or Atlantic or Pacific blue marlin are theoretical M estimates (Table 1).

The most elaborate age-structured billfish stock assessment to date was done on western Atlantic swordfish (SEFC 1987). "Virtual population analysis" (VPA) was used to estimate the number of fish present in past years, annual fishing mortality from the annual catch, and the annual number of survivors. The annual number of survivors can be estimated by working backwards, using an assumed constant M to estimate the fraction that died of natural causes each year and knowing the number caught each year. One must start with an estimate of the total number in the population, which can be calculated from M and the most recent catch by guessing the most recent annual value of F (terminal F). One also has to know the age distribution of the fish caught each year. Two "reasonable" estimates of M (0.1 and 0.2) used by SEFC (1987) were similar to theoretical M estimates based on K parameters from the otolith ridge count growth curves (Table 1). The growth curve used to age the catch was based on tag-and-recapture data and an assumed size at age 0 (Fig. 1).

The western Atlantic swordfish stock assessment workshop (SEFC 1987) concluded that the stock was not being overfished during 1982-1985. How would different assumptions about growth and mortality rates alter these conclusions? Recent estimates of growth rate are much slower than those used by SEFC (1987), which considered and rejected growth models based on spines (Berkeley and Houde 1983) and did not consider otolith ridge count estimates (Radtke and Hurley 1983). The growth curve based on dorsal spines was significantly different from the curve based on tag-and-recapture data. Consequently, workshop participants decided that, without validation, they could not use the spine data. What if the slower adult growth rate data (Fig. 1) are correct? Slower growth estimates produce lower theoretical M estimates (Table 1). An older population indicates a lower Z. This means the swordfish population would be replacing itself through growth and recruitment more slowly than SEFC (1987) suggests. What effect does a lower turnover rate have on estimates of F and the status of the swordfish stock? It is not necessary to wait until hardpart age estimates are validated to address this important question.

Other Vital Rate Statistics

Research on other vital rates such as migration, reproduction, and recruitment rates is extremely limited. Billfish migration rates have not been quantified, even though they confound estimates of mortality (SEFC 1987) and are critical for management. Instead, tag-and-recapture data have been used to describe qualitative movement patterns. The arrow diagram approach has been used to suggest segregation of stocks for assessment (SEFC 1987) and to explain seasonal changes in catch. However, without attention to the distribution of effort responsible for the recapture of tags, quantitative statements about movement are not possible from tagging data. Future tagging programs should make a concerted effort to monitor the fisheries involved in returning tags.

Miscellaneous information concerning size at maturity, fecundity, seasonality of reproduction, spawning areas, and larval distribution in billfish can be found in Shomura and Williams (1974,1975). The major use of such data for management purposes has been in separating stocks for assessment (e.g., SEFC 1987) rather than estimating reproductive rates or recruitment.

I was not able to find estimates of recruitment for any of the billfish except those resulting from the swordfish VPA in SEFC (1987). Such estimates result only from a concerted effort to analyze extensive size-frequency distribution data. The utility of recruitment rate estimates would be in estimating variation in productivity and in determining stock recruitment relationships in order to set minimal levels for the spawning stock. However, stock recruitment relationships are only one factor affecting recruitment. There is a need to understand the effects of environmental changes and species interactions on all of the vital rates. Current methods tend to assume that vital rates are constant.

Summary

The use of vital rate statistics such as growth and mortality rates in age-structured billfish stock assessments is a relatively recent development. Much work on growth rates has been accomplished recently, but only two age-structured billfish assessments have been made. The availability of size frequency data is a limiting factor. The implications of new estimates of growth rate based on hard parts have not been fully examined. Hardpart estimates suggest much older ages than do earlier studies based on analysis of length-frequency modes and growth of recaptured fish. Mortality estimates based on simulated length-frequency samples, using a growth curve to assign ages suggest that a large variance and considerable bias in age-at-size estimates result in acceptable levels of random error and comparable levels of bias. However, the discrepancies between results of different methods of estimating billfish growth are so large that mortality estimates based on the wrong growth model could be biased by >100%. This level of accuracy is not acceptable. Slower growth and lower mortality rate estimates suggested by hardpart ageing studies indicate a slower turnover rate. The turnover rate is crucial in determining the amount of fishing the stock can sustain.

Age-structured stock assessment efforts have avoided using the most recent hardpart growth estimates because of a lack of validation or verification. Verification is being obtained through new techniques, but validation is extremely difficult for billfish. Increased attention to billfish tagging studies, resulting from the increased participation of sportfishermen, could help resolve the discrepancies between growth estimates. Techniques should be promoted to improve size estimation at tagging and to administer hardpart marking chemicals to validate growth rate estimates. However, it would not be wise to wait for hardpart age validation before examining the implications of much slower growth rates on the status of billfish stocks.

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Strategy For Management Modeling

B.J. Rothschild and C.M. Stagg

Fishery-management modeling techniques generally relate to much simpler situations than those that occur in the real world. Available techniques do not lend themselves to the complex problems of analysis of variability, multiple-species interactions, and multiple cohorts generated by multiple or extended spawning within a single year. Available techniques are difficult to apply to many of the world's complex fisheries, which are characterized by thousands of fishing units, very large numbers of landing sites, and numerous species in the catch.

If the "simple" stock assessment techniques are inadequate, then how can the day-to-day problems of user-group conflicts and bioeconomic optimization be successfully managed? It might be thought that more realistic models could close the gap between available techniques and real-world complexity. The more realistic and necessarily more complex models are difficult to interpret, however, and they may involve estimation schemes that are difficult to implement, as experience has shown.

Closing the gap between the simplicity of available fishery models and the requirements of fishery management in a complex world has led to two approaches. In one, the problem has been ignored and has generally led to suboptimal management advice. In the other, the analyst's intuition is used to close the gap. This has generally led to advice which is good, but possibly restricted in scope.

An alternative is to rejuvenate the idea of fishery management systems (Rothschild 1971, 1973), particularly in the context of recent developments in expert-system technology (Golden et al 1987). This modern approach extends the ideas of management systems into the arena of artificial intelligence, expert systems, and decision-support systems. To lead into a discussion of how the "gap" might be closed, using recent technologies, we consider, (1) the requirements for success in modeling systems, (2) the adequacy of existing models, and (3) the alternatives.

Requirements For Success In Modeling Systems

"Success" can be measured according to criteria which can be distilled into an evaluation of costs and benefits. Typically, costs and benefits refer to the fishery as a whole, not just a "modeling system." A model system that is successful can, however, contribute to increasing the benefit-cost ratio of fishery management for the fishery as a whole by, (1) stimulating the collection and archiving of appropriate data, (2) organizing critical issues relative to management, (3) identifying elements that may be important, but excluded from consideration, and (4) providing a point of departure for new systems development.

What would such a model-system look like? The question highlights the dichotomy between the desirable and the feasible. It is desirable to have a model that takes into account all of the activities of fishery management because, without this breadth, control or evaluation of all of the activities in the context of a total system would be impossible. So little is understood about many fishery-management activities, however, it may not seem useful to incorporate the least understood activities in the system. On the other hand, if all activities could be included, whether they were well understood or not, then the sensitivity of the system as a whole to the least-understood elements could be explored, suggesting possible areas of future research.

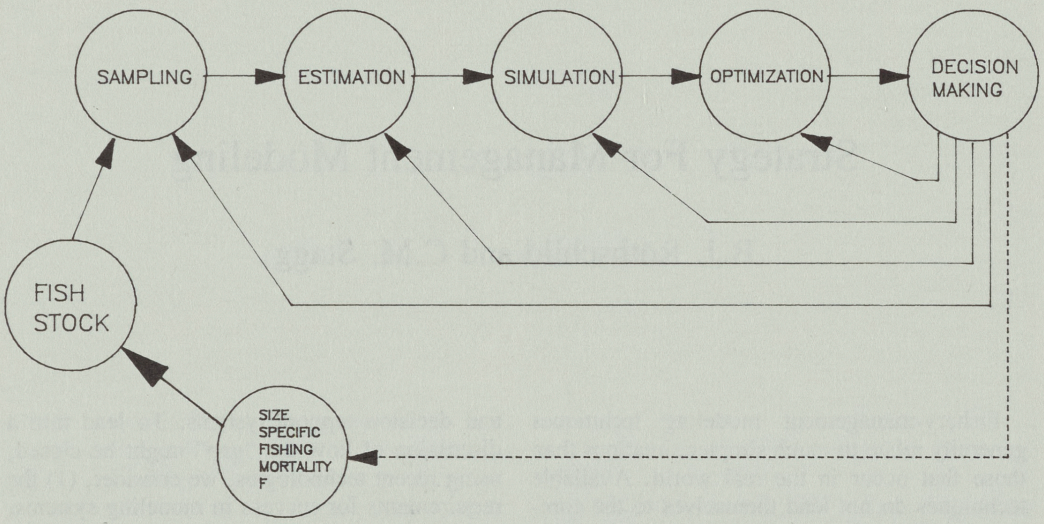

Figure 1. Components of an ideal fishery management system. Three kinds of decisions are involved: (1) decisions on how size-specific effort should be related to the stock (heavy arrow), (2) decisions on the nature of size-specific effort (dashed arrow), and (3) decisions on the dynamics, structure, and interrelationships of sampling, estimation, simulation, optimization, and decision-making components. It is important to recognize that decisions on the interactions among activities are often not included in approaches or systems involving management.

As a point of departure then, let us consider a "desirable system" as a system that includes all fishery-management activities. These are: (1) sampling, (2), estimation, (3) simulation, (4) optimization, and (5) decision making (Fig. 1). The names of these various functions or activities are self-explanatory. Sampling refers to the accrual of data on fishing or biological characteristics of the stocks. Estimation of means and variances of catch, effort, and fish lengths, for example, would be embraced by sampling theory. While these statistics provide considerable information on the status of the stocks, more complex statistics and estimation techniques such as fishing and natural mortality, growth, and recruitment are generally required from stock assessment. These more complex techniques are considered for the purpose of this chapter as estimation techniques. Inasmuch as many estimation techniques relate to the temporal trajectories, time series in the form of ARIMA (autoregressive integrated moving average), even lower-frequency events than those considered using ARIMA, may be of interest (Box and Jenkins 1970). Temporal trajectories in either the sampling statistics or in the advanced statistics may be studied non-parametrically. Simulation implies the specification or identification of models and using these models along with estimated parameters to forecast future scenarios.

Once the sampling statistics and various derived statistics are determined, it is then possible to consider issues of optimization generally in the context of an underlying parametric or nonparametric model in which maximum catch for fixed fishing effort or cost of fishing, for example, can be determined. Judgements of what is optimal and what is not depends on the quality of underlying information which can be assessed via decision theory. Decision theory requires information on states of nature, alternative actions, various metrics of performance such as catch or economic value, discount rates, utility function, hypotheses on population dynamics including those on recruitment, and the identification of appropriate planning horizons (Rothschild and Heimbuch 1983).

Beyond all components, a "desirable" and hence successful system might have additional requirements. This subject of evaluating system success was developed in the mid-1960s. A central theme is that successful systems take into account and deal with well known errors that constrain system success. These have been pointed out by Quade and Boucher (1968) and

include: "(a) underemphasis on problem formulation, (b) inflexibility in the face of evidence, (c) adherence to cherished beliefs, (d) parochialism, (e) communication failure, (f) overconcentration on the model, (g) excessive attention to detail, (h) neglect of the question, (i) incorrect use of the model, (j) disregard of the limitations, (k) concentration on statistical uncertainty, (l) inattention to uncertainties, (m) use of side issues as criteria, (n) substitution of a model for the decision maker, (o) neglect of the subjective elements, and (p) failure to reappraise the work."

We are now in a position to compare existing models with our ideal system which now has both structure and the design specification articulated by Quade and Boucher *(op. cit.)*.

Adequacy Of Existing Systems

It is difficult to conceive of a system template that would not look like Figure 1. Our desirable system can be compared with existing systems and models. Two sorts of comparisons seem warranted. The first involves the adequacy of systems as a whole and the quality and efficiency of the linkages and interrelationships among the various components of the system. The second deals with the adequacy of individual components.

The System as a Whole

With regard to the system as a whole, we can inquire as to whether existing systems contain the components identified in Figure 1 and the quality of the linkages among the components. The simplest issue involves whether the system contains all of the "necessary" components. With respect to existing systems, the answer depends upon the particular components of concern. For example, nearly all existing systems contain a sampling and estimation component. While optimization may be attempted, it is generally limited to deterministic models which focus on yield per recruit, production, or recruitment and stock. Questions of economics or variability are left begging. While decisions are made, they are generally not made in a decision-theoretic setting. We can conclude that while sampling and estimation are generally included in management systems, optimization (in the operations-research sense) and decision-theoretical decison making are lacking.

We now turn to the linkage among components and observe that if some components are not present, then a complete interaction among *all* components cannot exist and the system as a whole cannot work effectively. To be sure, even where all components are included, it is not unusual for linkage to be imperfect or nonexistent. For example, as pointed out, there are many instances where both statistical and estimation components are included in the management system. Yet it is not uncommon to find inadequate coordination between sampling and estimation components.

Individual Components

With regard to individual components, considerable effort needs to be utilized to bring existing techniques into harmony with the real world.

Sampling: Many fisheries cannot be sampled with a reasonable degree of confidence and reasonable budget constraints. For example, many fisheries involve thousands of small-scale fishermen who land their catches at many ports. The catches are highly variable and often consist of many species. These small-scale fisheries range from typical artisanal fisheries, such as canoe fishermen off the coast of Africa, to shrimp fisheries in the Gulf of Mexico, and to most recreational fisheries. It is clear that ordinary statistical sampling techniques, given reasonable budget constraints, are inadequate. One approach to the problem is so-called fishery-independent sampling. The difficulty is that, if fishery-independent sampling is indeed completely isolated from fishery information, it is difficult to inquire how fishery-independent sampling can be more efficient than a technique that combines the two approaches. In any event, the efficiency of sampling and its particular cost-benefit is a major issue in the design of any fishery management system.

Estimation: Use of the term "estimation" implies the estimation of parameters in a model. "Estimation" and "simulation" are difficult to disengage in the sense that any simulation model comprises parameters and the need to be estimated. There are four kinds of models in general use in fisheries work. These include the basic fisheries models, the vital-rates models, the parametric models, and the non-parametric models.

The basic fisheries models include the production model, the yield-per-recruit model, and the stock-and-recruitment model. The vital-rates models involve estimation of growth and mortality rates. The parametric models involve statis-

tical distribution, which the non-parametric do not.

The first two kinds of models, the basic and the vital-rates models, are the central core of fishing theory. These models have their good points and bad points. The good points relate to their simplicity and easy interpretability. The bad points are that they are narrow in scope and often used in situations which are more complex than the limits of the simple solutions used in their development.

To illustrate this point, as an example, consider cohort analysis. Cohort analysis is a particularly appropriate technique to discuss as not being a model as much as an estimation technique. Its charm results from the fact that, under simple circumstances and given certain assumptions, it is possible to estimate both the catchability coefficient and recruitment for a series of years. The fact that catchability can be estimated obviates the need to assume constant fishing mortality after some initial age at recruitment. Also, the capability to estimate recruitment from catch-at-age data, alone, makes it possible to determine in principle whether the abundance of a stock was increasing or decreasing, thereby implying certain management measures.

Ricker (1948) was the first to use the idea, applying it to the Pacific halibut *(Hippoglossus stenolepis)*. Ricker proceeded from Baranov's catch equation where the catch in any year is:

$$Y = [N]\ \left([\frac{F}{F+M}]\ [(1-e^{-(F+M)})]\right) \qquad (1)$$

which, in words, is:

catch of fish in a single year = number of fish at beginning of year × fraction of total deaths that owe to fishing × fraction of initial number that die during year from all causes

Now if we can write this equation for one year and we recognize that the catch in one year is linked to the catch in the next year and so on, we can write in mathematical terms the catches for any sequence of years, viz.:

$$Y_i = N_i \frac{F_i}{F_i+M_i}\ (1-e^{-(F_i+M_i)}) \qquad (2a)$$

$$Y_{i+1} = N_{i+1} \frac{F_{i+1}}{F_{i+1}+M_{i+1}}\ (1-e^{-(F_{i+1}+M_{i+1})}) \qquad (2b)$$

$$Y_{i+2} = N_{i+2} \frac{F_{i+2}}{F_{i+2}+M_{i+2}}\ (1-e^{-(F_{i+2}+M_{i+2})}) \qquad (2c)$$

$$\vdots$$

etc.

Suppose we are interested in three years i, i+1, i+2, then we can without any loss of information rewrite the above equations as two equations by dividing each subsequent equation by each precedent equation, viz.:

$$\frac{Y_{i+1}}{Y_i} = \frac{N_{i+1}}{N_i} \cdot \frac{F_i}{F_{i+1}+M_{i+1}} \cdot \frac{F_i+M_i}{F_i} \cdot \frac{(1-e^{-(F_{i+1}+M_{i+1})})}{(1-e^{-(F_i+M_i)})} \qquad (3)$$

$$\frac{Y_{i+2}}{Y_{i+1}} = \frac{N_{i+2}}{N_{i+1}} \cdot \frac{F_{i+2}}{F_{i+2}+M_{i+2}} \cdot \frac{F_{i+1}+M_{i+1}}{F_{i+1}} \cdot \frac{(1-e^{-(F_{i+2}+M_{i+2})})}{(1-e^{-(F_{i+1}+M_{i+1})})} \qquad (4)$$

Now we have two equations. In general, we know the catches in each year. Further, we know that the ratio $N_{i+1}/N_i = e^{-(F_i+M_i)}$ so, to have an estimate of either the mortality rate or recruitment, we need to solve the two equations for F_i, F_{i+1}, F_{i+2}, M_i, M_{i+1}, and M_{i+2}.

We recall from elementary algebra that this is impossible so we assume that $M_i = M_{i+1} = M_{i+2} = M$ and guess some value of M. Further we assume some value for F_{i+2}, so now we have two equations and two unknowns F_i and F_{i+1}. We solve the two equations and with the information at hand we can estimate both the catchability coefficient and recruitment.

This elegant procedure is not without problems. The problems can be considered to be internal to the methodology, as specified above, or external to the methodology.

The major internal problem relates to the amount of time it takes for the estimates to converge to a stable value. This means that if we assume year i = 1980; i+1 = 1981; i+2 = 1982, and we are interested in recruitment in 1980, we need to wait until 1982 to be comfortable with our estimate of 1980 recruits. Such a procedure is untenable in fisheries where urgency in decision making is required.

The external problem relates to attempts to improve on the assumptions. These attempts are two fold — to improve the "guessing" procedure by supplying external information or by circumventing the assumptions. The guessing procedure is also called tuning — supposedly, tuning techniques make the guessing procedure more quantitative or more precise. The additional information required for tuning may in its own right be imprecise.

Circumventions of the assumptions are used when data are not consonant with the requirement of the model. Perhaps the best known approach involved replacing age-based techniques with length-based techniques (Jones 1981). The idea is that there is a one-to-one correspondence

between age and length such that if age is unavailable or difficult to determine then length can be used instead.

This assumption becomes difficult when fish of the same length are not of the same age, as occurs for species with sexually dimorphic growth. Another difficulty with this procedure involves the circumstances when fish spawn over longer periods of time.

Since Pope (1972) published his discussion of the effect of erroneous estimates of terminal fishing mortality (F_t) on the cohort analysis approximation to virtual population analysis (VPA), a number of papers have appeared exploring other sources of error in cohort analysis. Pope (1972) demonstrated that errors in F_t converge to be almost negligible in estimating true F. Agger et al (1973) examined the effect of overestimation and underestimation of natural mortality (M) on the estimate of F obtained from cohort analysis. They concluded that when M is overestimated F will be underestimated and vice versa, regardless of the estimate of E_t, i.e. F/F+M. Ulltang (1977) examined a number of effects in cohort analysis of erroneously estimated M. The effects are as follows:

1. When true M is constant, the errors in estimated M create errors in the estimate of F of about the same magnitude but of a different sign, which is consistent with Agger et al *(op. cit.)*.
2. Stock size will be overestimated or underestimated when M is overestimated or underestimated, respectively.
3. The relative strength of weak and strong year classes will be wrongly estimated if M varies with year-class strength.
4. The errors in VPA caused by M and F being unevenly seasonal are "small and negligible."
5. It is very difficult to take emigration and immigration into account in cohort analysis, and an erroneous view of the stock is likely. Emigration can be treated as part of M with success but immigration cannot be accounted for.

The effect of a low F over a long time span on erroneous estimates of M is to create large relative errors in the estimate of recruitment ($\hat{N}_1$) according to Sims (1984). The error can range from -62% to 261%. An overestimate of M gives larger errors in $\hat{N}_1$ than an underestimate of M. This is a logical result because the relative importance of F(F:M) is reduced.

The results obtained by Bradford and Peterman (1988) are also consistent with Sims (1984). In looking at spurious time trends in stock abundance, due to erroneous M and F_t, they found that the magnitude of the error increased when fishing intensity is low. Hilden (1988) showed that, given constant M and F, the relative year-to-year estimates of $\hat{F}$ and $\hat{N}_1$ are correctly identified if F_t and the estimate of M are erroneous. The absolute values will, of course, be in error. In an analytical treatment of the problem Sampson (1988) looked at simultaneous errors in catch-at-age C_i and M. His conclusions were that, for some combinations of error in C_i and M, relative error in $\hat{N}_1$ will increase.

Again it is shown by Praeger and MacCall (1988) that the sensitivity of estimates of M, obtained through cohort analysis, decreases as F increases. In their study of the sensitivities and variances of VPA, they found, using empirical data for the mackerel *(Scomber japonicus)* fishery from 1929-1969, that in the early years of the time series coefficients of variation (CV) for the estimates were as high as 100%; in later years, when a better understanding of the fishery had evolved, CV were less than 25%. Most of the variability was attributable to erroneous estimates of M and "weights-at-age."

The partial recruitment problem in cohort analysis was examined by Roff (1981). He developed an alternative approach to the problem as compared to the usual method of using the ratio of the proportion of the partially recruited age or size class found in the commercial catch to the proportion found in a research sample. Bradford and Peterman *(op. cit.)* found that the effects of incorrect partial recruitment indices to VPA on time trends in stock abundance tend to diminsh with longer time series because "more complete cohorts become available."

The problem we are examining is akin to the partial recruitment problem. The problem is to identify the effects on estimates of $\hat{F}$ and $\hat{N}_1$ due to multiple cohort recruitment spaced at different times of the year. Multiple or continuous spawning is a common phenomenon in subtropical and tropical species. The robustness of cohort analysis applied in this setting has not been examined in the literature.

Tables 1 and 2 give examples of the type of situation we are investigating. It will be noticed that in each year spawning occurs in months 1, 2, and 3 and in month 9. Each cohort is depleted by a total mortality of $Z = 1.0$, and $F = 0.5$.

Table 1. (a) The number of recruits surviving to the end of each month for a simulated equilibrium population with 4 cohorts spawned respectively in months 1,2,3, and 9, compared to (b) the number of recruits surviving to end of each year for the same population (total mortality, Z = 1.0; fishing mortality, F = 0.5).

	AGE IN MONTHS																																			
TIME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	1000	0	0	0	717	0	0	0	0	0	435	400	368	0	0	0	264	0	0	0	0	0	160	147	135	0	0	0	97	0	0	0	0	0	59	54
2	1000	920	0	0	0	659	0	0	0	0	0	400	368	338	0	0	0	243	0	0	0	0	0	147	135	125	0	0	0	89	0	0	0	0	0	54
3	1000	920	846	0	0	0	607	0	0	0	0	0	368	338	311	0	0	0	223	0	0	0	0	0	135	125	115	0	0	0	82	0	0	0	0	0
4	0	920	846	779	0	0	0	558	0	0	0	0	0	338	311	287	0	0	0	205	0	0	0	0	0	125	115	105	0	0	0	76	0	0	0	0
5	0	0	846	779	717	0	0	0	513	0	0	0	0	0	311	287	264	0	0	0	189	0	0	0	0	0	115	105	97	0	0	0	69	0	0	0
6	0	0	0	779	717	659	0	0	0	472	0	0	0	0	0	287	264	243	0	0	0	174	0	0	0	0	0	105	97	89	0	0	0	64	0	0
7	0	0	0	0	717	659	607	0	0	0	435	0	0	0	0	0	264	243	223	0	0	0	160	0	0,	0	0	0	97	89	82	0	0	0	59	0
8	0	0	0	0	0	659	607	558	0	0	0	400	0	0	0	0	0	243	223	205	0	0	0	147	0	0	0	0	0	89	82	76	0	0	0	54
9	1000	0	0	0	0	0	607	558	513	0	0	0	368	0	0	0	0	0	223	205	189	0	0	0	135	0	0	0	0	0	82	76	69	0	0	0
10	0	920	0	0	0	0	0	558	513	472	0	0	0	338	0	0	0	0	0	205	189	174	0	0	0	125	0	0	0	0	0	76	69	64	0	0
11	0	0	846	0	0	0	0	0	513	472	435	0	0	0	311	0	0	0	0	0	189	174	160	0	0	0	115	0	0	0	0	0	69	64	59	0
12	0	0	0	779	0	0	0	0	0	472	435	400	0	0	0	287	0	0	0	0	0	174	160	147	0	0	0	105	0	0	0	0	0	64	59	54
13	1000	0	0	0	717	0	0	0	0	0	435	400	368	0	0	0	264	0	0	0	0	0	160	147	135	0	0	0	97	0	0	0	0	0	59	54
14	1000	920	0	0	0	659	0	0	0	0	0	400	368	338	0	0	0	243	0	0	0	0	0	147	135	125	0	0	0	89	0	0	0	0	0	54
15	1000	920	846	0	0	0	607	0	0	0	0	0	368	338	311	0	0	0	223	0	0	0	0	0	135	125	115	0	0	0	82	0	0	0	0	0
16	0	920	846	779	0	0	0	558	0	0	0	0	0	338	311	287	264	0	0	205	0	0	0	0	0	125	115	105	97	0	0	76	0	0	0	0
17	0	0	846	779	717	0	0	0	513	0	0	0	0	0	311	287	264	0	0	0	189	0	0	0	0	0	115	105	97	0	0	0	69	0	0	0
18	0	0	0	779	717	659	0	0	0	472	0	0	0	0	0	287	264	243	0	0	0	174	0	0	0	0	0	105	97	89	0	0	0	64	0	0
19	0	0	0	0	717	659	607	0	0	0	435	0	0	0	0	0	264	243	223	0	0	0	160	0	0	0	0	0	97	89	82	0	0	0	59	0
20	0	0	0	0	0	659	607	558	0	0	0	400	0	0	0	0	0	243	223	205	0	0	0	147	0	0	0	0	0	89	82	76	0	0	0	54
21	1000	0	0	0	0	0	607	558	513	0	0	0	368	0	0	0	0	0	223	205	189	0	0	0	135	0	0	0	0	0	82	76	69	0	0	0
22	0	920	0	0	0	0	0	558	513	472	0	0	0	338	0	0	0	0	0	205	189	174	0	0	0	125	0	0	0	0	0	76	69	64	0	0
23	0	0	846	0	0	0	0	0	513	472	435	0	0	0	311	0	0	0	0	0	189	174	160	0	0	0	115	0	0	0	0	0	69	64	59	0
24	0	0	0	779	0	0	0	0	0	472	435	400	0	0	0	287	0	0	0	0	0	174	160	147	0	0	0	105	0	0	0	0	0	64	59	54
25	1000	0	0	0	717	0	0	0	0	0	435	400	368	0	0	0	264	0	0	0	0	0	160	147	135	0	0	0	97	0	0	0	0	0	59	54
26	1000	920	0	0	0	659	0	0	0	0	0	400	368	338	0	0	0	243	0	0	0	0	0	147	135	125	0	0	0	89	0	0	0	0	0	54
27	1000	920	846	0	0	0	607	0	0	0	0	0	368	338	311	0	0	0	223	0	0	0	0	0	135	125	115	0	0	0	82	0	0	0	0	0
28	0	920	846	779	0	0	0	558	0	0	0	0	0	338	311	287	0	0	0	205	0	0	0	0	0	125	115	105	0	0	0	76	0	0	0	0
29	0	0	846	779	717	0	0	0	513	0	0	0	0	0	311	287	264	0	0	0	189	0	0	0	0	0	115	105	97	0	0	0	69	0	0	0
30	0	0	0	779	717	659	0	0	0	472	0	0	0	0	0	287	264	243	0	0	0	174	0	0	0	0	0	105	97	89	0	0	0	64	0	0
31	0	0	0	0	717	659	607	0	0	0	435	0	0	0	0	0	264	243	223	0	0	0	160	0	0	0	0	0	97	89	82	0	0	0	59	0
32	0	0	0	0	0	659	607	558	0	0	0	400	0	0	0	0	0	243	223	205	0	0	0	147	0	0	0	0	0	89	82	76	0	0	0	54
33	1000	0	0	0	0	0	607	558	513	0	0	0	368	0	0	0	0	0	223	205	189	0	0	0	135	0	0	0	0	0	82	76	69	0	0	0
34	0	920	0	0	0	0	0	558	513	472	0	0	0	338	0	0	0	0	0	205	189	174	0	0	0	125	0	0	0	0	0	76	69	64	0	0
35	0	0	846	0	0	0	0	0	513	472	435	0	0	0	311	0	0	0	0	0	189	174	160	0	0	0	115	0	0	0	0	0	69	64	59	0
36	0	0	0	779	0	0	0	0	0	472	435	400	0	0	0	287	0	0	0	0	0	174	160	147	0	0	0	105	0	0	0	0	0	64	59	54

TIME \ AGE	1	2	3
1	2086	768	282
2	2086	768	282
3	2086	768	282

Table 2. (a) The monthly yield in numbers of fish taken from the cohorts displayed in Table 1, a simulated equilibrium population with 4 cohorts spawned respectively in months 1,2,3, and 9, compared to (b) the total annual yield taken from the same population (mortality, Z = 1.0; fishing mortality, F = 0.5).

	AGE IN MONTHS																																			
TIME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	40	0	0	0	29	0	0	0	0	0	17	16	15	0	0	0	11	0	0	0	0	0	6	6	5	0	0	0	4	0	0	0	0	0	2	2
2	40	37	0	0	0	26	0	0	0	0	0	16	15	14	0	0	0	10	0	0	0	0	0	6	5	5	0	0	0	4	0	0	0	0	0	2
3	40	37	34	0	0	0	24	0	0	0	0	0	15	14	12	0	0	0	9	0	0	0	0	0	5	5	5	0	0	0	3	0	0	0	0	0
4	0	37	34	31	0	0	0	22	0	0	0	0	0	14	12	11	0	0	0	8	0	0	0	0	0	5	5	4	0	0	0	3	0	0	0	0
5	0	0	34	31	29	0	0	0	21	0	0	0	0	0	12	11	11	0	0	0	8	0	0	0	0	0	5	4	4	0	0	0	3	0	0	0
6	0	0	0	31	29	26	0	0	0	19	0	0	0	0	0	11	11	10	0	0	0	7	0	0	0	0	0	4	4	4	0	0	0	3	0	0
7	0	0	0	0	29	26	24	0	0	0	17	0	0	0	0	0	11	10	9	0	0	0	6	0	0	0	0	0	4	4	3	0	0	0	2	0
8	0	0	0	0	0	26	24	22	0	0	0	16	0	0	0	0	0	10	9	8	0	0	0	6	0	0	0	0	0	4	3	3	0	0	0	2
9	40	0	0	0	0	0	24	22	21	0	0	0	15	0	0	0	0	0	9	8	8	0	0	0	5	0	0	0	0	0	3	3	3	0	0	0
10	0	37	0	0	0	0	0	22	21	19	0	0	0	14	0	0	0	0	0	8	8	7	0	0	0	5	0	0	0	0	0	3	3	3	0	0
11	0	0	34	0	0	0	0	0	21	19	17	0	0	0	12	0	0	0	0	0	8	7	6	0	0	0	5	0	0	0	0	0	3	3	2	0
12	0	0	0	31	0	0	0	0	0	19	17	16	0	0	0	11	0	0	0	0	0	7	6	6	0	0	0	4	0	0	0	0	0	3	2	2
13	40	0	0	0	29	0	0	0	0	0	17	16	15	0	0	0	11	0	0	0	0	0	6	6	5	0	0	0	4	0	0	0	0	0	2	2
14	40	37	0	0	0	26	0	0	0	0	0	16	15	14	0	0	0	10	0	0	0	0	0	6	5	5	0	0	0	4	0	0	0	0	0	2
15	40	37	34	0	0	0	24	0	0	0	0	0	15	14	12	0	0	0	9	0	0	0	0	0	5	5	5	0	0	0	3	0	0	0	0	0
16	0	37	34	31	0	0	0	22	0	0	0	0	0	14	12	11	0	0	0	8	0	0	0	0	0	5	5	4	0	0	0	3	0	0	0	0
17	0	0	34	31	29	0	0	0	21	0	0	0	0	0	12	11	11	0	0	0	8	0	0	0	0	0	5	4	4	0	0	0	3	0	0	0
18	0	0	0	31	29	26	0	0	0	19	0	0	0	0	0	11	11	10	0	0	0	7	0	0	0	0	0	4	4	4	0	0	0	3	0	0
19	0	0	0	0	29	26	24	0	0	0	17	0	0	0	0	0	11	10	9	0	0	0	6	0	0	0	0	0	4	4	3	0	0	0	2	0
20	0	0	0	0	0	26	24	22	0	0	0	16	0	0	0	0	0	10	9	8	0	0	0	6	0	0	0	0	0	4	3	3	0	0	0	2
21	40	0	0	0	0	0	24	22	21	0	0	0	15	0	0	0	0	0	9	8	8	0	0	0	5	0	0	0	0	0	3	3	3	0	0	0
22	0	37	0	0	0	0	0	22	21	19	0	0	0	14	0	0	0	0	0	8	8	7	0	0	0	5	0	0	0	0	0	3	3	3	0	0
23	0	0	34	0	0	0	0	0	21	19	17	0	0	0	12	0	0	0	0	0	8	7	6	0	0	0	5	0	0	0	0	0	3	3	2	0
24	0	0	0	31	0	0	0	0	0	19	17	16	0	0	0	11	0	0	0	0	0	7	6	6	0	0	0	4	0	0	0	0	0	3	2	2
25	40	0	0	0	29	0	0	0	0	0	17	16	15	0	0	0	11	0	0	0	0	0	6	6	5	0	0	0	4	0	0	0	0	0	2	2
26	40	37	0	0	0	26	0	0	0	0	0	16	15	14	0	0	0	10	0	0	0	0	0	6	5	5	0	0	0	4	0	0	0	0	0	2
27	40	37	34	0	0	0	24	0	0	0	0	0	15	14	12	0	0	0	9	0	0	0	0	0	5	5	5	0	0	0	3	0	0	0	0	0
28	0	37	34	31	0	0	0	22	0	0	0	0	0	14	12	11	0	0	0	8	0	0	0	0	0	5	5	4	0	0	0	3	0	0	0	0
29	0	0	34	31	29	0	0	0	21	0	0	0	0	0	12	11	11	0	0	0	8	0	0	0	0	0	5	4	4	0	0	0	3	0	0	0
30	0	0	0	31	29	26	0	0	0	19	0	0	0	0	0	11	11	10	0	0	0	7	0	0	0	0	0	4	4	4	0	0	0	3	0	0
31	0	0	0	0	29	26	24	0	0	0	17	0	0	0	0	0	11	10	9	0	0	0	6	0	0	0	0	0	4	4	3	0	0	0	2	0
32	0	0	0	0	0	26	24	22	0	0	0	16	0	0	0	0	0	10	9	8	0	0	0	6	0	0	0	0	0	4	3	3	0	0	0	2
33	40	0	0	0	0	0	24	22	21	0	0	0	15	0	0	0	0	0	9	8	8	0	0	0	5	0	0	0	0	0	3	3	3	0	0	0
34	0	37	0	0	0	0	0	22	21	19	0	0	0	14	0	0	0	0	0	8	8	7	0	0	0	5	0	0	0	0	0	3	3	3	0	0
35	0	0	34	0	0	0	0	0	21	19	17	0	0	0	12	0	0	0	0	0	8	7	6	0	0	0	5	0	0	0	0	0	3	3	2	0
36	0	0	0	31	0	0	0	0	0	19	17	16	0	0	0	11	0	0	0	0	0	7	6	6	0	0	0	4	0	0	0	0	0	3	2	2

TIME \ AGE	1	2	3
1	1041	385	142
2	1041	385	142
3	1041	385	142

It will be noted that this particular example reduces to the standard equilibrium model if we partition the figure into annual age-time cells. That is to say that at the start of age 1 there are 2086 fish; at the start of age 2 there are 768 fish; at the start of age 3 there are 282 fish; and 1,041 age 0 fish, 385 age 1 fish, and 142 age 2 fish have been harvested. This is summarized in Tables 3 and 4.

If we did not recognize that fish were recruited over several months then we would perform our cohort analysis on the data in Table 2b.

However, the flaw in combining the monthly data approach can be recognized when we compare Tables 2a and 2b in the context of the generally employed cohort analysis approach which is to assume a constant natural mortality and a terminal "F" and then estimate Fs that apply over the whole life of the cohort.

We can see in our example, however, that a particular cohort doesn't exist in the sense that one-year-old recruited fish can range in age from 16 to 24 months (note also that at the end of the calendar year fish of 13 to 15 months do not exist). This means that the exposure to mortality can vary from 4 to 12 months in the year zero, which is not consonant with the assumptions of cohort analysis, a problem recognized in studies on partial recruitment.

To demonstrate this problem, we simulated a wide range of recruitment patterns. The scope of our simulations is shown in Table 5. As an example, Figure 2 illustrates three recruitment patterns for a hypothetical population that spawns in each month of the year. In the first case, spawning is concentrated in the first four months of the year or, in other words, the distribution of spawning displays right skewness. The third case is the converse of the first case, i.e., the distribution of spawning is skewed left. The second case is an example of a normal symmetrical distribution of spawning; it is concentrated in the middle months of the year, but is relatively strong throughout the year.

Populations with one cohort spawning in the first month of the year, two and three cohorts spawning at different times of the year, and 12 cohorts (as described above) were simulated. Each pattern of spawning is identified with an index number in Figures 3, 4, and 5, and is explained in Table 6. The simulated populations were depleted, using a wide range of natural and fishing mortality rates, and yields were tabulated for each month from individual cohorts. The yields from individual cohorts were then summed by age classes, as in the standard approach, such that, for example, yield from a 15-month-old fish and yield from a 23-month-old fish were both taken to be yields from a 1-year-old fish, as in Table 2b.

Cohort analysis was executed on the aggregate yields shown in Table 2b. Thus, yields were removed from continuous and multiple spawning-simulated populations by cohort, but cohort

Table 3. Summary of the number of recruits surviving to the end of each calendar year by actual age in months (individual cohorts) and total number of recruits of nominal age in years, for the same population of 4000 fished spawned in months 1,2,3, and 9 in 4 cohorts of 1000 fish each in Table 1.

	Number of fish	Nominal Age (Years)	Actual Age (Months)
	400	0	12
	435	0	11
	472	0	10
	749	0	4
Sum	2086	0	
	147	1	24
	160	1	23
	174	1	22
	287	1	16
Sum	768	1	
	54	2	36
	59	2	35
	64	2	34
	105	2	28
Sum	282	2	

Table 4. Summary of the number of fish harvested (yield) by the end of each calendar year by actual age in months (individual cohorts) and total number of recruits of nominal age in years, for the same population of 4000 fished spawned in months 1,2,3, and 9 in 4 cohorts of 1000 fish each in Table 1.

	Number of fish	Nominal Age (Years)	Actual Age (Months)
	316	0	12
	300	0	11
	283	0	10
	142	0	4
Sum	1041	0	
	117	1	36
	111	1	23
	105	1	22
	52	1	16
Sum	385	1	
	43	2	36
	41	2	35
	39	2	34
	19	2	28
Sum	142	2	

Table 5. Range of recruitment patterns for simulated populations used in examining cohort analysis comprising 22 scenarios. The number of cohorts spawned in a 12-month period is either 1,2,3, or 12, and for more than one cohort the distribution of spawning throughout the year can be skewed right or left or be symmetrical.

Month Cohorts Enter Fishery	Number of Fish Recruited in Each Month (Distribution of Recruitment Throughout the Year) Skewed Right	Skewed Left	Symmetrical
12 Cohort Scenario:	Scenario 1	Scenario 2	Scenario 3
1	36000	300	1000
2	24000	500	2000
3	15000	800	6000
4	9000	1300	8000
5	6000	1700	14000
6	3000	2400	19000
7	2400	3000	19000
8	1700	6000	14000
9	1300	9000	8000
10	800	15000	6000
11	500	24000	2000
12	300	36000	1000
TOTAL	100000	100000	100000
3 Cohort Scenario:	Scenario 4	Scenario 5	Scenario 6
(a) 1	60000	10000	25000
2	30000	30000	50000
3	10000	60000	25000
TOTAL	100000	100000	100000
	Scenario 7	Scenario 8	Scenario 9
(b) 5	60000	10000	25000
6	30000	30000	50000
7	10000	60000	25000
TOTAL	100000	100000	100000
	Scenario 10	Scenario 11	Scenario 12
(c) 10	60000	10000	25000
11	30000	30000	50000
12	10000	60000	25000
TOTAL	100000	100000	100000
2 Cohort Scenario:	Scenario 13	Scenario 14	Scenario 15
(a) 1	70000	30000	50000
2	30000	70000	50000
TOTAL	100000	100000	100000
	Scenario 16	Scenario 17	Scenario 18
(b) 5	70000	30000	50000
6	30000	70000	50000
TOTAL	100000	100000	100000
	Scenario 19	Scenario 20	Scenario 21
(c) 11	70000	30000	50000
12	30000	70000	50000
TOTAL	100000	100000	100000
1 Cohort Scenario:			Scenario 22
1			100000
TOTAL			100000

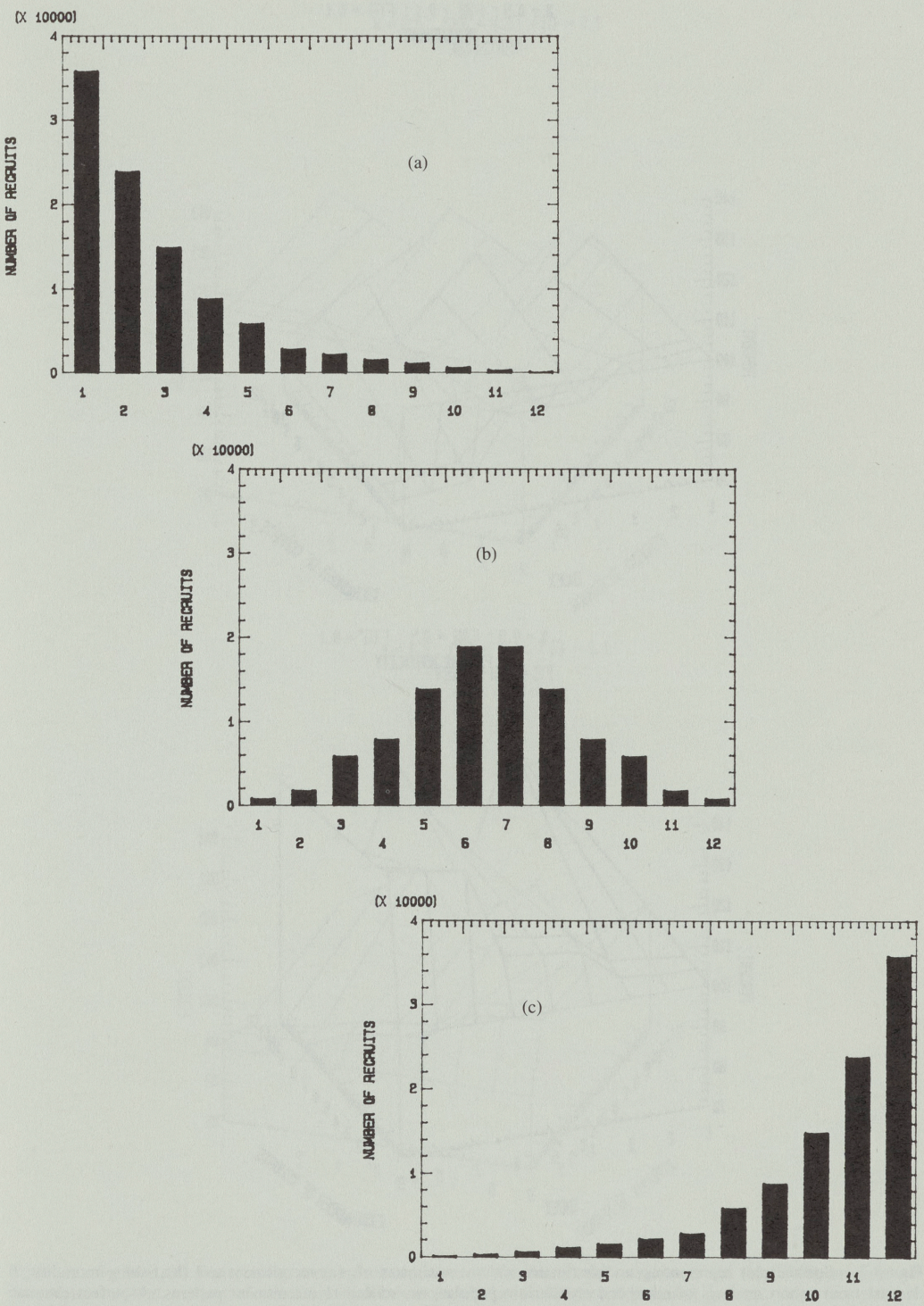

Figure 2. A hypothetical population that spawns over 12 months showing three possible distributions of spawning throughout the year (a) skewed right; (b) symmetrical; (c) skewed left.

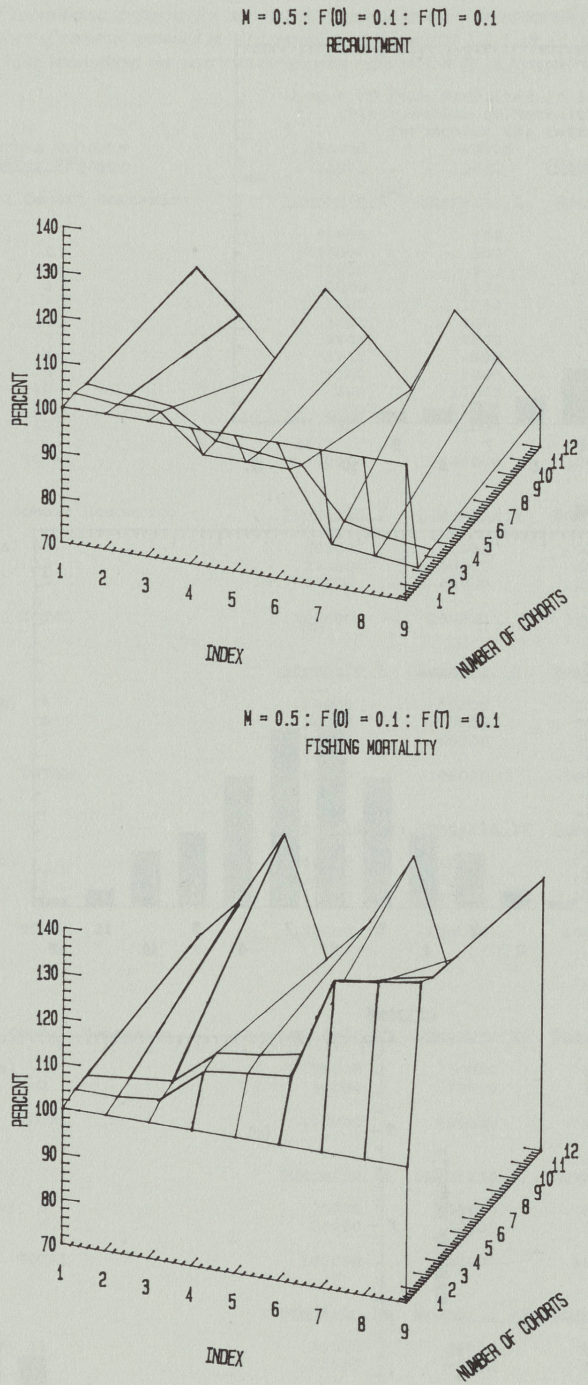

Figure 3. Surface plot representing underestimates and overestimates of, (a) recruitment and (b) fishing mortality, F derived from cohort analysis of simulated equilibrium populations, related to recruitment patterns. A perfect estimate would be 100 percent, where percent refers to the percent of known recruitment (or F) estimated by cohort analysis. See Table 6 for explanation of INDEX. (Natural mortality, $M = 0.5$, actual fishing mortality, $F_0 = 0.1$, terminal fishing mortality, $F_t = 0.1$).

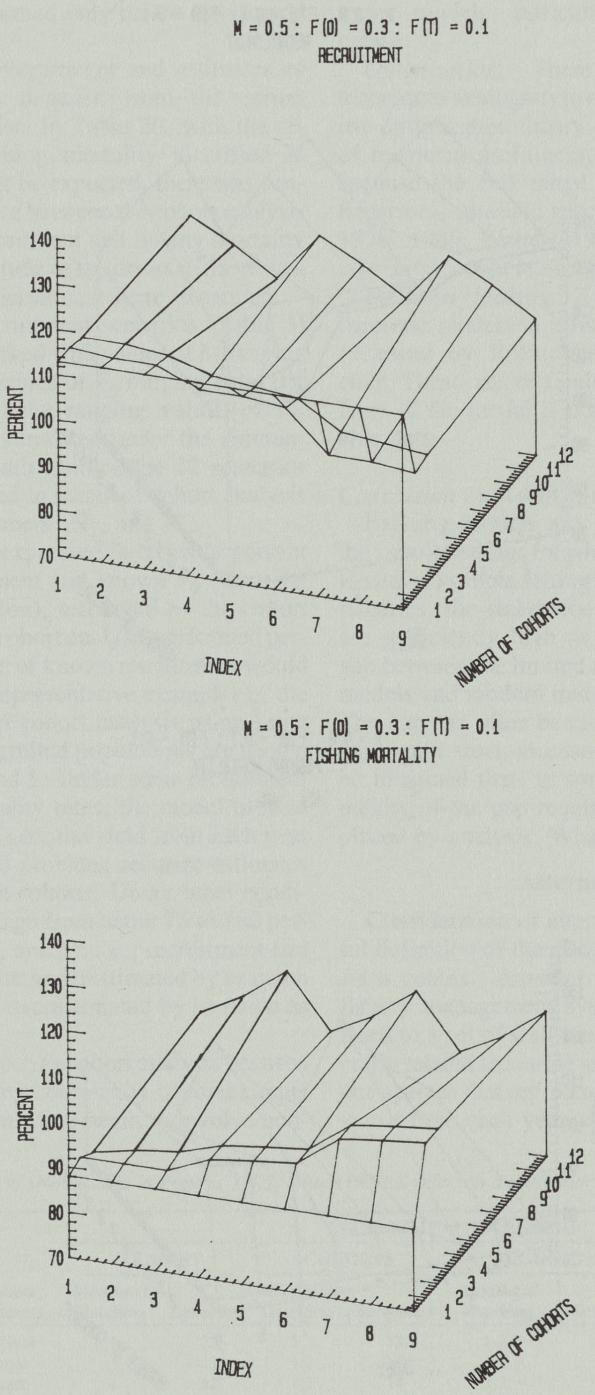

Figure 4. Surface plot representing underestimates and overestimates of, (a) recruitment and (b) fishing mortality, F derived from cohort analysis of simulated equilibrium populations, related to recruitment patterns. A perfect estimate would be 100 percent, where percent refers to the percent of known recruitment (or F) estimated by cohort analysis. See Table 6 for explanation of INDEX. (Natural mortality, $M = 0.5$, actual fishing mortality, $F_0 = 0.3$, terminal fishing mortality, $F_t = 0.1$).

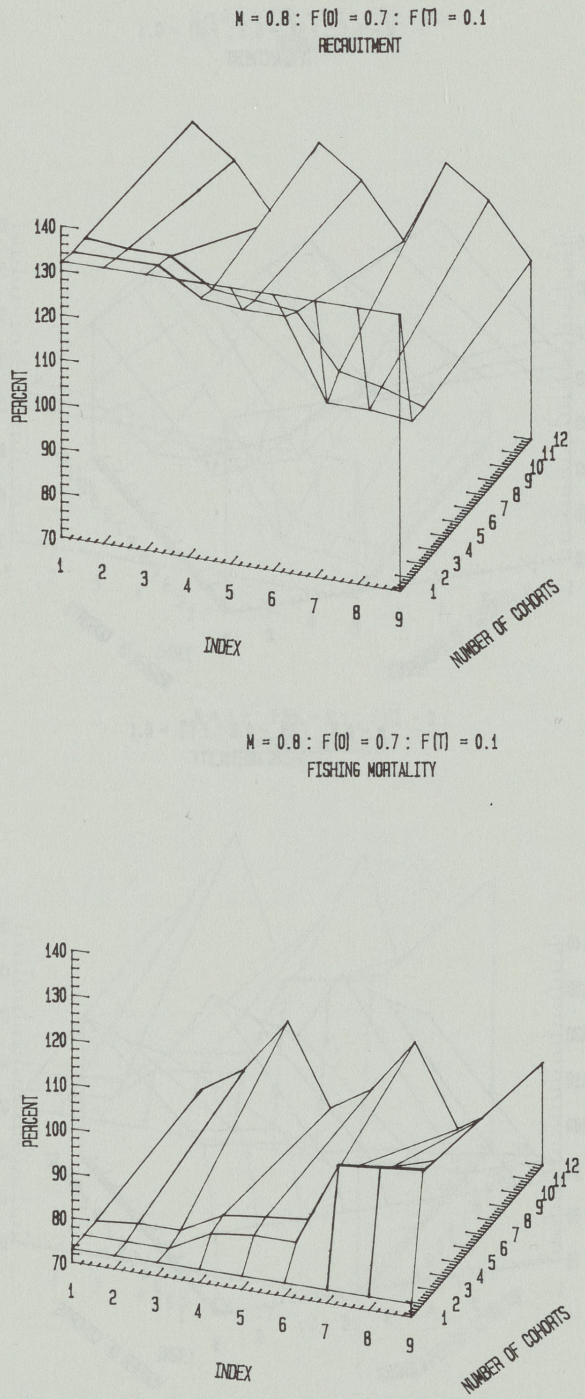

Figure 5. Surface plot representing underestimates and overestimates of, (a) recruitment and (b) fishing mortality, F derived from cohort analysis of simulated equilibrium populations, related to recruitment patterns. A perfect estimate would be 100 percent, where percent refers to the percent of known recruitment (or F) estimated by cohort analysis. See Table 6 for explanation of INDEX. (Natural mortality, $M = 0.8$, actual fishing mortality, $F_0 = 0.7$, terminal fishing mortality, $F_t = 0.1$).

analysis was performed only on the aggregated year classes.

We compared recruitment and estimates of fishing mortality, deduced from the cohort analysis and the data in Table 2b, with the recruitment and fishing mortality identified in Table 1a. As might be expected, there was considerable divergence between the cohort analysis and the actual recruitment and fishing mortality values. The magnitude of the errors in the resulting estimates of recruitment were examined.

Twenty-two recruitment scenarios (Table 5) were examined, linked with values of M ranging from 0.2 to 1.5, values of F_0 ranging from 0.1 to 1.5, and similarly ranging values of F_t. Populations were simulated under the assumptions associated with each of the 22 scenarios and the results used in standard cohort analysis to estimate recruitment, $\hat{N}_1$, and $\hat{F}$.

The results are expressed in terms of percent of known recruitment and known F_0 (from the simulated population), estimated by the cohort analysis. Thus, if cohort analysis performed perfectly, the estimate of known recruitment would be 100 percent. Representative examples of the results of standard cohort analysis using input from simulated recruited populations are shown in Figures 3, 4, and 5. Under some recruitment patterns and mortality rates, the model used in the standard way (i.e., the yield from each year class in aggregate) provides accurate estimates even with multiple cohorts. Under other conditions, estimates range from about 75 to 150 percent (Figures 3, 4, and 5), i.e., recruitment and fishing mortality are underestimated by as much as 25 percent and overestimated by as much as 50 percent.

As techniques such as cohort analysis are used in modalities having complexity beyond simple analytic expressions, and begin to involve nonlinear models, difficulties of estimation increase.

Optimization: There are a number of techniques analogous to the standard models that use optimization theory. These models are also of restricted usefulness, as a practical matter, because the full range of problems — nonlinearities, multiple species, variability (Clarke 1976, 1985; Walters 1986) — are difficult to take into account in a single optimization model.

Decision Making: The standard decision-theoretic models in a fishery setting have been reviewed by Rothschild and Heimbuch *(op. cit.)*. These are difficult to apply because the form of the model is not consonant with available data.

Conclusion on Adequacy of Models

Existing models are generally adequate for the simple settings for which they were intended. However, simple settings seldom exist. In many fisheries, the stakes for adequate management are sufficiently high as to require closing the gap between the limited resolution of the simple models and modern management requirements. The gap can often be closed by the intuition of the expert stock-assessment analyst, but it can be imagined that, in some instances, the complexity of the gap requires that intuition be replaced by analysis. What are the alternatives?

Alternatives

Consideration of alternatives requires a careful definition of the question to be investigated. As a context, consider that our conception of fishery management systems tends to be confined to a set of well-known models. They generally related to simple situations involving only one species that reproduces only in a short interval of time each year, and a species for which

Table 6. Explanation of INDEX axis in Figures 3,4,5, where INDEX refers to a particular recruitment pattern.

		RECRUITMENT SCENARIO							
		1 COHORT		2 COHORTS		3 COHORTS		12 COHORTS	
Index	Distribution of Recruitment	Months of Hatching	Scenario	Months of Hatching	Scenario	Months of Hatching	Scenario	Months of Hatching	Scenario
1	Skewed Right	1	22	1,2	13	1,2,3	4	1-12	1
2	Symmetrical	1	22	1,2	15	1,2,3	6	1-12	3
3	Skewed Left	1	22	1,2	14	1,2,3	5	1-12	2
4	Skewed Right	1	22	5,6	16	5,6,7	7	1-12	1
5	Symmetrical	1	22	5,6	18	5,6,7	9	1-12	3
6	Skewed Left	1	22	5,6	17	5,6,7	8	1-12	2
7	Skewed Right	1	22	11,12	19	10,11,12	10	1-12	1
8	Symmetrical	1	22	11,12	21	10,11,12	12	1-12	3
9	Skewed Left	1	22	11,12	20	10,11,12	11	1-12	2

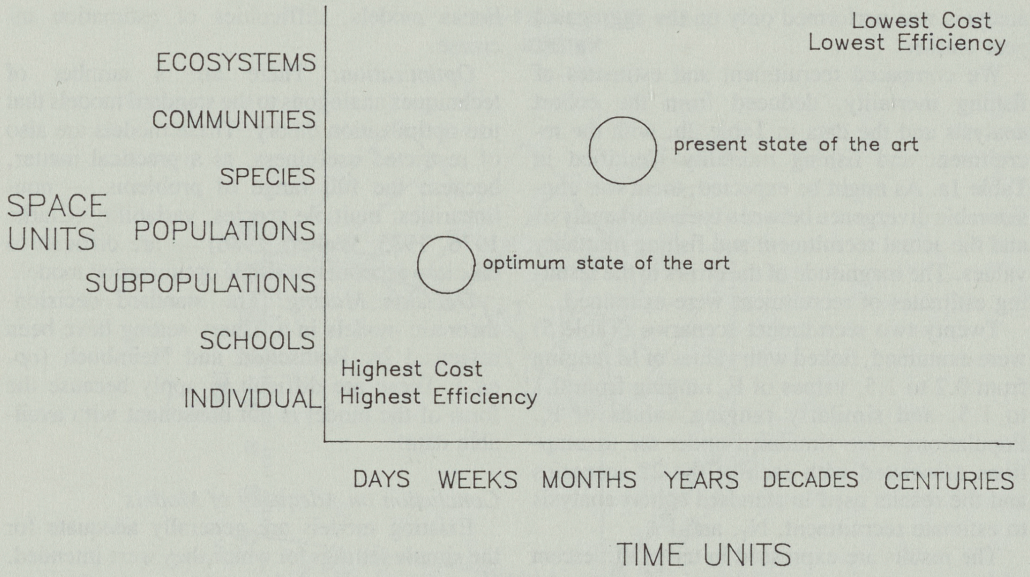

Figure 6. Relationships among time and space scales, present management capabilities, and cost and efficiency in fishery management.

a single annual measurement of abundance is available.

To what extent does the adequacy of fishery management models based upon the simpler approach involve an optimal mix of costs and benefits?

To make this point clearer, consider Figure 6 which shows the present state of management as a function of both taxonomic aggregation and time scale. If cost were not a consideration, then the most desirable levels of management control would be at the individual and the day scale (the lower left hand corner of Fig. 6). The least desirable management control would be on the century-ecosystem intersection. The presumption is that, if one could manage individuals, one could manage ecosystems but, if one could only manage ecosystems, information at lesser degrees of aggregation could not be accommodated. Costs of managing at the individual day-to-day scale would be astronomical and the benefits of managing at the ecosystem-century scale (i.e., not taking into account resolution finer than ecosystems or centuries) are not obvious.

There must be a middle ground. It is obvious that the middle ground, the optimal target of taxonomic-time resolution is not yet clear. Before it can be made clear, questions on the relation of subpopulations to populations, populations to species, and species to aggregations of species, need to be made clear. In addition, the relation between all time scales and the variability of fish stocks needs to be made precise.

It is important to study the performance of various fisheries management systems while evaluating the appropriate focus for management systems (in terms of economic and other criteria). Such study, in principle, seems not only possible but important. The approach is to develop a systematic model by which the performance of fisheries management can be evaluated. Such a model can be developed using techniques developed in the study of artificial intelligence.

Artificial intelligence (AI) is a branch of computer science concerning the theory of intelligence and its application to the programming of computers to reproduce intelligent human behavior. Coulson et al (1987) identified three areas of AI having particular relevance to natural resource management, namely, (1) integrated expert systems, (2) intelligent geographic information systems, and (3) AI modeling of animal behavior-environment interactions. An expert system (ES) is a computer program that solves problems in a limited area of expertise as a human expert would. In particular, we have applied an expert system to decision-making in fishery management, from which we elicit the term expert support system (ESS).

The components of a knowledge-based management expert system are illustrated in Figure 7. The knowledge base (KB) is a repository of domain-specific facts, the rules relating those facts, and the rules-of-thumb (heuristics) used by the expert to solve a domain-specific problem. The inference engine is the program code, or the set of procedures invoked by the expert system to solve a problem. The inference engine program code links the KB with input from the user to obtain a solution to the problem under consideration or to reach a decision.

Expert systems evolved in an academic setting using the LISP programming language. LISP and PROLOG are the two principle logic-processing or declarative languages currently in use (rather than procedural languages like FORTRAN, PASCAL, and BASIC). Much of the tedium (and time) of writing routine program code can be eliminated because of the increasing availability of expert system shells or building tools. An expert system shell is a software package that is structured to create the links between each component of an expert system.

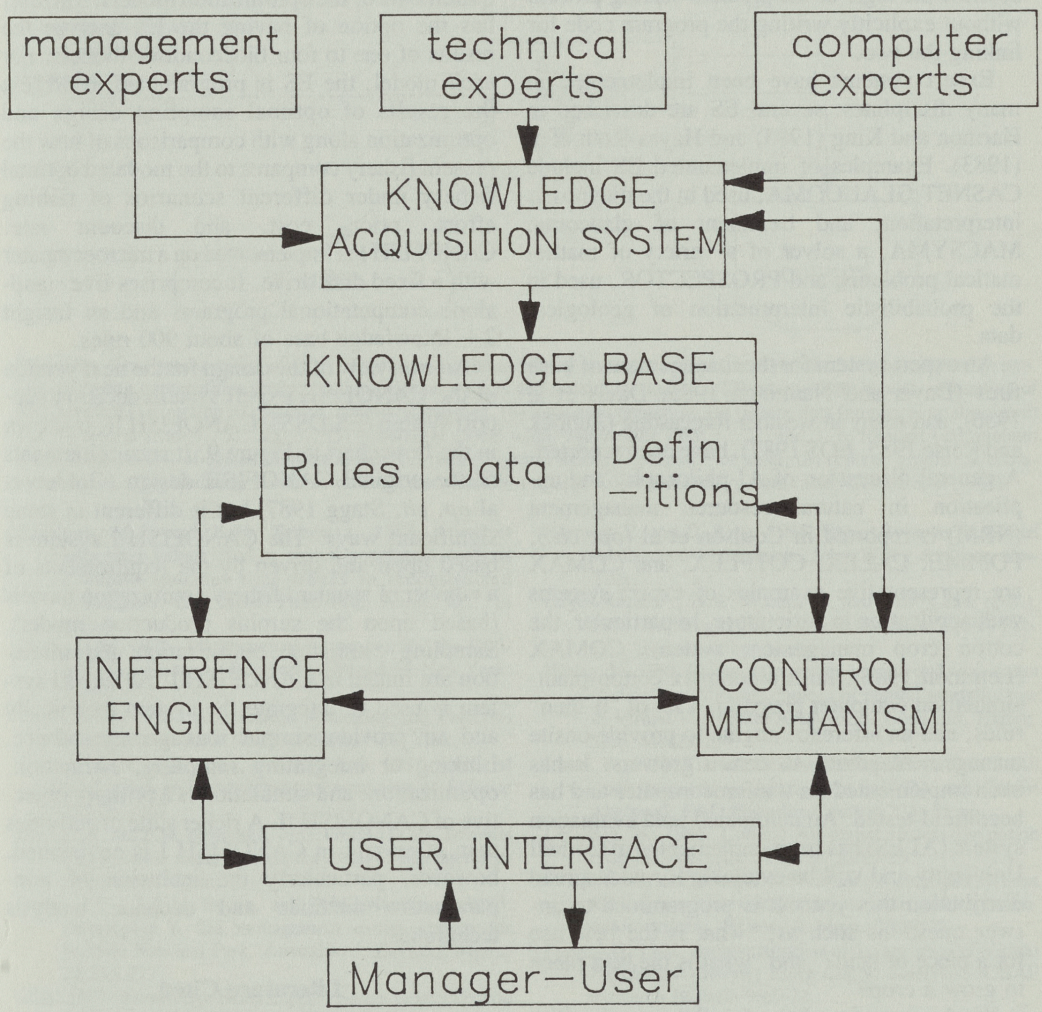

Figure 7. Components of a knowledge-based expert system (after Moser and Christoph, 1987).

The ES developer does not, for example, need to program the logic explicitly between "facts" and "rules." Expert system shells are usually written in higher-level computer languages that more closely resemble English than does a computer language like LISP, PROLOG, or FORTRAN. Examples of expert system shells include, among others, *Insight 2+* (the one we have used), *HypertExpert Systems, NEXPERT OBJECT* and *VP-Expert*. The use of an expert system shell enables the expert system developer to create the knowledge base and the rules that describe the logic of the problem-solving process without explicitly writing the program code for linking the two.

Expert systems have been implemented in many disciplines; several ES are described in Harmon and King (1985) and Hayes-Roth et al (1983). Examples of implemented ES include CASNET/GLAUCOMA, used in the diagnosis, interpretation, and treatment of glaucoma; MACSYMA, a solver of a variety of mathematical problems; and PROSPECTOR, used in the probabilistic interpretation of geological data.

An expert system for the management of bush fires (Davis and Nanninga 1985, Davis et al 1986), and many in weather forecasting (Zubrick and Reise 1985, EOS 1987), have been reported. A general discussion of AI philosophy and application in natural resource management (NRM) is reported in Coulson et al *(op. cit.)*. POMME, CALEX, COTFLEX, and COMAX are representative examples of expert systems with application in agriculture. In particular, the cotton crop management system, COMAX (Lemmon 1986), links a complex cotton-plant-simulation computer program, a set of "if-then" rules, and an inference engine to provide onsite management advice to cotton growers. It has been implemented on a microcomputer and has been field-tested. An automated land evaluation system (ALES) has been implemented at Cornell University and will be available for widespread distribution this year. It is programmed to answer questions such as, "what is the best use for a piece of land?" and "what is the best place to grow a crop?"

We have explored the feasibility and utility of using an expert system to improve the stock assessment-fishery management process and have implemented a system. The system, CANOFISH, or canonical fishery management system, is currently in the second phase of development (CANOFISH II). The design of CANOFISH I was first reported in Golden et al *(op. cit.)*. The design of CANOFISH I allows for the express linking of sampling, estimation, optimization, and simulation in an integrated system, and broadens the temporal and spatial scope of stock assessment (Fig. 8).

A number of commonly-used models are included in CANOFISH I for pedagogic reasons. Bioeconomic optimization is central to the system. Cost-effective sampling, estimation, and simulation are coordinated to meet the data requirements of the optimization models. The user has the option of having the ES analyze the results of one to four bioeconomic models. For each model, the ES is programmed to present the results of optimal sampling design and optimization along with comparisons of how the present fishery compares to the modeled optimal fishery under different scenarios of fishing effort, price, cost, and discount rate. CANOFISH I is implemented on a microcomputer with a fixed disk drive. It comprises five stand-alone computational programs and an Insight 2+ knowledge base of about 900 rules.

An overview of the design for the next version of the CANOFISH expert system/decision support system (ES/DSS), CANOFISH II, is shown in the flow chart in Figure 9. It retains elements of the original CANOFISH design (Golden et al *op. cit,* Stagg 1987) but is different in some significant ways. The CANOFISH I system is based upon and driven by the requirements of a number of standard fishery optimization models (based upon the surplus production model). Sampling, estimation, optimization, and simulation are linked in CANOFISH I. An expert system is used to integrate the system technically and to provide simple management advice. Linking or integrating sampling, estimation, optimization, and simulation is a primary objective of CANOFISH II. A richer suite of activities than is present in CANOFISH I is envisioned, however, particularly the inclusion of non-parametric methods and decision analysis techniques.

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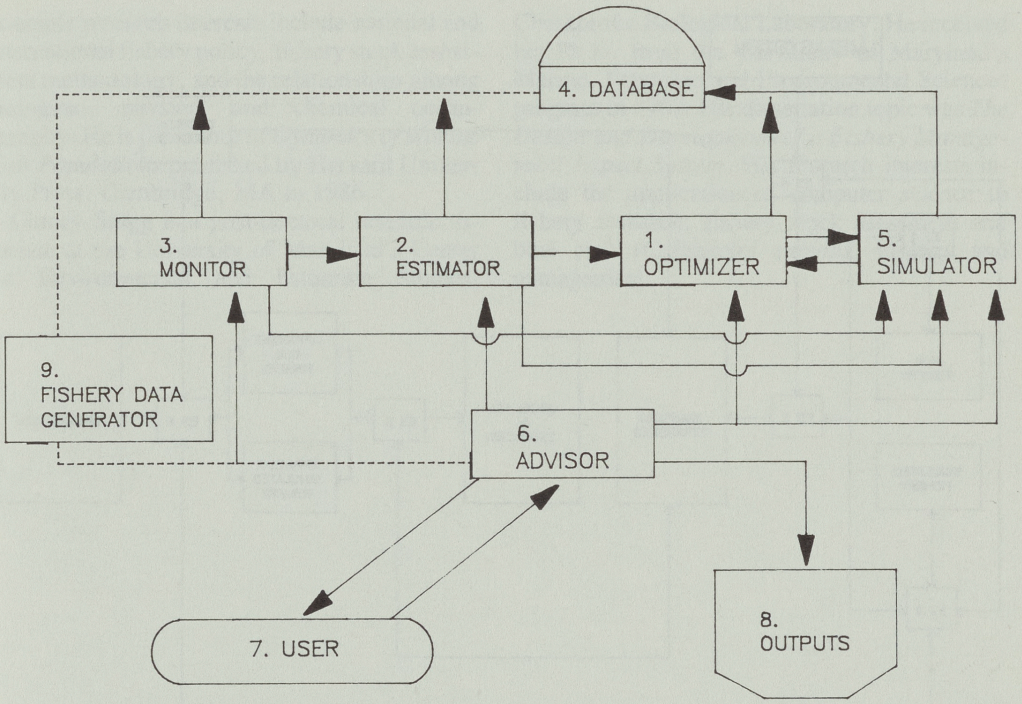

Figure 8. Conceptual design of CANOFISH I, a canonical fishery management system, a proof-of-concept expert system. The following explanations apply: (1) optimization models and sensitivity analysis, (2) intermediate results, estimation of parameters, (3) sampling of database, summary statistics, (4) database containing, (a) fishery data (empirical or simulated) and (b) results from 1., 2., and 5., (5) simulation model using data/results from 1., 2., and 3. to forecast (extrapolate) fishery, (6) control of system, expert system (7) user of system through computer terminal, (8) reports, graphs, telecommunications, (9) simulation model to create fishery data in the absence of real fishery data (after Golden et al 1987).

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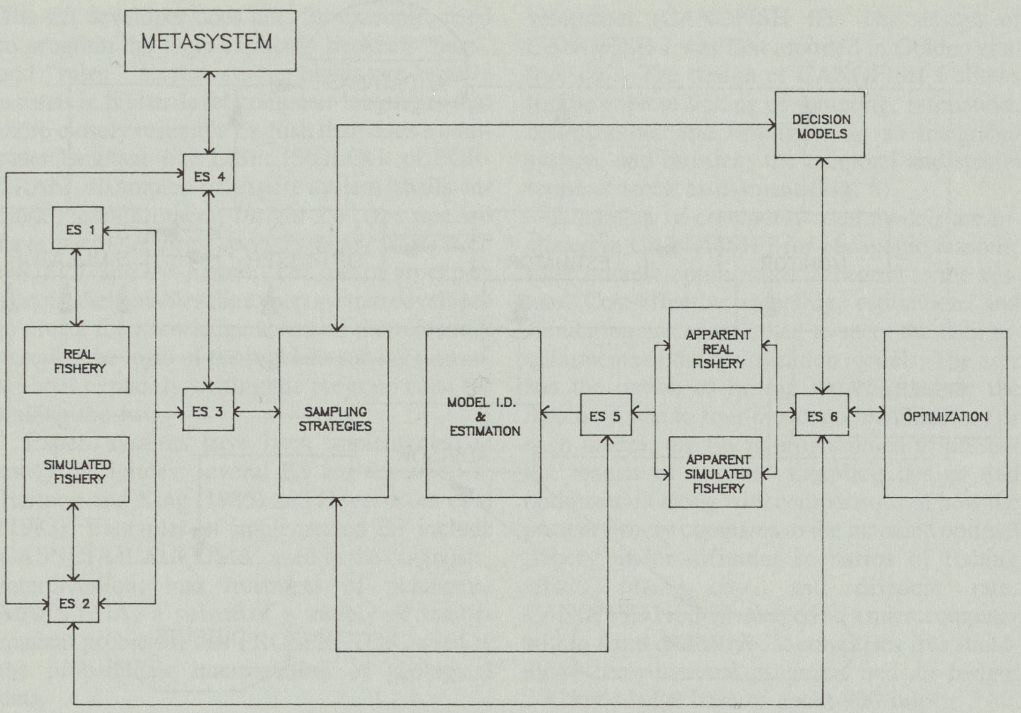

Figure 9. Schema of a fishery management metasystem where sampling, estimation, optimization, simulation, and decision-making are integrated (para/non = parametric and nonparametric models; ES = expert system).

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Socio-Economic Information Needs

David B. Rockland

The Magnuson Fishery Conservation and Management Act requires that fisheries management incorporate socio-economic considerations when establishing management measures. When the actual application of economics and sociology in fisheries management is reviewed, however, various shortcomings are found. Part of the reason for this lack of appropriate attention to the "people" side of fisheries management is that this science is fairly new and still relatively undeveloped. Empirical studies and data often are lacking, even where the theoretical science has been developed.

This chapter reviews the economics information that should be incorporated into fishery management decisions. The concepts of economic value and economic impact are reviewed. Consideration of the economic values that non-users of the resource place on the resource, such as the value placed on the option to use the resource some day, are also shown to be of relevance to fishery management decisions.

Economic Considerations

There are several economic concepts that should be considered in billfish management. The two broad categories of economic benefits that result from the fishery resource are *economic impact* and *economic value*. An economic impact is the answer to the question, "What is the economic activity generated by the use of the resource?" Economic value is the answer to the question, "How much value do people place on the resource?" These two benefits are distinct, but they are not entirely separable. Neither benefit type has greater merit as an economic concept than the other. Rather, they answer two distinct questions.

Each question is important for different reasons. Local and state government officials often base decisions on the economic impact in their region which translates into jobs, income, and tax receipts. In contrast, economic value is the value people place on the resource. This concept is certainly important to those people who value the fishing experience and the fish stock as a component of that experience. In addition, it has become a concept with increasingly greater application in fisheries management. However, economic value remains a vague concept to many people regardless of its definite existence.

User Values

User values related to billfish can take three forms: Consumptive use, non-consumptive use, and indirect use. Consumptive use values accrue to fishermen and other "consumers" of the fishery resource. Catch-and-release fishing is considered a consumptive use. It could be argued that catch-and-release is more of a non-consumptive use, although the actual activity the user undertakes is most similar to catch-and-keep fishing, and the two are considered together for definitional purposes.

The fact that fishermen go fishing in preference to another activity, and consequently spend money, time, and effort doing so, indicates they value the fish stock and the opportunity to go fishing. If faced with the choice, moreover, many would be willing to pay additional money before being excluded from using the resource. Willingness to pay over and above current expenditures of money, time, and effort is a further indication of consumptive use value. The entire willingness to pay, including current expenditures, is the total value to the resource user.

Just as fishermen place value on billfish and

sport fishing, so do others who may receive value from directly viewing the resource. This concept may have greater application to wildlife (i.e., bird-watching, whale-watching), but it is also clearly relevant to fisheries. The popularity of non-consumptive snorkeling and scuba-diving attests to the validity of the concept of non-consumptive use value, as does the prevalence of people who watch salmon on their annual spawning run. The relevance of this concept to billfish, which are not readily observable, may be less than for other species of fish. A willingness to pay before foregoing non-consumptive use is an indication of a value of the fishery resource to non-consumptive users, just as are the expenditures and efforts made to undertake the activity.

An indirect use is when people do not come into direct contact with the resource, but still derive personal satisfaction from it. Indirect use includes reading about fish, viewing pictures of fish, watching television specials about fish, and related activities. Examples of indirect use include watching a television special on catching billfish or reading *Marlin* magazine. People spend money (e.g., on books, magazines, television) to use the resource indirectly which, in itself, is an expression of value. There may be additional monies that an indirect user would be willing to pay before having to forego the opportunity for indirect use.

Non-user values are also referred to as intrinsic values and result from sentiments about the resource that are not related to current use. Non-use values are categorized as option and existence values. Option value reflects uncertainty about future resource use and represents the value the individual places on the availability of resource use in the future. In other words, individuals will value the option of having the resource available in the future in the event they want some day to fish for billfish.

The value of the option of future use is termed "ordinary option value." Quasi-option value is where new information is expected in the future and therefore a value exists in holding off a decision about use until that information exists. For example, suppose commercial fishery development was pending which could destroy the billfish resource. If research will tell you in the near future where the commercial market will degrade the resource, a value potentially exists in allowing a choice to be made in the future where preservation is an alternative to irreversible change.

Some people may value the billfish resource even if they know they will never use it themselves. These values are called existence values. Existence values generally are motivated by altruism or the unselfish concern for other people or for the fishery resource.

One type of existence value is bequest value which captures the desire to endow the resource to future generations. An example would be the value placed on knowing that one's child will eventually have an opportunity to fish for billfish. Other existence values may be motivated by altruism toward the fishery resource, itself, in the same way that people place a value on knowing that whales and bald eagles continue to exist in the wild.

Economic Impact

The expenditures made in the course of consumptive (i.e, sport fishing for billfish), non-consumptive (i.e., watching billfish), or indirect use (i.e., reading fishing magazines) may impact the local, state, and/or national economies. These impacts are expressed in terms of jobs, sales, or wages and salaries. Total economic impact is based on expenditures made by consumptive, non-consumptive, and indirect users. The fact that total economic impact exceeds the expenditures results from the premise that sales in one industry not only impact that industry but the industries that supply goods and services to the initially affected industry. Three levels of economic impact are discernible:

- *Direct Impact:* The initial purchases by the recreational fishermen.
- *Indirect Impact:* The purchases of inputs by the directly impacted business to produce the goods and services demanded by recreational fishermen. The initial round of indirect purchases has further indirect impacts as the suppliers to the direct businesses make purchases to meet that demand.
- *Induced Impact:* The purchases of goods and services resulting from the wages paid by the directly and indirectly affected businesses. Induced impacts have additional indirect and induced impacts as well.

An example of the direct, indirect, and individual impacts would be where the direct impact was the purchase of a fishing rod by an angler. The indirect impact would include the purchase of graphite, paint, and guides to make the rod.

Further indirect impacts might include the purchase of pigments by the paint supplier and aluminum by the guide supplier. The induced impacts would include the purchases by households with wages made by employees of the tackle, graphite, paint, guide, pigment, and aluminum manufacturers.

Economic impact analysis is primarily the process of calculating the total economic impact, which is the summation of the three levels of impact. This summation process is usually undertaken with an economic model of the study region. The economic effect of any activity may be seemingly infinite, as the initial expenditure is spent and re-spent by suppliers and households. However, there are a variety of limiting factors to the total economic impact. The expenditures are only impacts if they take place within the region. For example, in the case of a fishing rod, the suppliers of paint, graphite, and aluminum are probably not located in the same region as the tackle manufacturer. Households, which are the source of the induced effects, save part of their wages and have part withheld in taxes. Businesses do not spend a dollar for every dollar they taken in. These reductions provide a finite limit to the effects of the initial expenditure.

Once expenditures or sales occur outside the study region, they are no longer considered part of the study region's economic impact and are considered leakages. Therefore, the larger the study region, the greater the economic impact of a particular local expenditure since less of the indirect and induced impacts leak out. As a result, the economic impact on a state will exceed the impact on a local sub-state region, and the state impact will be less than the national impact.

Atlantic Billfish Plan

At the time of this writing (June 1988), the Fishery Management Plan for the Atlantic Billfishes (FMP) is before the Secretary of Commerce for review with a decision expected from the Secretary on September 2, 1988. This Plan has been in the preparation stage for approximately 11 years. Part of the reason for this lack of progress is that the FMP is a product of five regional fisheries management councils, and achieving the necessary consensus among this number of decision-makers requires time. In due course, however, the FMP has been agreed to by all the councils and is now before the Secretary for consideration.*

The objectives of the FMP are to:

1. Maintain the highest availability of billfishes to the U.S. recreational fishery by implementing conservation measures that will reduce fishing mortality.
2. Optimize the social and economic benefits to the nation by reserving the billfish resource for its traditional use which, for the continental U.S., is almost entirely recreational fishing. In the Caribbean, the fishery is both a recreational and small-scale handline fishery where billfishes are used as food.
3. Increase understanding of the condition of the billfish stocks and the billfish fishery.

Objectives 1 and 2 are socio-economic goals and allocate the fishery to the recreational fishery based on socioeconomic criteria. These objectives are carried out in the FMP by prohibiting the sale of billfish and prohibiting imports. These two management measures allocate the fish stock to recreational users. To make such an economic decision requires the use of economic information to understand the costs (the lost commercial fishery) and benefits (gains in the recreational sector) of the management measures.

The economic analysis in the Plan is constrained by the fact that few data are available for the analysis. The analysis focuses on the economic value associated with consumptive use; it is based on data from a study undertaken in New Jersey, where the following question was asked of recreational billfish anglers:

> "Considering the amount of fish caught on a typical day, how much extra would you be willing to pay in trip costs to catch one more fish of the following species?"

The foregone commercial catch is valued at dockside, and the loss of this exvessel value is taken as the cost of the management measure (as well as the management costs). The offsetting benefits are calculated by taking the number of fish not caught by the commercial fishermen as a consequence of the prohibition of sale, adjusting that number by the probability of the fish being taken by recreational fishermen, and multiplying the result by the average answer to the question from the New Jersey survey.

This approach has several shortcomings, including the fact that it ignores the economic impacts of the recreational fishery for billfish.

*Editor's Note: The Billfish Plan was approved by the Secretary of Commerce, effective 18 October 1988.

However, this problem, as well as most of the other shortcomings of the economic analyses in the FMP, is due to the lack of socioeconomic data available for billfish. The following presents the available information this author was able to obtain on the economic impacts and values associated with billfish:

Economic Values

The two estimates that are available reflect the value sport fishermen place on catching an additional billfish while on a billfish fishing trip. These values are:

- The Preliminary Fishery Management Plan for Billfish prepared in June 1983, includes a value of $500 in 1981 dollars for an additional billfish to a sport fishermen. In 1988 dollars, this value is approximately $625.
- The survey of big-game fishermen in New Jersey, described above, asked the question, "Considering the amount of fish caught on a typical trip, how much extra would you be willing to pay in trip costs to catch one more fish?" The average responses were:
  — White Marlin *(Tetrapturus albidus)* = $163.39
  — Blue Marlin *(Makaira nigricans)* = $354.89

Economic Impacts

The following are various measures of economic impacts of the recreational billfish fishery:

- Expenditures by participants in the 1977-1978 recreational billfish fishery were estimated to be approximately $100 million.
- In the 1983 mid-Atlantic marlin and tuna recreational fishery, total expenditures were over $40 million. Approximately $7,400 was spent by recreational fishermen for each billfish landed.
- The survey of big-game fishing in New Jersey revealed the following:
  — Total charter expenditures for marlins, yellowfin tuna *(Thunnus albacares)*, and bigeye tuna *(T. obesus)* fishing were $1.4 million or $922 per trip.
  — The average fishing trip by a private boat cost $286.33, or $3.3 million for the fishery.
  — The average boat spent $5,063 in seasonal expenses such as rods, reels, insurance, tackle, mooring, and club dues. This totaled to $3.9 million for the private boat fleet.
  — The total cost of the vessels in the New Jersey private boat fishery for big-game species was $97.0 million.
- A 1986-87 survey of sport fishermen in the Florida Keys showed that the average charter boat fishermen who caught a marlin or sailfish *(Istiophorus platypterus)* spent $423.49 in the Keys for the day of fishing on which he or she caught the fish. The total number of charter trips in the Keys was 17,665 boat-trips or 77,196 person-trips. An estimated 12.8% of the trips, where a fish was caught, caught a billfish. Therefore, a ballpark estimate of the amount the charter fishery for sailfish and marlin generated in the Keys economy was: 77,196 × .128 × $423.9 = $4.2 million. This estimate is biased downward if other fish were caught on unsuccessful marlin and sailfish trips.

The conclusion to be drawn from the statistics presented here is that few data are available on the economic characteristics of billfish; no data are available about the dynamic characteristics of the fishery. Any economic analysis of the billfish fishery that observes only static conditions, or looks at the fishery as it currently exists, would be incomplete. An analysis of regulatory impacts that considered only the characteristics of the present billfish fishery might conclude that no management action is necessary. However, such an analysis would have missed the point of the plan, which is to protect a valuable recreational fishery from expected future changes.

One of the dynamic changes is an emerging commercial market for billfish. For example, commercial landings increased 588.8 percent from 1979 to 1986. The nominal value of landings is still low but, if the past seven-year trend were to be repeated over the next dozen years, commercial landings by the year 2000 would exceed two million pounds. This level of billfish landings would certainly affect both the stock and a very valuable recreational fishery. An analysis that fails to incorporate this increasing commercial market is missing the key ingredient of the economic forces taking place in the fishery.

A second dynamic effect in the fishery, accompanying an emerging commercial market, is a change in behavior by recreational fishermen. The health of the billfish stocks is predi-

cated on the practice of catch-and-release fishing. For example, a 1977-1978 survey of the billfish fishery showed that recreational fishermen release the following portions of the fish they catch:

- Blue Marlin — 63 percent released
- White Marlin — 70 percent release
- Sailfish — 74 percent released

Fewer releases would be expected in a developing commercial market. Recreational fishermen will lose their incentives to release fish for two reasons: 1. they will believe that any fish they release will be taken by other fishermen (sport or commercial) and sold; and 2. they will forego opportunities to make money if they release their fish.

A Research Agenda

A workshop was held May 6-7, 1987, in Tampa, Florida, to develop a research agenda for the economics of red drum *(Sciaenops ocellatus)*. Workshop participants agreed that the agenda was relevant to any fishery and could serve as a basis for research pertaining to the management of any stock. That research plan serves as the basis for the research agenda for billfish as presented here. This agenda reflects the thoughts both of this author and of the 18 other workshop participants, as well.

Economic Issues for Billfish Management

Questions related to billfish management focus primarily in two areas: 1. allocation of fish between commercial and recreational fishermen; and 2. the effects of fisheries regulations on recreational and commercial fishermen. The specific questions are:

1. What is the net present value of the stream of yields from the resource under alternative regulation scenarios?
2. What is the optimal allocation between user groups?
3. What are commensurate measures of value and numbers of users between sport and commercial fishermen?
4. How do economic benefits in the commercial and recreational industries change with stock changes?
5. What are the nature, operation, and business structure of charter boats?
6. What are the social, economic, and demographic characteristics of recreational and commercial fishermen?
7. How much do the economic benefits of either user group rely on the availability of the target species, and to what degree is there substitution?
8. How do anglers respond to management measures, and what are the cumulative impacts of a series of regulations?
9. How do the values and methods of valuation of commercial and sport fishing compare?
10. To what degree is the value of tourism a function of the existence of commercial fishing operations, due to the availability of locally caught seafood in restaurants and the aesthetic appeal of a fish dock?

The foregoing questions are not mutually exclusive and cover a broad range of issues. Analysis of these questions would generate much of the information needed to evaluate the economic tradeoffs between recreational and commercial fishermen. The analysis would also look at economic tradeoffs over time. If managers choose disappropriate benefits now (as opposed to future periods), they could evaluate the costs of that choice in terms of discounted foregone (larger) future returns.

Theoretical Concerns

A major issue for the management of billfish in the Atlantic Billfish Plan is the allocation of fish among competing user groups. If theoretical economic principles are used for allocation purposes, then allocation is based on marginal changes in economic value instead of on economic activity. The latter is measured in terms of jobs, tax receipts, sales, income, etc. These measures are intuitively appealing, but are theoretically incorrect for purposes of allocation based on economic theory. They do not describe the dollar amounts the users would be willing to pay for more of the resource or would require to be paid for a decreased use of the resource.

One of the reasons that economic activity is not a theoretically valid measure of economic welfare for fishery allocation decisions is that the expenditures made for commercially-taken billfish, or for goods and services used for sport fishing for billfish, primarily represent the costs associated with the catch and retention of fish. These do not measure the value placed on additional harvesting by the two groups. Further, economic activity in each industry exists at the expense of economic activity in other industries. For example, if people could not purchase fish in the store they might buy chicken. Therefore,

the economic activity in the commercial fishing industry exists at the expense of corresponding economic activity in the chicken industry since chicken farmers would experience a greater demand for chicken in the absence of commercial fishing.

The same argument holds for sport fishing. If people did not go sport fishing they might, instead, go bowling or boating, attend movies, or play tennis. Therefore, the sport fishing industry can be said to exist at the expense of other recreation industries.

The economic theory of allocation requries the use of marginal analysis. Simply stated, each fish should be allocated to the user group generating the highest value for that fish. Each successive fish given to a group will have a lesser value than the previous fish allocated to the group. At some point, the value for an additional fish may decrease such that it makes more sense to allocate that fish to the other user group. At this point, the value of the fish at the margin, when allocated to either user group, will be the same. In the economic theory of allocation, the goal is to derive an allocation strategy where the last fish given to each user group is worth the same amount. The term for this procedure is "equating the margin." When marginal values to each user group are equal, taking the fish away from one user group and giving it to the other will result in a decrease in the combined total value of the fishery. The fish would have a lower value in its new use than it did in its previous use.

The calculation of optimal economic allocations at the margin requires knowledge of the value that each user group places on the fish stock and how those values change for different allocations of the stock to the user group. On the commercial side, the analyst must estimate consumer demand for the fish product. This relationship of price and quantity purchased will provide measures of the surpluses accruing to consumers of the commercial catch.

To estimate all the economic surpluses created by the commercial product requires both that the prices and associated revenues from the commercial product be quantified and that the costs of producing that product be understood, as well. The specific costs of producing different quantities of the commercial product need to be quantified and subtracted from the revenues to derive net benefits to the producing sector for different levels of production.

When the recreational fishery is included in the allocation computations, information must be known on how the recreational fishermen value the opportunity to use the fish stock. To allocate at the margin, the analyst must have data on how the value associated with recreational fishing changes for different levels of catch — in total, for all recreational fishermen, and on a per trip basis. To derive estimates of consumers' surplus for the recreational fishermen, the cost of the fishing trip must be subtracted from the total value placed on the experience.

The net economic benefits associated with the provision of goods and services to the recreational fishermen by the sport fishing industry also require consideration. For this purpose, information on the prices of the various goods and services and the cost of production of each of those goods and services is required.

A Long-Term Research Agenda

Theoretical Research. The following are the projects that would fill the gaps in the existing economic theory and methodologies available to determine the economic information needed to manage billfish. Many of the projects are more akin to specific tasks of a broader research project and, hence, several of the tasks could be aggregated under a single research effort.

1. Identify appropriate demand-and-supply modeling methods for the recreational billfish fisheries. These methods should take account of spatial and temporal factors.
2. Develop methods for estimating and comparing producer and consumer surplus for recreational and commercial fisheries. The specific data needs for such analyses need to be outlined.
3. Determine the appropriate roles for the analyses of expenditures, exvessel and retail values of recreational and commercial fisheries, and regional economic impacts of each user group in allocation decisions. Specifically define where and when these types of analyses have validity and under what circumstances they can be used from an economics perspective. Identify where equity and economic concepts differ, and the economic consequences from making allocation decisions strictly on the basis of one concept or the other. Also, develop the methodologies for evaluating industry

transfer costs resulting from management decisions and user industry exits.

4. Develop the means and methods for evaluating the effects of various regulatory measures. These methods should deal with the effects of the measures of economic benefits and socio-economic importance identified in the previous research efforts.

Specific Applications. Specific applications are research projects that could be undertaken, given a resolution of the methodological issues identified above and with available data. Generally, the degree to which data are available significantly affects the ability to conduct particular studies and the precision of the resulting analyses.

1. Analyses of the demand for recreational fishing trips is a key issue. The specific tasks for research efforts pertaining to recreational fishing demand are:
   a. Determine the demand elasticities of billfish anglers, such as success, price, and income;
   b. Estimate demand curves for specific ports or origins using the travel cost method;
   c. Use the travel cost method with data aggregated for multiple ports and determine the changes in precision between using single and multiple ports as well as any biases in the resulting surplus estimates;
   d. Investigate methods to transfer site-specific demand curves to other sites and species;
   e. Evaluate alternative methods of estimating the demand for recreational billfish fishing trips;
   f. Determine the effects of management measures such as bag limits on the demand for billfish recreational fishing trips.
2. Investigate the specialization of recreational fishermen seeking billfish and the preferences and levels of trip satisfactory for all anglers from different compositions of the catch (i.e., weight of fish versus number of fish).
3. Determine the impact on domestic fisheries of international harvesting agreements.
4. Prepare cost/earnings studies for the commercial harvesting and processing sectors and the suppliers of goods and services to recreational billfish anglers.
5. Identify the market channels for billfish and the importance of joint product marketing to the ability to market billfish and other fishery products.
6. Determine the substitutability of commercial species for producers as a function of the relative market prices of complementary species.
7. Develop demand-and-supply curves for commercial fishery sectors accounting for multi-species production.
8. Define the specific user groups in the billfish fishery and the degrees of interchange among those groups.
9. Estimate dynamic models (e.g., using control theory) for the billfish fishery and perform sensitivity analyses on the estimated parameters to account for dynamic effects.
10. Measure the local, state, and regional economic impacts of each sector in the fishery and the degree to which management measures affect the estimated economic activity. Specifically, derive the effects of those management measures already in the fishery, such as game fish status of billfish in Florida and Massachusetts.

Data Collection. In general, the validity or precision of an analysis is contingent upon the data available to the analyst. Managers may occasionally confuse the imprecision of an economic analysis as a lack of specificity in the science while, in fact, the problem is the lack of good data with which to perform the analysis or lack of data relative to the complexities of the model. The major data collection needs are:

1. Consider the Marine Recreational Fishery Statistics Survey as the primary general data collection vehicle for recreational fisheries data. The MRFSS offers the mechanism or framework to collect the data, and it does allow for modifications that would provide data for economic analyses. These modifications would include:
   a. Expand the sample sizes for the telephone and intercept surveys to allow for better estimates at the species and site levels;
   b. Include refinements to the existing (1987) questionnaire to better specify the target species and "joint good" activities;
   c. Add a question on the number of planned trips in the next two months to comple-

ment the existing question on the number of trips in the previous two months;

d. Add several social/economic questions. Specific data elements that might be included are:
   i. Trip expenditures,
   ii. Disposition of catch,
   iii. Years angler has been fishing, income, number of vacation days,
   iv. Angler perception of management measures,
   v. Fishing motivation,
   vi. Location of, and number of trips to, most frequented fishing site in past year,
   vii. Number of trips for target species in past year,
   viii. Catch on average trip for target species,
   ix. Behavioral change for a change in catch,
   x. Alternative uses of leisure time,
   xi. Whether trip is single or multi-purpose, and
   xii. Satisfaction level;

   identifies willingness to pay for a species or a general change in catch rates.

2. Conduct the socio-economic survey of marine recreational fishermen, last conducted in 1981, every three to five years, or continuously.
3. Establish a data system that provides wholesale and retail price and quantity information for commercial products.
4. Further develop the Trip Interview Program to provide effort and costs and returns data for the commercial fishery.
5. Generally improve the timeliness of the data collected currently on the commercial fishery.
6. Establish categories for the reporting of exports of domestic fishery products that are commensurate with the import and domestic harvesting categories. Regularly provide these export data.

The foregoing various additions to current data collection efforts would provide much of the needed data for economic analysis of most fisheries. It should be noted, however, that billfishing is a "rare-event" fishery which can require intense site-specific surveys such as at a tournament, or surveys of select subsamples of the fishing population, such as selecting boats that exceed 25 feet in length from the boater registration files. These efforts may be needed to gather a sufficiently large sample size to generate precise estimates. The consequence may be that while the MRFSS will, with modification, provide valid data for most fisheries, it will not do so for big-game species. Therefore, studies such as that cited above for the New Jersey big-game fishery will be required.

Conclusion

The science of fisheries management is increasingly becoming the science of allocating scarce resources among competing wants. The management of billfish is no exception. The current FMP for Atlantic Billfishes allocates the resource to recreational users based on a perceived highest economic value and a need to conserve the limited stocks. The value is perceived because few economic data exist that provide estimates of the economic benefits of billfishes.

A need exists to develop economic data for billfishes and most other marine species. This chapter offers a research agenda for billfish that could satisfy the socioeconomic information needs for billfish. This agenda is generic, and can be applied to almost any fishery where allocation issues are being considered. Failure to undertake the needed data collection and economic analyses will make less precise the economic benefits and costs of fishery management decisions. The result can be significant net economic losses to the public, for whom the resources are managed, due to the inability to quantify accurately all the economic impacts, user values, and non-user values of a fishery resource.

David B . Rockland received an M.A. degree (economics) and the Ph.D. (marine economics) from the University of Delaware. His doctoral dissertation was an analysis of the economic characteristics of Delaware's recreational and commercial fisheries as a means for the Delaware legislature to understand the economic effects of various fishery regulations. He worked as a senior analyst and project manager on fisheries and oil and gas development projects for Centaur Associates, Inc. He joined the staff of the Sport Fishing Institute in Washington, D.C., as director of economics in 1985 and became Secretary in 1988.

Panel 3 Discussion

M. Okuno, Fisheries Agency of Japan:

Dr. Rockland, you presented figures showing that, for 1977-1978, the recreational fisheries for billfish produced $100 million. Also that, in 1982, the recreational fisheries produced $40 million in the Atlantic. Do these values include all of the direct, indirect, and induced values?

David Rockland:

Yes; those economic values reflect the direct, indirect, and induced impacts. The $100 million is for the entire Atlantic and Gulf of Mexico recreational billfish fishery. The $40 million is for the Mid-Atlantic billfish fishery. Those values reflect the calculations with multiplier effects.

M. Okuno:

My second question relates to the Fishery Management Plan for Atlantic Billfish. If I remember correctly, in the National Standards of the Magnuson Fishery Conservation and Management Act, you are obliged to take into consideration all users of marine fisheries, both recreational fishermen and commercial fishermen. There are some commercial fisheries in the Atlantic for billfish. In this case, you cannot ignore the benefits of the commercial fishery. The Atlantic Billfish Plan does not take the commercial fisheries for billfishes into account, and therefore seems unfair to commercial fisheries. Why aren't commercial fishermen taken into consideration?

Greg McIntosh, South Atlantic Fishery Management Council:

There is no directed commercial fishery on the Atlantic stocks of billfishes. The fishery that does exist is a by-catch fishery. The purpose of the plan is to reserve these fish for recreational fishermen; however, it does not preclude commercial fishermen from catching billfish.

John Gulland, London, England:

Dr. Skillman, you talked about stock structure. Do you agree that in many of these fisheries it's not possible, in fact, to talk about stock structure without defining what your problem is, what your aim is? And do you agree that a group of fish is a stock if you can treat it as a stock for the purpose of the analysis you're doing, and that it may change from time to time and place to place depending on the purpose of your analysis?

Robert Skillman:

I would agree with that, John. It depends on what types of questions you're asking. If the questions you're looking at are on a generational or almost evolutionary scale, you start defining sub-populations or stocks in one way. If you're concerned with management down to a year or less than a year, your concept of a stock is really different. The types of methods that you're going to employ to identify those stocks and to characterize what's going on with the population are quite different.

John Gulland:

Dr. Rothschild, you were a bit puzzled as to why one of the solutions of this gap between simple models and complicated situations was to go to an even simpler model. I think this may be because you have left out the third column, the actual management actions, which tend, for very good practical reasons, toward simple choices: you let more fishermen go fishing, you kick the foreigners out of your 200-mile limit, and so on. If your management problem is simple you may be able to use a very simple model. For example, in the Gulf of Thailand I think all of these complexities occur — you can't age the fish, you've got hundreds of thousands of fishermen, you've got hundreds if not thousands of species, etc. Yet the simple model of looking at total catch, the abundance of fish as represented

by the catch per hour of a research vessel, tells you what's happening. It tells you that your simple management action is to take a box of matches and go around and burn every other vessel. It's straightforward. I wonder whether that might be a way out of this dilemma, that is, both an explanation of why you might be able to go to a simpler model, and also how you might be able to treat this gap between models, which are mainly simple, and the reality. It would seem to me that you have left out the management choices from your display.

Brian Rothschild:

I think there are situations in complex fisheries, such as the Gulf of Thailand, that can be viewed in simple contexts. But let me give you another example that I'm not sure is amenable to that simple analysis. In the U.S. shrimp fishery, in the Gulf of Mexico, we're dealing with at least three species of shrimp, very many stocks, and thousands of fishermen. While it's clear that as a general management strategy it would be nice to reduce effort, there are many different options or ways of reducing effort. That is a complex situation. In many fisheries such as this, the question boils down to whether you want to have a gross and simple answer, or whether you want to have a more finely tuned answer. The issue is how valuable is the kind of decision that you want to make. If you're dealing with a fishery like the extremely valuable shrimp fishery, you really ought to think about fine tuning. If it's a grosser situation, why bother?

John Gulland:

Dr. Rockland, I have a question in relation to the allocation problem. As I understand it, the biological model in the allocation seems to be that there is a fixed supply of billfish which you then allocate to one user or another. That is certainly a great advance over the earlier fishery management model of the 19th century and much of the 20th century, which was that there was an infinite supply of fish. I'm wondering whether this is necessarily true for some of the billfish stocks we've heard about, and whether the sort of economic model is true which says the dollar value of a billfish to a recreational angler is, let's say, $1,000, and the dollar value to a commercial fisherman is $200? Obviously, just looked at that way as a fixed resource, you'd allocate to the sport fisherman. I'm just wondering, considering that not more than say 5% of your tagged fish are returned, whether to get one more fish to the recreational fisherman you would need to release 20 fish from the commercial fisherman? Thus, to get your extra $1,000 you would lose $4,000? Does that not seem a sensible way of bringing some biological information into your economic analysis?

David Rockland:

Economics as a science is defined as the allocation of scarce resources among competing wants. If the earlier models of biology were true and there was an infinite supply, economics really wouldn't have as much of a role to play as it does at the present. It would be helpful, if the tag return data are right, and you could be very certain, if a commercial fisherman lets a fish go, that there is such and such a probability that the recreational fishery will have access to it, and therefore increase the probability of capture of that fish by recreational fishermen. Again, recreational fishermen are perhaps fishing on the probability of catch rather than the certainty of capture, on the perception that they will catch more fish. A whole lot of variables exist but I would say, certainly in a perfectly rational world, that if you have perfect data your analysis will be perfect.

Brian Rothschild:

I thought the Fishery Conservation and Management Act talks about the criteria for setting catches, and I think it says that no such allocations shall be made on economic criteria alone. So I was wondering, after hearing your talk, what other non-economic criteria are used in the billfish plan with respect to setting the allocation?

David Rockland:

In addition to the biological criteria and the economic criteria there are certainly a great deal of sociological and anthropological considerations involved. We've allocated fish in this country in large part based on what we call traditional use.

Brian Rothschild:

In your talk you presented some persuasive economic arguments for the allocation of billfish, so I was just wondering what non-economic arguments are being used, since the

law says that no such allocations shall be made on economic criteria alone?

James McHugh, Mid-Atlantic Fishery Management Council:

Dr. Rothschild is right as far as the extract from the Magnuson Act is concerned, but the whole basis of the plan doesn't focus entirely on that consideration. When you explore the guidelines for the National Standards, you'll see that management plans may be predicated on socio-economic factors. Primarily, there is a conservation intent to protect what is demonstrably that portion of the fishing industry that derives the greatest economic value from utilization of those particular species. The better than 500 vessels in the longline fleet have a significant capacity for reducing the availability of a species which has been historically a recreational target.

Philip Meyer, Meyer Resources:

I've been tracking billfish a little bit for ten years, and I was real interested in what's been said at this conference. It seems that what we're still hearing is that there's been significant progress, a lot of ingenious approaches to doing better with limited data but, in fact, there is still this gap that everybody recognizes. There's precious little that can be delivered to management in the immediate future. I was interested in Brian Rothschild's efforts to get around to that in some interesting ways.

I've been working with the Western Pacific Council on an access management plan and the need there seems to be to predict rather than to understand. I'm making a distinction between the scientific work, which has traditionally been to understand, and management. I'm wondering whether there are some unutilized interdisciplinary tools that can complement the traditional models, which may provide some insight. One is searching for leading indicators, basically through lag correlation analysis of things that you don't necessarily think you could ever connect up. It would be really interesting to let the computer loose on doing some lag correlation searching with respect to effort in various parts of the world and the substantive status of the stocks data that we have. That might seem to be very unscientific; however, productionist scientific procedures, where you start by viewing a fact or data and then attempt to build a theory to explain what it is you're looking at is where major breakthroughs come. And it's my impression that major breakthroughs would be welcome in the billfish community. I wonder if there's a potential for this or other types of innovative model building that don't necessarily flow from traditional commitment and modes of science.

Brian Rothschild:

Basically, the models that you see depend a lot on estimates of fishing mortality, natural mortality, etc. As has been pointed out by several of the speakers, they are tremendously variable and we don't really understand much about the sources of variability. The other approach is the one that you mentioned, the leading indicator approach, which really in general you talk about on a time series. I have the notion that it hasn't been applied nearly enough to these sorts of data. I was really impressed after working on a lot of the tuna data and billfish data 18 years ago that the shape of the analyses today is pretty much the same as then. The one thing that we have today is a lot of time series data that do show some very interesting periodicity.

Larry Nielsen:

I'm going to ask all four panelists to make a decision. In all of these talks we've said we need to have more to do more. Okay, you have 10% of your budget assigned to manage marine fisheries in the Pacific or the Atlantic; what percentage would you devote to getting the kind of information you want related to billfish? And would that amount of money or that percentage be enough to do anything well that you're asking to be done? In other words, are billfish important enough for you to put the resources behind it, and take from other things, to do the things well that you're saying need to be done, given the data.

Chris Boggs:

Some things can be done pretty cheaply. When I look at things I try and recommend things that are possible to do. Validation studies on growth rates aren't going to cost much, especially if you can include sport fishermen in a tagging program. As for creating an international organization to get data from every fishery in the region, I couldn't get one year out of my budget. That I think is the most essential thing to occur to assess the stocks. But it's totally hopeless on my budget. What I'm looking to try and do in all the programs where I work

with pelagic fishes is try and get fishermen more involved in the work.

David Rockland:

I don't think in any one year anyone's ever spent more than about $500,000 to do economics research. But I would say if a realistic budget was having $10 million to do economics research on all marine species, that an allocation of $500,000 of that to do economics research relating to billfish would address a whole range of the questions that need to be addressed, and we'd do quite well at answering many of those questions. That's approximately what I would spend on billfish research.

John O'Brian, Australia:

I'd like to ask David Rockland whether economists take into account the contribution that recreational fishing makes to the quality of lifestyle? We've got an aging population, early retirement, and I suspect that people who fish live longer. At the same time, people who fish are less likely to get into trouble.

David Rockland:

The question of economic value addresses what something is worth to you. If you answer that question correctly, in essence you've captured what that resource or what that activity is worth to you in terms of how it affects your quality of life. Whether you could ever come up with how it affects the quality of life in a society as a whole is a good question. Using your example — there's less crime because kids take up fishing instead of drugs — I don't know if economics can really apply a valid measure to that. I would think sociologists could tell us a lot more about that subject.

James Joseph, Inter-American Tropical Tuna Commission:

My question is for Christofer Boggs, with respect to why the statistics for longlinging are so sparse, because I have a larger question about statistics. I listened this morning to the talk about models and the use of models and the shortcomings in the data. It seems almost like *deja vu* to me. Nearly 20 years ago, one of the basic issues in billfish assessment was the paucity of data and organizations and institutions were not collecting data that could be used to evaluate the impact of man's activities on the populations of fish. Here we sit again, almost 20 years later, addressing the same issue. I'm wondering if it's a problem with institutional arrangements, a problem of responsibility, and just what is happening here? It's been a long time. We've gotten some improvements, but most of the improvements I've seen today are in the quality of the slides that are presented. They're a lot more colorful and easier to look at than they were 20 years ago. I'd like to hear from all the panelists what they think about the adequacy of the data and, if inadequate, why so?

Christofer Boggs:

To play it safe, I would echo back what you said about it's being the institutions' responsibilities — who's paying attention and how much focus is being given to the problem. It's easy to understand why commercial fishermen don't spend more time insuring that their reports are viable. It's "a pain in the butt." The forms are long and complicated and hard to fill out and longliners are real tired when they get back from a trip. So, somebody's got to be in charge of making them do it. There's a breakdown there. As to why it hasn't been a higher priority to make reporting mandatory or to enforce it, or whatever, in my organization it seems to me that there has been an emphasis towards looking more at biology. I was employed as an ecologist. There's a lack of resources to address just the problem with the collection and management of the data. I haven't been long in the agency, but I was surprised at the number of people around me who are expert in my field and the lack of people going down to boats and going down to the shore and counting fish and looking into data bases. There's no concerted attempt in the state of Hawaii to make sure that everybody who's a commercial fisherman files his report.

David Rockland:

On the recreational sector, one might ask, since the NMFS does a recurring Marine Recreational Fisheries Statistics Survey, why doesn't that produce the adequate data for billfish? The reason it doesn't is that billfishing is a fairly rare event fishery, so they would have to have a tremendously large sample size to be able to come up with a statistically valid sub-sample for billfish. What's inadequate about those data is that there needs to be concrete micro-level studies on billfish anglers to come up with the kind of data that you could consider statistically valid.

Brian Rothschild:

As to why the data are inadequate, this is a more or less general problem. You can look at it either from a U.S. point of view or from a global point of view. In the U.S., if you wanted to get adequate data, you would think that the people who are in charge, for example the NMFS, would make that a top priority. I haven't heard anybody that's been in charge of the NMFS, or at high levels in the NMFS, indicate that to be a high priority and a key mission for the agency. Your own organization, the IATTC, has made it very clear that it's the highest priority, and that's why the tuna commission has good data. When putting together ICCAT, the people who participated made that a high priority. That's one reason why there are relatively good data on the Atlantic. So, basically, the problem lies with the individual governments and the people in charge; they're simply not interested in making it a high priority. The second thing is that if they did make it a high priority, then there'd be a considerable political backlash because the industries — the recreational and commercial industries — don't always see it in their best interest to provide data. So, it's a political decision. Basically, that's the reason you don't have really good data.

Robert Skillman:

The problem with the Hawaii data, and possibly other domestic data, is that the local governments are not really involved in their assessment and or evaluation in the processes leading to the management decisions based on the status of the stocks. There is, indeed, a separation of roles, in that there's no connection between the collection of data and the utilization of data, so the data aren't given any special value by those who collect them.

David Smith, angler, Melbourne, Australia:

Mr. Chairman, I have listened to all these informative discussions and have found them both interesting and significant. They have given me renewed hope for the future well-being of the billfishes. At the same time, given that we are all conservation-minded, I am moved to urge that we all ought now to take some positive conservation action in the immediate future while everything remains fresh in our minds. For example, I would suggest that all countries, both small and large, should immediately institute active billfish tagging programs through the recreational fisheries, with supply of tags, methods of deployment, and data correlation made available to anyone from those tagging programs that are already well established. Small as well as large nations individually should work out their own billfish conservation and management strategies. I urge that all of us try to do something specific in the next few months to help unite all billfish anglers in the spirit of conservation. Collectively, individual conservation measures can be meshed together into an international conservation approach, with a great many individuals involved worldwide, each feeling an important part of it.

Panel 4

Current and Potential Management Institutions and Procedures

James Joseph, Chairman

Development in the International Management of Tuna and Billfish Resources

Kazuo Shima

The topic of this chapter is the management of highly migratory species. The term "highly migratory species" covers species ranging from whales to tunas, billfishes, even fur seals. In a broader sense, this category might also be defined as including salmonids and similar species.

Looking also at the species cited in Article 64 of the United Nations Convention on the Law of the Sea, it becomes clear that highly migratory species are very diverse indeed. Each stock of these species follows its own specific migratory route. It is also evident, therefore, that we cannot classify each species simply as either "highly migratory" or "non-highly migratory".

Mankind has, for a long time, been perplexed over how to handle pelagic species that migrate widely beyond the jurisdictional limits of a single state. Particularly since 1977, with the global trend toward extending coastal state jurisdiction to 200 nautical miles, the issue of managing highly migratory species has taken on increased complexity. In the days when the human population was small, and the seas seemed vast in relation to this population, when fishing technology was relatively underdeveloped, and marine resources were truly huge in relation to fishing effort, there was little danger of pursuing a particular fishery resource to the point of depletion.

By the same token, however, the very fact that technology was underdeveloped meant that there were limits to the fishing grounds and resources that man could utilize. Disputes over fishing grounds were occasionally quite fierce as a result. In this sense, it could be said that the problem of fishery management has been with us since olden times. Particularly in the case of international fishing grounds, in which coordination was not placed in the hands of a single authority, it became essential that rules be developed to adjudicate such disputes.

With the sharp growth in global population following World War II, interest in marine resources increased significantly. Rapid development also occurred in fishing technology, based on scientific and technical advances. Development, in turn, gave rise to a danger of overexploiting particular fishery resources. In addition, fishery disputes surrounding the use of marine resources increased steadily in intensity and scope. In this sense, with the dawn of the 20th Century, the need for fishery management and consequent international cooperation became eminently clear.

North Pacific Fur Seals Convention

The Convention for the Preservation and Protection of the Fur Seals in the North Pacific Ocean was one international response to the first problem area in the management of highly migratory species.

From the 18th to the late 19th Centuries, hunters from the U.K. (Canada), the U.S., Russia, and Japan captured fur seals *(Callorhinus alascanus)* in the North Pacific. Without regulation of the hunt, the stock was estimated to have declined to a level of no more than 200,000 seals.

As a result, in 1911, these four nations concluded the Convention for the Preservation and Protection of the Fur Seals in the North Pacific Ocean, and collectively undertook the management of this resource. Thanks to their efforts, by the late 1950s the fur seal population had, reportedly, recovered to a level of 2,000,000

animals. This effort may, therefore, be cited as a highly successful example of international cooperation for management of wild animals. Although this Convention was temporarily voided by World War II, a new convention, the Interim Convention on Conservation of North Pacific Fur Seals, was concluded in 1957.

Notwithstanding these conservation efforts, the fur seal population is believed once again to have declined, to the 1,000,000 level. This circumstance has led to a clamor for more scientific research and increased international cooperation in this area. However, the U.S. did not ratify the 1984 Protocol, concerned chiefly with the extension of this Convention. As a result, the situation has remained in a vacuum since 1985, causing grave apprehension over the state of the fur seal resource.

Under the mechanism created by this Convention, fur seals may be taken only around the three main breeding islands of the Pribiloffs, the Commander, and the Robben Islands, which are located in U.S. or Soviet territory. The countries which lack breeding islands (Japan and Canada) are given 15% of the fur seal skins taken, in return for their pledge to abstain from catching seals that migrate to their waters.

The Atlantic Ocean

Various international fishery organizations were established in the Atlantic Ocean area at the beginning of the 20th Century. The first of these was the International Council for the Exploration of the Sea (ICES), a scientific organization concerned with the ocean and its living resources, organized in 1902. This body did little research on highly migratory species, but did pioneer research oriented to the development of theories on fishery management and resource evaluation.

With the revitalization of the fishing industries of many countries following World War II, the North-East Atlantic Fisheries Commission (NEAFC) was established in 1959 (Fig. 1). This body was concerned mainly with fishery management, focusing principally on groundfish species, haddock *(Melanogrammus aeglefinus),* cod *(Gadus morhua),* herring *(Clupea h. harengus),* and mackerel *(Scomber scombrus),* with narrow migratory ranges, and deriving the necessary scientific data from ICES.

The highly migratory species traveling through these waters include whales and bluefin tuna *(Thunnus thynnus),* but, those organizations have only rarely concerned themselves with management of highly migratory species.

The management of whale stocks in the Atlantic is undertaken by the International Whaling Commission (IWC), founded in 1946. Management of tunas had to await the establishment of ICCAT in 1966. The other organizations that have been established in this area are: ICNAF (founded in 1950), NAFO (1979), CECAF (1967), ICSEAF (1969), and WECAFC (1973). Except for the North-West Atlantic Fisheries Organization (the NAFO Convention clearly excluded highly migratory species from its jurisdiction) these organizations can manage highly migratory species in their convention areas (Fig. 1). In reality, however, they have not been involved with highly migratory species, entrusting their management entirely to ICCAT and IWC.

International Commission for the Conservation of Atlantic Tunas (ICCAT)

Background and Evolution. In 1960, a tuna symposium was held in Dakar, Senegal sponsored by FAO. In view of the rapid development of the tuna fishery in Atlantic tropical waters since the late 1950s, this symposium resolved, by majority vote, to establish an international organization along the lines of the Inter-American Tropical Tuna Commission (IATTC). They sought to ensure the stable development of the tuna fishery and proper resource conservation on the high seas by both African and non-African states. The resulting International Commission for the Conservation of Atlantic Tunas (ICCAT) Convention came into effect in March, 1969 (Fig. 2).

Management Mechanism. The species covered by the Convention, based on the Preamble and Article 4 of the ICCAT Convention, are set as, (a) tunas and (b) tuna-like fishes, including billfishes.

The management objective, as defined in the Preamble, is to maintain the resources of tunas and tuna-like fishes at levels producing a maximum sustainable yield (MSY) for food. The key point to be noted here is that the basic management concept is MSY and that food production has been set as the prime utilization objective.

ICCAT is charged with the conduct of research to shed light on the condition of the tuna and billfish resources. However, the principle underlying this research activity is to utilize data and scientific and technical services provided

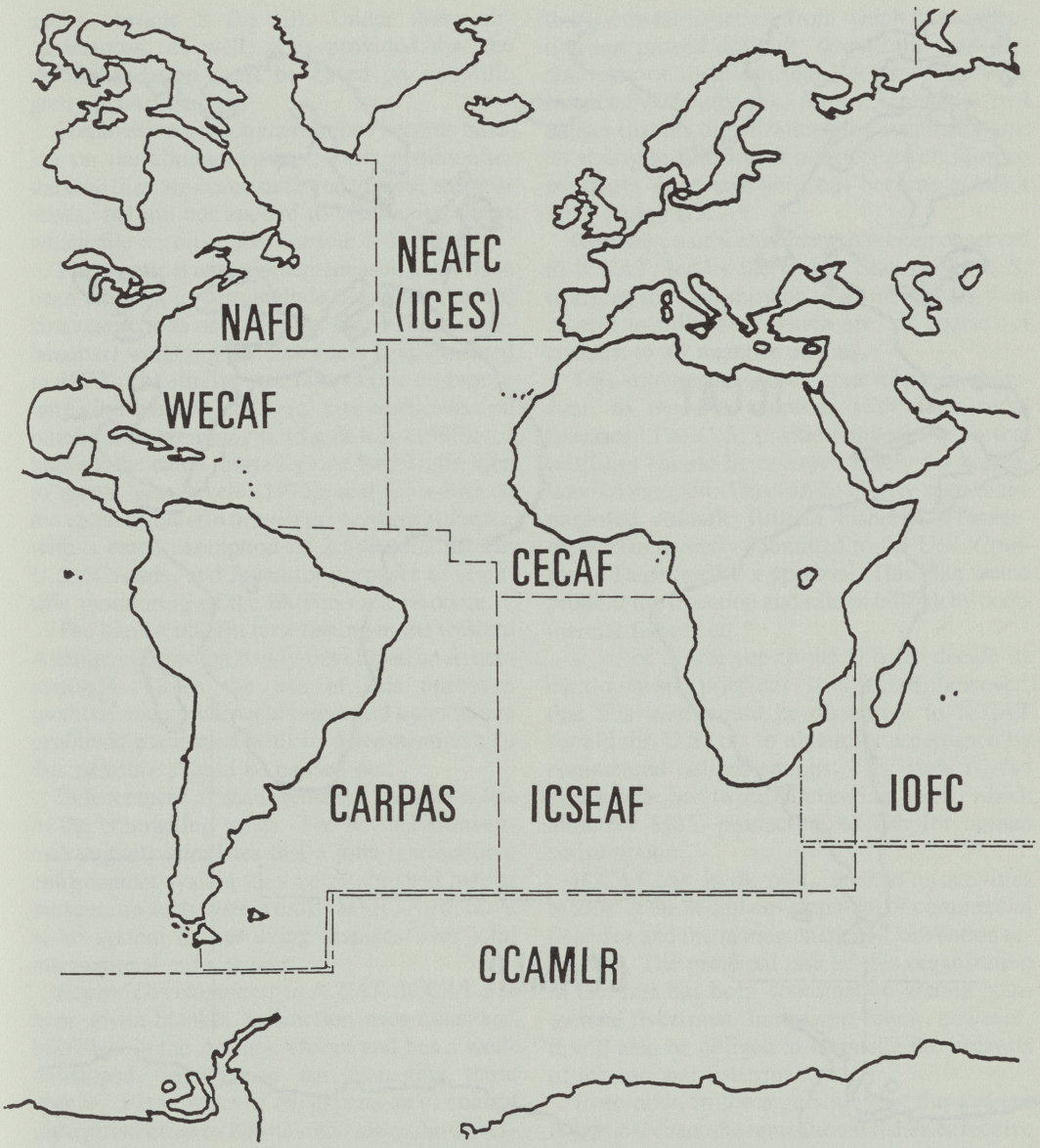

Figure 1. Jurisdictional areas of international fishery organizations in the Atlantic Ocean.

by the governmental agencies of the various contracting states (Article 4.1).

In other words, the collection and analysis of catch data are the duty of the contracting states, with the Commission intended to coordinate these research activities. Under certain conditions, the Commission may find it necessary to conduct supplementary research under its own auspices. In the latter case, such research is to be conducted within the limits of available budgets. In this respect, the ICCAT differs fundamentally from the IATTC, which maintains its own research staff and carries out its own surveys independent of the contracting states.

With respect to management measures, the Commission may recommend to the contracting states, based on scientific grounds and a simple majority vote of the member states, such mea-

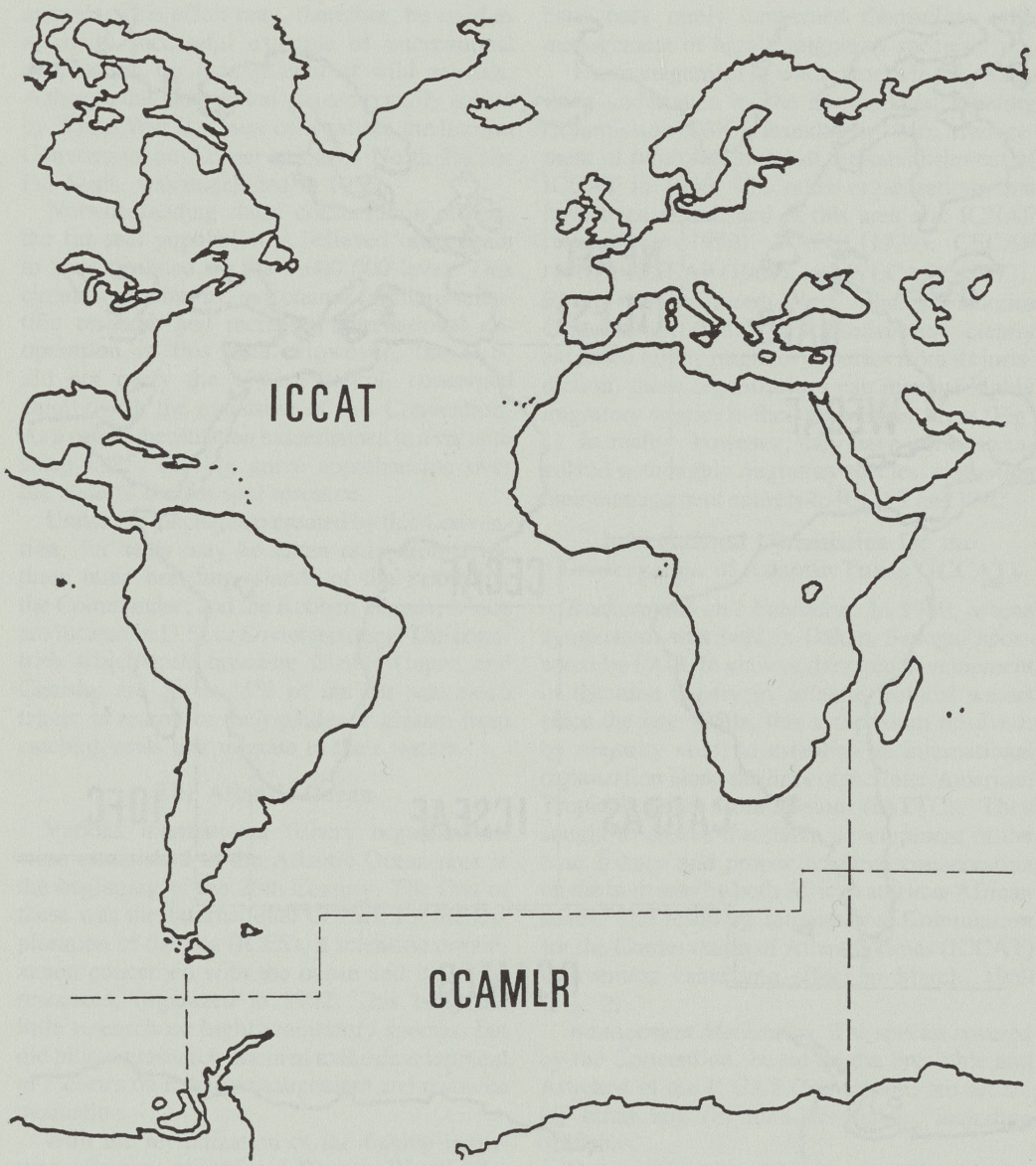

Figure 2. Jurisdictional areas of the International Commission for the Conservation of Atlantic Tunas (ICCAT).

sures as may be required to maintain the MSY for tuna and billfish resources (Article 8.1 (a) of the Convention). There are detailed provisions with regard to the procedures applicable to the adoption of recommendations and their binding effect on the contracting states. In short, recommendations regarding management measures should be based initially on a careful examination by the Panel, based on scientific research, following which the proposed Panel recommendations must be presented to the Commission for final adoption (Article 6).

The Commission, itself, as distinct from the Panels, may propose management measures. To prevent the passage of unreasonable proposals of a political nature, even if emanating from within the Commission, itself, the proposal must be approved by two-thirds of the contracting

states (Article 8 (b) (i)). Under these circumstances, as well, it is provided that the recommendation must be based on scientific grounds (Article 8.1).

Commission's recommendations become binding on the contracting states six months after the date they are communicated to these member states, but are not applied to contracting states which file an objection (Article 8.2 to 8.5).

The principal management measures that have been adopted to date include the following: (a) size restrictions on yellowfin tuna *(Thunnus albacares)* weighing 3.2 kg or less (implemented in 1973); (b) similar size restrictions on bigeye tuna *(T. obesus)* (1980); (c) size restrictions on bluefin tuna weighing 6.4 kg or less (1980); (d) holding the catch mortality rate for bluefin tuna to recent year levels (1975); and (e) a ban on the catch of bluefin tuna in the western Atlantic, with a catch exemption of 2,660 tons for the U.S., Canada, and Japan for purposes of scientific monitoring of the bluefin tuna resource.

The ban on bluefin tuna fishing in the western Atlantic is based on newly-developed analytical methods. Given the use of this unproven method, and certain qualitative and quantitative problems associated with it, a reassessment of this measure should be carried out.

Enforcement of management measures is left to the contracting states. The ICCAT Convention vaguely stipulates that a joint international enforcement system may be established but, at present, no such system exists at sea. Also, there is no system for resolving disputes over joint international enforcement.

Recent Developments in ICCAT. ICCAT has been given blanket jurisdiction over tunas and billfishes in the Atlantic Ocean and has a well-developed organization for managing these species. In the wake of the expansion of coastal state jurisdiction to 200 nautical miles, however, it has become very difficult for the commission to manage each species in uniformity. For example, the catch data that used to be provided by Japan's tuna longline fishery are no longer made available. This fact makes time series analysis impossible, thereby causing serious problems with resource evaluation, including billfishes.

There is also the problem that the ICCAT membership does not include countries (such as Turkey and Greece) which have, in recent years, been increasing their catch and efforts for tunas in the Atlantic (particularly bluefin). Also not included are countries (like Italy) with traditional coastal fisheries, from which data collection has proved difficult, despite the considerable size of their catches. Recent world-wide financial difficulty has, in turn, created a real danger that the organization may eventually lose its ability to function at a proper level. How to surmount these problems has become a major issue within ICCAT.

Recently, a new movement has been observed in ICCAT, led by the United States. The U.S. is urging the Commission to do more work with respect to billfishes, which are, of course, of concern to all member nations.

This movement causes great concern, however, to member countries with commercial fisheries. The U.S. position appears to be that billfishes should be reserved solely for recreational fishermen. This can be clearly seen in the proposed Atlantic Billfish Fisheries Management Plan recently submitted to the U.S. Commerce Department for approval. This Plan would prohibit the retention and sale of billfish by commercial fishermen.*

It is, of course, up to the U.S. to decide its own domestic priorities. It is feared, however, that this view could be disruptive to ICCAT should the U.S. try to obtain its acceptance by commercial fishing nations. This view is also in contradiction to the Convention, itself, which aims for MSY production of fish for human consumption.

ICCAT has, in the past, directed its activities mainly at the sound development of commercial fisheries and the management of Convention resources. The principal task of this organization in the past has been coordination among commercial fishermen. In the near future, however, it will also be obliged to reconcile the interests of recreational fishermen.

Even now, in the regulations for the western Atlantic Ocean, the recreational fisheries receive favored treatment compared to the commercial fisheries. Although a small quota of tuna is permitted, to conduct research for stock assessment, a disproportionate share of the quota goes to recreational fisheries, making it difficult to get a true assessment of the resources.

The Pacific Ocean

As explained earlier, in the Pacific Ocean area, fishery conventions date back to 1911. In

*Editor's Note: The Atlantic Billfish Plan was approved by the U.S. Secretary of Commerce, effective October 18, 1988.

comparison with the Atlantic, however, the number of active fishing countries in Pacific waters was rather low. In the western Pacific, prior to World War II, Japan was the only country that had developed a distant waters fishery. No international fishery organizations, except for fur seals, existed during the immediate post-war period. In the eastern Pacific, fishing organizations had been created between Canada and the U.S. for resources in which they shared a common interest, like halibut *(Hippoglossus stenolepis)* and salmon *(Oncorhynchus* spp.).

The first open mutilateral international organization to make its appearance in the Pacific was IATTC; in other areas, the tendency was to settle problems mainly on a bilateral or trilateral basis. For the most part, these groupings involved Japan with one or two other nations, such as: Japan-Korea (1965), Japan-China (1975), Japan-U.S.S.R. (1956), Japan-U.S. (1977), and Japan-U.S.-Canada (INPFC; 1952).

Inter-American Tropical Tuna Commission (IATTC)

Background and Evolution. Prior to World War II, fishing activity on the high seas beyond the 3-mile territorial limit was considered by international custom to be completely free. Following the war, however, a concept emerged that, even in the case of high-seas resources, the various countries concerned should cooperate in their conservation. This idea was first embodied in the "Proclamation Concerning the Policy of the United States with Respect to Coastal Fisheries in Certain Areas of the High Seas", issued by U.S. President Harry S. Truman, in September, 1945, just after the cessation of the World War II. This proclamation established a 9-mile conservation zone contiguous to the U.S. 3-mile territorial limit and stated that, in waters where only U.S. nationals operated, the U.S. alone would institute fishing regulations. On the other hand, in waters where a number of fishing nations operated, such controls would be based on agreements among the countries concerned. The Truman Proclamation was said to be directed at the imposition of restrictions on Japan's salmon fishery in the north Pacific but, at the same time, it also came to have an impact on the tuna fishery of the U.S., itself.

The precipitating force behind the establishment of the Inter-American Tropical Tuna Commission (IATTC) was the proclamation by Costa Rica in 1946 that it intended to establish a conservation zone extending 200 miles from shore. The U.S., fearful that its tuna fishing vessels would thereby lose a broad expanse of fishing waters, established an international commission together with Costa Rica. In 1949, they drafted a "Convention between the United States of America and the Republic of Costa Rica for the Establishment of an Inter-American Tropical Tuna Commission (IATTC)".

This Convention, which came into effect in March, 1950 (Fig. 3), provided for scientific research on the tuna resource and for recommendations of necessary measures based on such research. The IATTC was established pursuant to the provisions of this Convention. The present member countries are France, Japan, Nicaragua, Panama, and U.S.A.

Management Mechanism. The species governed by the Convention, based on the Preamble and Article 2 of the subject Convention, were set as: (a) yellowfin tuna and skipjack tuna *(Katsuwonus pelamis);* (b) species normally used as bait by tuna fishery; and (c) other species taken by tuna vessels. Billfishes were effectively included in the Convention on the basis of the following characteristics: billfishes are taken in the same waters, during the same periods, and with the same gear as for tuna; catch statistics on billfishes are included under the category "tuna-like fishes" in the FAO Yearbook of Fishery Statistics, and other fishery statistics.

With respect to the waters to be covered by the Convention, in Article 2.4, reference is made to "high seas and waters under the jurisdiction of the contracting states" in the eastern Pacific as the geographic scope of research activities to be conducted by the Commission. In addition, the Commission's Yellowfin Regulatory Area (CYRA) was established.

The declared management objective was to maintain the stocks of fishes taken directly or indirectly by the tuna fishery at levels permitting a maximum sustainable yield (MSY). It is believed that the original objective was to maintain an MSY for tuna and billfishes on a species by species basis. This was because, at the time the IATTC was founded, the resource management theory was generally keyed to the concept of MSY.

In order to accomplish the management objectives, research work on tuna and billfish resources, and the collection and analysis of scientific data, were made functions of the Commission. In fact, one of the unique characteris-

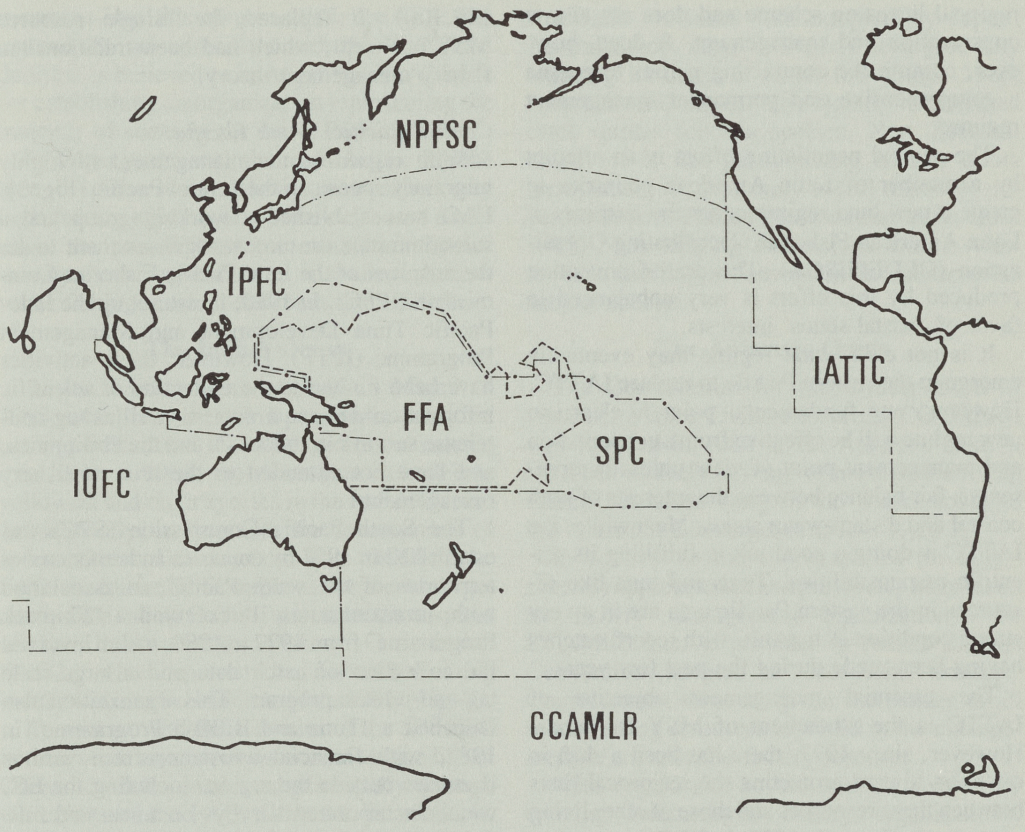

Figure 3. Jurisdictional areas of international fishery organizations in the Pacific Ocean.

tics of the IATTC is that the Convention established an independent scientific staff.

Management measures are recommended to the contracting states by unanimous vote on the basis of scientific studies carried out by the Commission (Articles 2.5 and 1.8 of the Convention). The contracting nations all agree to establish domestic legislation to implement the recommended management measures (Article 3). A specific example of the management measure is that relating to restrictions on overall yellowfin catches in the CYRA, which was adopted in 1966. The total catch allocation at that time was 79,300 short tons, but this was gradually increased to 175,000 ST in 1986 — 2.2 times the initial level.

In past years, the total allowable yellowfin catch was allocated among the fishing countries pursuant to negotiation. A portion of the total catch was allocated to certain coastal states but fishermen of the other countries concerned, including non-contracting states, were free to take yellowfin on a "first-come, first served" basis until the total allowable catch was reached.

Strict enforcement of these management measures is delegated to the contracting states (Article 3), and there is no system of joint enforcement by these states. Since there are no agreements on enforcement, there is also no system for adjudicating disputes.

Recent Developments in IATTC. During the past ten years, there has been considerable activity in the area of management structure for the highly migratory species of the eastern Pacific Ocean. In 1977, multilateral negotiations began seeking to create a new organization which would replace IATTC. After nearly three years of intensive effort, the negotiations broke down. Since that time, two separate negotiating efforts have been undertaken. One is the negotiation of the Eastern Pacific Ocean Tuna Fishing Agreement (EPOTFA), which is essentially an interim

regional licensing scheme and does not aim at conservation and management. It does, however, commit the contracting parties to pursue a comprehensive and permanent management regime.

The second negotiating effort is an attempt by a number of Latin American countries to create a new tuna regime under the auspices of Latin American Fisheries Coordinating Organization (OLDEPESCA). The draft Convention produced by this effort is very unbalanced in favor of coastal states' interests.

It is not clear what regime may eventually emerge in the eastern Pacific to replace IATTC. However, one fundamental point is clear: no new regime will be effective from a conservation and management point of view unless it represents a fair balance between the interests of both coastal and distant-water states. Meanwhile, the IATTC is doing a good job in fulfilling its scientific responsibilities. Tuna and tuna-like resources in the eastern Pacific area are in a very strong condition as a result, with record catches having been made during the past few years.

The essential management objective of IATTC is the attainment of MSY for tunas. However, since 1977, there has been a shift in direction toward protecting the reciprocal links between these resources and those of other living marine organisms. In 1977, IATTC, in response to the strong insistence of the U.S., decided to implement a tuna-porpoise program with a view to protecting porpoises incidentally taken during tuna purse-seine operations.

The fact is that the large-scale take of porpoises by the U.S. purse-seine fleet in IATTC waters had become a major problem in the U.S. and was one of the reasons for enacting the Marine Mammal Protection Act (MMPA). It is said that the U.S. tuna fishery associations, which were the target of this criticism, had no alternative but to initiate some sort of movement to protect porpoises in order to be exempted from application of the MPA (MMPA Para.101 (a) (2)).

Still another reason exists for the attention being given to porpoise protection. It is that a new management philosophy had emerged, aimed at the conservation and effective utilization both of targeted species and of living marine resources interdependent on each other. This management concept has been given concrete expression in the U.N. Convention on the Law of the Sea in the section entitled "Conservation of living resources" (UNCLOS Art. 61.3; Art. 119.1(a)). It replaced the "single resource MSY" concept, which had been traditional in fishery management theory.

Central Pacific, South Pacific

With regard to the management of highly migratory species in the central Pacific (Fig. 3), FAO has established a working group and a sub-committee on tuna stock assessment under the auspices of the Indo-Pacific Fisheries Commission (IPFC). In 1980, it also set up the Indo-Pacific Tuna Development and Management Programme (IPTP). However, these activities have been limited to the collection of scientific information and catch data, as well as tag-and-release surveys in Indonesia and the Philippines, and have not extended to the area of fishery management.

The South Pacific Commission (SPC) was established in 1947 by countries and autonomous territories of the south Pacific, in association with suzerain states. It executed a "Skipjack Programme" from 1977 to 1980, which involved the collection of catch data and a large-scale tag-and-release program. This organization also launched a "Tuna and Billfish Programme" in 1987, with financial assistance from various countries outside the region, including the EC, which incorporated surveys on tunas and billfishes. In addition, it held a research symposium in that same year on the albacore *(Thunnus alalunga)* resource in the south Pacific.

The South Pacific Forum (SPF), which is a regional administrative organization that excludes suzerain states, at a meeting in Suva in 1978, took an initiative toward managing tunas resources, including distant-waters fishing countries operating in its region. Most unfortunately, owing to the wide economic disparities within the area, it was not possible to form an organization embracing the majority of the target countries.

In the following year (1979), this organization set up the South Pacific Forum Fisheries Agency (FFA), which was given the responsibility for intra-regional coordination and negotiations with countries outside the region. (Fig. 3).

Japan, the Republic of Korea, and Taiwan, which operate tuna fisheries in the south Pacific, have concluded various bilateral fishery agreements. The U.S.S.R. has signed fishery agreements with Kiribati and Vanuatu.

Spurred by the seizure of U.S. vessels in the Solomons Islands, in 1984, and the U.S.S.R.

incursion into this area in 1985, the U.S. has entered into an agreement with the FFA. This decision is believed to have generated a climate for establishing an organization representing the majority of states in the south Pacific.

In recent years, with the major influx into the area of purse-seine fisheries possessing very high fishing efficiencies, there can be no doubt about the pressing need to establish a fishery management organization, including distant-water fishing nations, for tunas and billfishes.

The Indian Ocean

At the FAO conference held in Miami in 1968, which was the starting point for scientific activity before the ICCAT convention entered into force in 1969, the discussion extended to yellowfin and other species in the Indian Ocean. Subsequently, in line with the development of Indian Ocean Development Plan (IODP), the FAO established a Committee for the Management of the Indian Ocean Tuna under the auspices of the Indian Ocean Fishery Commission (IOFC), which sponsored a research meeting jointly with a subcommittee of the IPFC (Fig. 3).

In contrast with the activities of the SPF/SPC in the Pacific area, stock assessment in the Indian Ocean has been conducted principally through the efforts of the FAO. With the introduction, particularly since 1984, of the purse seine fleets of France and Spain, which had previously been operating in the Gulf of Guinea in the Atlantic, activity in this organization has suddenly acquired new momentum. Deliberations have been proceeding in the direction of strengthening resource management for tunas and billfishes in the Indian Ocean, either by strengthening the existing IOFC, or by creating an entirely new organization.

Since 1975, a problem has developed over a decline in the southern bluefin tuna *(Thunnus maccoyii)* resource in the Indian Ocean, a high-quality fish which is distributed in the higher latitudes. Effective in 1971, the Japanese longline fleet unilaterally introduced time-area closure, with a view to avoiding the catch of smaller fish. Subsequently, as a result of an increase in the catch of small fish by Australian surface fisheries, a decrease also took place in the adult fish resource. As a result, since 1983, Australia, Japan, and New Zealand have been giving consideration to the possibility of a trilateral fishery management system to protect this resource. In addition, therefore, to the restrictions on small fish adopted by Japan, Australia, too, since 1984, has been gradually reducing its catch of small fish. Since 1986, Australia and Japan have jointly established catch quotas for this species. New Zealand, however, is not participating in this quota arrangement, as its fishery is still relatively underdeveloped. These three countries have, since 1987, been holding discussions with a view towards drafting a convention to conserve the subject species.

The Antarctic Ocean

The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), was founded in 1982 in the Antarctic area. It has been actively striving to manage the living marine resources lying in the waters south of the Antarctic Convergence (Figs. 1, 2, 3).

In contrast to the single-species (or multi-species) approach that had previously been taken by fishery management organizations, the CCAMLR has, as provided in Article 2 of its Convention, adopted an "ecosystem" concept. Consideration must be given thereunder to all related living resources involved in the management of a particular fishery resource.

With regard also to the species covered by existing international fishery organizations, such as ICCAT, IATTC, and IWC, the CCAMLR concept shows that it is appropriate for whales and tunas inhabiting CCAMLR waters to be managed by CCAMLR.

Given the present scientific levels, however, the available body of scientific knowledge required to carry out this concept, as outlined in Article 2 of the Convention, is inadequate. Therefore, discussions would have to be held to develop a new methodology for this purpose.

International Whaling Commission

The move to establish the International Whaling Commission (IWC) had its origins even before World War II. The organization did not actually come into existence until 1946. From the very beginning, the IWC did establish prohibited whale species and undertook the management of these species. This attempt at resource conservation by individual species did not work particularly well. I must, in all candor, acknowledge that this policy led directly to the overexploitation of major whale stocks.

Starting with the U.N. Conference on the Human Environment, held in Stockholm in

1972, the IWC adopted the concept of MSY for individual species. As a result, many major whale stocks were designated as prohibited stocks, while the other stocks were subsequently managed on a very conservative basis. In 1982, however, in complete disregard of the recommendations of its Scientific Committee, and without benefit of distinction between stocks in good and poor condition, the IWC passed a total blanket moratorium on commercial whaling activity.

This decision was clearly a major departure from the original purpose of the IWC Convention, which was to strive to develop a sound whaling industry that would provide a healthy resource for the use of mankind. It also departed from the basic duty of the Commission to manage whale stocks in a sound manner. This decision produced the highly unusual phenomenon of the Commission, itself, contravening the objectives of its own Convention. There is clearly a pressing need to correct this bizarre state of affairs at the earliest possible moment.

Whatever the underlying reasons, the belief that not a single whale should be killed has come to dominate the IWC organization. As a consequence, countries which have traditionally eaten whale products, such as Japan, Iceland, and Norway have been placed in a highly perilous situation. Their minority views are no longer protected, despite the fact that the U.S.A., U.S.S.R., Denmark, and St. Vincent conduct whaling activities under the category of aboriginal subsistence whaling.

Moreover, the anti-whaling faction has, from the outset, labeled scientific research as "disguised commercial whaling," thereby depriving member states of their freedom to conduct such research. It is essential, from the standpoint of the sound development of the IWC, itself, that this sort of situation be rectified at the soonest possible time.

Changes in the International Fishery Order

The First Conference on the Law of the Sea, in 1958, resulted in the enactment of the following conventions: Four Conventions relating to the Law of the Sea, the Convention on the Territorial and the Contiguous Zone (which came into effect in 1964), the Convention on the High Seas (effective in 1962), the Convention on the Continental Shelf (effective 1964), and the Convention on Fishing and Conservation of the Living Resources of the High Seas (effective 1966). These conventions, however, were essentially codifications of previous customs and practices.

The Third Conference on the Law of the Sea, in the wake of a speech by Pardo at the 22nd meeting of the General Assembly of the United Nations, in 1967, was originally convened to discuss the problem of seabed mineral resources. Its mandate was later extended to the consideration of more general issues.

The text of this Law of the Sea Treaty, which has now been codified, provides a detailed system for seabed resource development. The methods, and criteria for such development have been clearly described. With respect to the problem of conservation and management of living marine resources, however, the Treaty does not go beyond the introduction of the concept of an exclusive economic zone extending 200 nautical miles from shore. With regard particularly to the conservation and management of marine resources on the high seas, and of highly migratory species, the fact remains that no improvements have been made beyond the wording of the existing four Law of the Sea Treaties.

For example, with regard to highly migratory species, the Law of the Sea goes no farther than to state that, when the fish migrate inside the 200-mile zone they are under the jurisdiction of the particular coastal state, but when the fish migrates across the exclusive economic zones of two or more countries, or across the high seas, the countries concerned should cooperate in its conservation and management. The fact is that no suggestions are given whatsoever as to how this management and conservation are to be implemented. There is, accordingly, a pressing need for these concerned countries to discuss, either among themselves or at appropriate regional fishery organizations, ways and means of conserving and managing these highly migratory species.

As I mentioned earlier in my review, within the context of the current world order, it is no longer appropriate to consider only a single species for purposes of fishery management. If we now start thinking in the direction of an ecosystem approach, which pays close attention also to species on which the target species depend, then must we not undertake a fundamental restructuring of existing fisheries organizations, dissolving those that take a single species approach in favor of new ones that adopt a macroscopic ecosystem approach?

I feel, for example, that there must be one

core fishery organization in each major area — the Atlantic, the Pacific, the Indian Ocean, and the Antarctic Ocean — with provision, as required, for sub-committees or panels, organized by sub-area or species, within each organization to deliberate management problems. In that case, naturally, a number of approaches might be considered. It may be felt that there should be a separation between the management organization and the research organization, as in NEAFC or ICES, or that the secretariat should conduct research with an independent staff assembled from various countries.

It is quite strange, as in the present IWC, that delegates of countries conducting no whaling operations should devote themselves so vigorously to the conservation and management of whales in the vicinity of Japanese archipelago. The proper direction would be for the countries concerned to form regional fishery organizations to handle such resource management. In this sense, I feel that the first step toward proper resource management would be to transfer whale matters relating to the Antarctic to CCAMLR and those relating to other areas to regional fishery organizations in those areas.

At present, the problem of reconciling the interests of recreational and commercial fishermen around the world is becoming the focus of ever greater attention. We should realize that this problem has occurred only recently or, if it did occur previously, it did so only on a minor level. In the future, it is essential that both recreational and commercial fishermen exchange views on an equal basis. Instead of unilaterally asserting their own interests, they should compromise, where possible, by looking at matters from the others' perspective, and thereby maintain equitable access to the resource for both groups.

In many cases, the recreational fishery is supported by the public's interest in recreation, often without consideration of the food supply or human livelihood. Against this sort of powerful pressure, commercial fishermen are liable to be ignored. Both the government and recreational fishermen should understand the standpoint of commercial fishermen and seek a reconciliation of views through the coordination of national governments, public regional organizations, or suitable third-party organizations.

In concluding my remarks I should like to introduce a bright prospect for conservation and management tunas and billfishes. The Japanese government has made considerable effort to establish an appropriate technique for rearing Pacific bluefin tuna from egg to adult. We have not yet succeeded, but I believe such technique will be established by the end of this century. Rational management of bluefin tunas in the Pacific will be conducted under the new management body. If it were to succeed, is there no reason why such technique will be applied to billfishes?

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A Critical Evaluation Of Existing Mechanisms For Managing Highly Migratory Pelagic Species In The Atlantic Ocean

Christopher M. Weld

There are three mechanisms for the management of highly migratory species in the Atlantic: the Law of the Seas Convention (LOSC), the International Convention for the Conservation of Atlantic Tuna (ICCAT), and the Magnuson Fishery Conservation and Management Act of 1976 (MFCMA). All of these affect different nationals in different ways, and to understand their interaction and to answer the question whether they are effective, or whether they can be made to be effective, it is necessary to understand how they came into being and the influences that shaped them and continue to shape their implementation.

While Annex I to the LOSC lists seventeen catagories of highly migratory species, including marlins, sailfish *(Istiophorus platypterus),* swordfish *(Xiphias gladius),* sharks, porpoises, and whales, this chapter will be limited to management mechanisms only as they relate to billfishes and tunas. The politics of offshore fisheries management have always been driven by tunas, because tunas have always been the species of primary interest to the offshore and distant-water fisheries. To put that in perspective, 380.4 thousand metric tons of Atlantic tunas of various species were landed in 1985, compared to only 34 thousand metric tons of swordfish. Except for a few small artisanal fisheries, the direct commercial exploitation of marlins in the Atlantic Ocean is a very recent development, and marlin steaks are still a novelty in U.S. restaurants and fish markets. To understand how billfish are or could be managed in the Atlantic, therefore, it is necessary to understand the politics of tuna fisheries.

Development of Fishery Laws

Until the twentieth century, the international law of fisheries was based upon the freedom of fishing. As stocks were considered inexhaustable, there was no perceived need for regulating their exploitation. This perception was not universal because, as far back as the Middle Ages, the conflict between national ownership and freedom of navigation provoked the Anglo-Dutch Wars (Cuyvers 1984). Since the Dutch did not want to pay for licenses to trade and navigate or fish, Holland's leading international lawyer, Hugo Grotius, spelled out the argument in favor of freedom of the seas: "The sea, since it is as incapable of being seized as the air, cannot be attached to the possessions of any one particular nation." This argument made good economic as well as philosophic sense and, since no nation could really enforce its claims over the sea, it was this doctrine that prevailed. Grotius' principles survived as late as 1958, when they were incorporated in the Geneva Convention on the High Seas. The Convention defined the "high seas" as being, "all parts of the sea that are not included in the territorial sea or in the internal waters of a State," and defined the freedom of the seas to include freedom of navigation, freedom of fishing, freedom to lay submarine cables and pipelines, and freedom to fly over the high seas. The Convention also provided that, "the seas being open to all nations, no State may purport to subject any part of them to its sovereignty." This proved, however, to be a last flourish. Forces were already at work which would culminate in Ecuador's unequivocal declaration in 1966 of a 200-mile territorial sea and the be-

ginning of a new era of international maritime law. Even at the conference, itself, the prevailing sentiment among the delegates was that the proper limit of the territorial sea and fishery jurisdiction should be extended from three miles to twelve (Loring 1971).

From the beginning, the value of commercial tuna landings on the West Coast greatly exceeded the U.S. catch in the Atlantic. In recent years, according to the FAO Yearbook of Fishery Statistics, about 70 percent of the global tuna harvest has been taken in the Pacific Ocean, compared to 22 percent in the Atlantic and 8 percent in the Indian Ocean. Since the early 1900s, until recently, the majority of tuna catches landed in the United States have been harvested off the Pacific coasts of Mexico and Costa Rica by southern California fishermen who traditionally paid fees for access to those territorial waters. The American Tuna Boat Association (ATA) was formed in 1923 as a nonprofit fishery cooperative whose purpose was to represent the tuna fleet in their fee negotiations with the government of Mexico. At first, the fishermen, themselves, dealt directly with the respective governments, acknowledging fees owed for fishing within the three-mile limit. Outside three miles, they claimed the right of freedom to fish the seas (Wade 1986).

With the announcement of the Truman Proclamation, in 1945, the U.S. provided precedent for unilateral national jurisdictional claims, and set the climate for future jurisdictional conflicts. By unilateral declaration the United States proclaimed the right to establish conservation areas in the high seas according to certain principles. In particular, the Truman Proclamation provided that, "the right of any state to establish conservation zones off its shores in accordance with the principles is conceded, provided that corresponding recognition is given to any fishing interest of nationals of the United States which may exist in such areas."

Strong protests from California tuna interests inspired second thoughts in the Truman Administration; as a result, the proclamation was not allowed to enter into effect. No matter; the genie was out of the bottle. The first half of the Proclamation provided the impetus for a rash of jurisdictional extensions. The fact that the United States refused to acknowledge the legitimacy of such claims did not prevent the seizure by 1954 of twenty U.S. tuna vessels by various South American countries. Congress reacted by adopting the Fishermen's Protective Act to provide reimbursement for resulting fines and charges paid to foreign governments. Such seizures have continued, and the U.S. has adopted a policy of escalating responses in the form of trade embargoes and reductions in foreign aid against offending nations. This policy has had the effect of kindling deep resentment against "Yankee Imperialism" and hardening the bargaining positions of Third World coastal states thereby thwarting the principle of U.S. tuna policy.

In the words of Secretary of State George Shultz (1987), "Most coastal nations claim 200-mile jurisdiction over tuna. The United States, however, neither claims nor recognizes jurisdiction over tuna beyond twelve nautical miles from the coast. U.S. policy mandated by MFCMA has been to negotiate international agreements to insure effective conservation and management of tuna and to secure access for fishermen to the stocks wherever they migrate beyond a narrow belt of coastal waters."

On the one hand, the U.S. does not recognize jurisdiction over tunas, even though it is forced to negotiate and pay large fees to 'secure access for fishermen' within such jurisdictions. On the other hand, it claims no jurisdiction over tuna within the U.S. 200-mile zone, creating unhappy consequences for stocks of marlins and swordfish in the Atlantic. By contrast, there is total agreement among the other nations of the world that highly migratory species are subject to coastal state jurisdiction. The only exceptions are the United States and the Bahamas (Burke 1984). The policy is apparently dictated by and for the benefit of an industry that has moved offshore and a fleet whose carrying capacity has shrunk from 113,655 metric tons in 1983 to 77,677 metric tons in 1987 (King and Bateman 1985). In the words of one commentator, "U.S. policy concerning highly migratory species is widely recognized to be out of step with state practice throughout the world. The U.S. defines highly migratory species in a manner that defies both science and the (LOS) Convention. Developing nations . . . resent a fishery policy in which U.S. officials argue that tunas should not be managed by coastal states but then assert management over other species of highly migratory fish in order to appease domestic interest groups" (Harrison 1984).

With the introduction of purse seines and longlines in the Atlantic in the late 1950s, the total catch of Atlantic bluefin tuna *(Thunnus*

thynnus) increased so rapidly that, in 1966, a concerned Food and Agricultural Organization (FAO) of the United Nations convened an international conference of experts in Rio de Janeiro, Brazil, to study the situation and make recommendations. By 1969, as a result, the required first seven nation-signatories, an initial group consisting of Canada, France, Ghana, Japan, South Africa, Spain and the United States, had signed the proposed International Convention for the Conservation of Atlantic Tunas (ICCAT), thereby bringing it into force. In time, other nations ratified the treaty and became members of the Commission created by the treaty, including Brazil, Morocco, Portugal, South Korea, and the Soviet Union. In addition, some other nations participate on the Commission as observers. It is a weakness of ICCAT that at least one major harvester (Taiwan) and several potentially important future harvesters such as Mexico and Venezuela, are not signatories.

Chief among the concerns voiced by the conferees was the concern that insufficient data were available to assess accurately the true status of tuna stocks. Accordingly, creating the mechanism for obtaining such data was a major thrust of the treaty. Unfortunately, from the beginning, ICCAT was hampered by the fact that the treaty did not create an independent scientific capability. Instead, the Commission relies upon contributed science which is evaluated by a standing committee that seeks consensus on scientific issues. The result is that scientific conclusions, in various degrees tainted by national interest, are analyzed in a politicized forum. In these circumstances, few want to find evidence of overfishing; therefore, they rarely do. More serious still, like most other multi-national fishing treaties, ICCAT lacks any enforcement authority. Many nations may be *for* conservation, but few favor ceding real authority to an international body of any kind. Consequently, ICCAT can make recommendations, but it cannot make regulations.

Initially, ICCAT's focus was to have been limited to tunas, but the United States' delegation to the FAO conference successfully engineered the inclusion of billfishes, as well. They argued that, in addition to exhibiting some of the same migratory characteristics as tunas, billfishes are a bycatch in many tuna fisheries and at that time some billfish stocks were already exhibiting signs of stress from heavy fishing. For example, the overall catch rate for blue marlin *(Makaira nigricans)* as measured by fish caught per thousand hooks declined from 3.81 in 1956 to 0.29 in 1970 and for white marlin *(Tetrapturus albidus)* from 2.06 in 1962 to 0.80 in 1970 (Mather 1974). Until recently, however, ICCAT has evinced little interest in billfish, not even the swordfish, a species of commercial interest to fishermen on both sides of the Atlantic, which have been regarded by some for several years as perilously depleted.

The jurisdiction of ICCAT is limited to the high seas. Article II of the Convention states: "Nothing in this Convention shall be considered as affecting the rights, claims or views of any Contracting Party in regard to the limits of territorial waters or the extent of jurisdiction over fisheries under international law." Its recommendations are implemented within U.S. jurisdiction through an enabling act called the Atlantic Tunas Convention Act of 1975. It is interesting that although the ICCAT Commission began meeting on a regular basis in 1970, the Tunas Act was not passed until five years later. It was passed over the opposition of the Administration which in common with the California tuna industry, regarded the Atlantic bluefin as a tradeoff for more substantial yellowfin tuna *(T. albacares)* resources in the Pacific. Approximately 25 percent of the total annual harvest weight of Atlantic bluefin tunas in the 1970s was taken within 200 miles of the U.S. coast, but bluefins accounted for less than four percent of the total catch of all tunas in the Atlantic; Table 1 (Joseph and Greenough 1979).

Sentiment in favor of extended fishery jurisdiction in the United States grew apace with the buildup of foreign fishing in the western Atlantic, which began in the late 1960s. Almost as soon as the first Soviet trawlers appeared on Georges Bank, bristling with antennas, the eastern press began raising a cry against Russian "spy ships." That some of them were engaged in electronic snooping is a foregone conclusion. Most of the "spy ships," however, were engaged in scouting America's fishery resources. They were followed by an armada of trawlers, factory ships, oilers, and supply ships. In a few years, small trawlers based upon 'mother ships' were replaced by large trawler/processor vessels using the latest in fishery technology; and large mesh nets were replaced by smaller mesh nets. The eastern Europeans were soon followed by western Europeans and it was hard to determine who were the more rapacious harvesters: puta-

tive friends or traditional foes. The foreign fishermen engaged in a method of systematic overexploitation called "pulse fishing." As a result domestic landings of leading market species such as haddock *(Melanogrammus aeglefinus),* cod *(Gadus morhua),* and flounder *(Paralichthys dentatus;* and other spp.) plummeted, and usually quiet eastern seaboard fishermen began screaming to their Congressmen.

By the time that U.S. fishermen were galvanized into political action, many nations had established 200-mile limits. All the more reason that east coast fishermen were dismayed to find that the State Department, and, therefore, the Administration, was dead set against "getting the foreigners out" by establishing a 200-mile limit of our own. The Pacific yellowfin tuna was still "king," and the ATA was still calling the shots, regardless of how many people might be put out of work as a result of the imminent collapse of the east coast fisheries.

Several bills were filed in Congress that would have extended U.S. fishery to 200 miles offshore. None garnered much support until large numbers of sport fishermen were enlisted in a concerted effort by those who had been over the horizon and had become alarmed by the foreign invasion. They found champions in Warren Magnuson in the Senate and Gerry Studds in the House. In 1974, Senator Magnuson convoked a workshop in a Senate Commerce Committee hearing room. Present were representatives of major regional commercial fishing interests from Alaska, the Northwest, the Gulf of Mexico, and New England. The ATA was there as were two angler-conservationists. Much to the delight of the latter it soon became evident that in return for giving the fishermen what they wanted Congress intended to exact a price in the form of federal fishery regulation. The purpose of the workshop was to forge a set of principles that would form the parameters of a regulatory regime.

As the Studds bill (H.R. 200) made its way from committee to committee in the House and the Magnuson bill (S.961) did the same in the Senate, the extent of the Administration's opposition to any change in the status quo became manifest. It was believed that U.S. global interests, especially in freedom of navigation on the high seas, so important to commerce and military strategy, might be harmed by extension of fisheries jurisdiction (Jacobson and Davis 1983). Hardest of all to overcome was the implacable opposition of the California tuna industry. In the end, it was necessary to compromise by excluding highly migratory species from federal fishery jurisdiction, because the sponsors of the two bills believed that it had no chance of adoption otherwise. At the last minute an amendment from the floor of the House to the definition of the term 'highly migratory species' narrowed the exclusion to tunas. In other words, under the Magnuson Fish Conservation and Management Act (MFCMA), the United States can regulate fishing for billfish and sharks but not tunas. Although hailed by recreational fishermen as a great victory at the time, as a practical matter the amendment yielded few benefits at the cost of considerable resentment among other coastal nations. From a domestic management perspective the net result of the exclusion has been to defeat completely every attempt to regulate fishing for large pelagic species beyond the territorial seas, pursuant to MFCMA. It can only prevent directed billfish fisheries by foreign flag vessels inside the 200-mile limit, which are controlled by the Secretary of Commerce through adoption of Preliminary Management Plans (PMP) and Governing International Fishing Agreements (GIFA's).

Table 1. Tuna and billfish landings in metric tons (000s omitted).

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Atl. Bluefin Tuna													
Tot. Atl.	14.2	23.6	26.1	28.4	25.7	20.6	18.4	19.1	19.3	23.2	23.7	27.2	26
W. Atl.	3.7	5.6	5.1	5.9	6.9	5.8	6.3	5.9	5.9	1.5	2.7	2.4	2.7
Giants only	2.2	2.1	2.8	4.4	5.4	4.5	5.1	5.1	4.8	1.4	2.6	2.3	2.7
Albacore	75.9	72.5	59.5	77.1	75	72.2	73.2	61.2	59.3	72.3	66.7	56.9	69.9
Skipjack tuna *(Katsuwonus pelamis)*	78.2	117	60.5	74.8	109.8	105.9	88.3	109	129	156	138	135	139.7
Yellowfin tuna	94.6	106	124.7	123	128.8	130.7	125.2	126	151	163	164	116	134.6
Swordfish	13.2	13.2	13.5	13	13.4	18.8	18.9	22.2	18.4	22.7	25	31.6	34
Blue Marlin*			3030	2036	1322	1274	1487	1725	1600	2587	1600	2084	2097
White Marlin*			1572	1812	977	937	1012	955	1130	1091	1672	1099	1194

*Landings in metric tons

The resulting regulatory regime in the Atlantic is that ICCAT has the authority to make recommendations for the conservation of tunas and billfish in the high seas. Coastal nations may, if they elect to do so, implement the recommendations within their territorial seas or exclusive economic zones (EEZs). As ICCAT has no authority to enforce its recommendations, the effectiveness of ICCAT as a management mechanism depends both on its ability to make wise recommendations and on the willingness of the harvesting nations to adopt them.

The Law of The Sea Convention

At the same time the struggle for a 200-mile limit was going on in the United States, one of the most ambitious international assemblies in modern times was meeting to hammer out a comprehensive Law of the Sea treaty, covering a long agenda in which fishing was only one comparatively insignificant item. In the event, the fisheries section was drafted early and reflected such a broad consensus that none of the provisions were subsequently reopened for renegotiation. The Convention went on for years, and virtually all of the world's coastal nations, as well as many landlocked ones, participated in it. The fact that the Convention was so long in the making and represents an overwhelming consensus among nations, gives its provisions, particularly those that are for the most part codifications of existing practice, nearly the same effect as universally accepted international law.

Prior to the convocation of the Third United Nations Conference on Law of the Sea (UNCLOS), several nations had unilaterally asserted extensions of jurisdiction against the strong protests of the United States, Japan, and other major maritime states. Several more enacted 200-mile limits while the UNCLOS was in session and, when China and the Soviet Union supported them in the Conference, the major maritime powers soon found themselves in the minority. The concept of a 200-mile zone, in which coastal states would have the exclusive rights both in relation to fisheries, and for the purpose of exploring, exploiting, and managing all of the living and non-living natural resources therein, became the accepted norm and was adopted in Article 56. The treaty delegates sovereign fisheries management authority to the coastal state (Burke 1984). Its discretion in determining the allowable catch in its EEZ is not reduced by its responsibility to promote optimum utilization (Article 61), a nontraditional concept introduced by the U.S. reflecting its interest in access to the fisheries of other nations. Article 61 to the contrary notwithstanding, a coastal state may set the entire allowable catch at the level of its capacity to harvest, even if such level is below the level which would ensure optimum use of the fishery resource, thus cutting off access of foreign nations to any surplus which the coastal state cannot harvest (Sohn 1984).

The internationalists in the Carter Administration drummed up powerful sentiment in favor of the treaty in academic and diplomatic circles. It appeared that considerable momentum in favor of signing the treaty had been generated in Congress despite opposition from the non-ferrous mining industry which objected to the seabed mining provisions of the draft treaty. The election of 1980 intervened, however, and when President Reagan labeled the LOS Convention as "nothing more than an international entitlement program" its fate, at least for the time being, was sealed. Nevertheless, even though the United States did not sign the treaty, and the treaty has not yet entered into effect, the sovereign power of the coastal state's control over fisheries in its EEZ is almost universally accepted customary law, and is as binding upon the United States as it would have been if the United States had signed and ratified the treaty.

It is generally agreed that a customary rule of international law grows out of concordant practice by a number of states over time and is generally acquiesced in by other states. At what point a usage becomes binding as a general custom is one of those mysteries of the law that has never been fully unravelled. Carefully considered rules of international conduct having been subjected to the scrutiny of states and, having been adjusted to take into account the political demands of states, when they emerge as a draft treaty open to ratification and accession are bound to have considerable influence and weight (Anand 1984). The LOS Conference had a tremendous influence on the development and acceptance of customary law of the sea, which had already been adopted and applied in practice by a large number of nations. The result was that the Convention, at least in so far as it relates to the absolute authority over fishing within the EEZ, became the customary law binding upon signatories and non-signatories, alike.

This circumstance was more or less conceded by President Reagan on March 10, 1983, when he said, "the convention also contains provisions with respect to traditional uses of the oceans which generally confirm existing maritime law and practice and fairly balance the interest of all states." Why, then, has Secretary of State Shultz continued to take the position that the U.S. does not recognize jurisdiction over tunas beyond twelve nautical miles from the coast?

Fishery Laws in Operation

There are many ironies involved in the difference between the probable effectiveness of a law as it appears on paper and its real effectiveness resulting from its implementation. For example, the apparently impotent mechanism of ICCAT has produced far greater restraint on domestic harvests of highly migratory species in the U.S. EEZ than the MFCMA despite its nearly limitless regulatory authority within the EEZ. Unfortunately, neither ICCAT nor the MFCMA has halted the depletion of bluefins or swordfish, and there is reason to believe that marlin populations are trending in the same direction. It is ironic also that the National Marine Fisheries Service (NMFS), with its exemplary record as a regulator of tuna fishing, should be such a dismal failure as a manager of billfishes. In defense of the NMFS, however, it should be pointed out that while there are few who deserve to share the credit for attempting to stop the overexploitation of bluefins, there are many who have earned a share in the blame for the ongoing billfish debacle. Chief among them is the U.S. State Department and its stubborn pursuit of an outdated, counterproductive, illogical, and illegal policy. Billfish management in both the Atlantic and the Pacific has been a primary victim of that policy.

Beginning in the spring, bluefins concentrate on spawning grounds in the Gulf of Mexico. In the late 1970s, Japanese vessels took large catches of tunas during the spawning season. In response to a crescendo of outrage among U.S. fishermen, the Japanese departed in 1981, to be followed by domestic commercial fishermen fishing primarily for yellowfin tuna (Hinman 1988). Spawned-out bluefins move up the eastern side of the Straits of Florida, where the once continuous stream of fish provided world famous sport for boats based on Bimini and Cat Cay. The fish then ride the Gulf Stream to New England waters, arriving in June, where they are joined by schools of small (15 to 131 lbs) and medium (135 to 309 lbs) fish. Some push on up the coast of Canada's Maritime Provinces as far north as Newfoundland. In the late fall, having fed ceaselessly throughout their stay, giant and medium bluefins resume their migration and disappear from the fishery. The small fish move to the edge of the continental shelf where they are harvested in the winter months by Japanese longliners.

The summer fishing in the northeast is prosecuted by purse seine, harpoon, handline, and rod-and-reel, each pursuant to a quota imposed by the NMFS. Although the longliners catch a few swordfish in winter and summer, neither the summer nor the winter longline fisheries in the northeast involves a bycatch of marlins. The tuna fisheries south of Cape Hatteras are a different story because the presence of tunas coincides with the presence of large numbers of billfish, especially swordfish. According to data gathered by on-board observers, the tuna fishermens' bycatches are steady but not staggering. The bycatches of marlins and bluefins by swordfish and yellowfin longliners is far more alarming. Nevertheless, the problem caused by the presence of tunas, swordfish, and marlins in the same geographical area is more of a political one than a failure of regulatory mechanisms.

While steadfastly denying the validity of coastal state jurisdiction over tunas beyond 12 miles, U.S. diplomats engaged almost continuously in the last decade in negotiations with nations in both the eastern and the western Pacific to purchase, sometimes at exhorbitant prices, access to fishing for California fishermen. If the State Department's policy with respect to the 200-mile claims of other nations was ambiguous, its zealous protection of foreign tuna fishermen in the U.S. EEZ has consistently thwarted all attempts to manage billfish. The result has been the rapid collapse of the swordfish fisheries in the EEZ.

The U.S. commercial fishery for swordfish in the Atlantic has been relatively insignificant until recently; consequently, early harvest data are sketchy. Ironically, as the fishery began to expand with the introduction of longlining in the 1970s, landing data became harder to obtain because the fishery went largely underground in order to avoid the Food and Drug Administration's sporadic attempts to enforce a ban prohibiting the sale of swordfish having high mercury content. Until very recent years, there was

virtually no information concerning catch per unit of effort or size frequency. Even recent data are somewhat suspect, as swordfishermen seek to avoid regulation. It is not surprising, therefore, that scientists are cautious in their conclusions about a species concerning which so little is known. The fishermen, on the other hand, demonstrate their conclusions in the most pragmatic ways. Harpoon fishermen have either quit or adapted their vessels to other fisheries. The longliners have either switched to the yellowfin tuna fishery or moved on to new fishing grounds in the Caribbean or the north-central Atlantic. For management purposes it is assumed that they are still fishing on the same stock of fishes as there is insufficient evidence to define separate stocks.

The "bottom line," at least within the U.S. EEZ, is clear enough. Swordfish catch rates have declined dramatically for larger fish, along with average size in all areas of the fishery. Landings within the EEZ show a continual decline from a high of 8.4 million pounds in 1980 to 3.9 million in 1986, a reduction of 54 percent. At the same time, the total number of swordfish taken within the U.S. EEZ declined from 102 thousand to 69 thousand, a reduction of approximately 32 percent (Hoey and Nelson 1988).

Soon after they were created by the MFCMA, the regional fishery management councils began to prepare a Management Plan for Atlantic Billfishes. The plan which the councils produced would have closed the Gulf of Mexico to longliners from May to October and the EEZ along the Atlantic Coast during the months of June through September. In November, 1979, it was submitted for approval and hit a stone wall erected by the State Department, which, judging from the remarks of Secretary Shultz, that agency has no present intention of lowering. While disclaiming any wish "to obstruct or frustrate legitimate U.S. interests in sound billfish conservation," a Department spokesman advised the South Atlantic Council, by letter, that "a disruption of the tuna fishery of this magnitude does not appear to be consistent with offering a reasonable opportunity to the foreign fleet to fish for tuna in the U.S. 200-mile zone." "Nevertheless," the letter continued, "we believe that billfish conservation, with its attendant benefits to the Nation, and to the U.S. recreational fishery in particular, can be addressed without prejudice to the U.S. juridical position with respect to highly migratory tuna" (Storer 1980). The "U.S. juridical position," of course, was that which had already been rejected by the LOS Conference in favor of absolute coastal state sovereignty over all fishing within the EEZ. Nevertheless, the councils were to learn that any form of billfish regulation which imposed a restraint on tuna fishing was considered by the State Department to be an indirect form of tuna regulation which somehow undermined the "leverage" or bargaining position of the tuna industry in its negotiation with other countries — even though nobody could satisfactorily explain what that leverage was in view of current international practice and emerging customary law.

Five years after the first proposed Billfish Plan was quashed, when there could no longer be the slightest doubt that the U.S. was absolutely isolated in its position on highly migratory species, the State Department blocked approval of a Management Plan for Atlantic Swordfish, saying, in a letter that, "As the Magnuson Fishery Conservation and Management Act specifically excludes tuna from the exclusive management authority of the United States, any incidental regulation of tuna longliners based upon their bycatch of swordfish or billfish must be taken with the greatest care." So that there could be no misunderstanding as to why or for whose benefit this policy was being pursued the letter continued, "The ability to secure favorable terms in these negotiations for U.S. tuna fishermen is directly linked to United States regulations which affect foreign tuna fishermen in the U.S. EEZ" (Wolfe 1985).

At issue was a provision of the Swordfish Plan which prohibited nighttime fishing for tunas. On the face of it, this should not be an unduly burdensome restraint as tunas are daytime feeders. Swordfish, on the other hand, are nocturnal feeders and few would be caught if longlines were not deployed during the hours of darkness. Modern longlines, however, are so long — sometimes stretching 50 to 70 miles from end to end — that it takes all night to retrieve the previous day's set and make a new set for the next day. Lost to view in the dialogue between the councils and the State Department was the practical result. Where there is no regulation of foreign fishing, there can be no regulation of domestic fishing because it is politically impossible to prohibit domestic fishermen from doing what they know foreign fishermen are allowed to do in the same waters.

With the State Department to point the way, foreign fishing interests have been quick to perceive that as long as the State Department maintains its present position, they can thwart the implementation of billfish and swordfish management by court action. In *Federation of Japan Tuna Fisheries Co-Operative Associations v. Baldrige et. al.,* (1986), an action brought in the United States District Court for the District of Columbia, the logic of the Complaint precisely tracked the arguments made by the State Department in the letters quoted preceding. Specifically, the plaintiffs claim that seasonal closures and the prohibition against night fishing were really tuna regulation "in the guise of purporting to conserve swordfish (that) render uneconomical and as a practical matter eliminates during the prescribed times the commercial fishing for tunas" by the plaintiffs. Whether for reasons associated with the filing of this complaint — which agency spokesmen deny — or otherwise, the NMFS refused to accept the Swordfish Plan as submitted.

Conclusions and Recommendations

Eight years have passed since the first time the State Department killed a proposed billfish management plan, and no billfish plan has been adopted.* To be sure, under PMPs promulgated by the Secretary of Commerce pursuant to the MFCMA, foreign fishermen fishing in the U.S. Gulf and Atlantic EEZ are required to release all billfish taken incidentally. Unfortunately this does not prevent billfish mortality, as most billfish are dead when they are "released." Swordfish fishing within the U.S. EEZ is in a state of collapse. The average size of swordfish caught inside the EEZ has declined from 114 pounds in 1978 to 56.2 pounds in 1987. The harpoon fishery, which depended upon a population of fish of 150 pounds and up and supported a fleet of 70 vessels, no longer exists. Bluefin tuna populations continue to shrink at an alarming rate. According to recent ICCAT studies, the adult (age 10 to 30 years) stock size is about 30 percent of the 1970 level. The stock size of medium size fish (age 6 to 9 years) is about 20 percent of the 1970 level, and the juveniles (age 1 to 5 years) are only at about 15 percent of that level. Insufficient data exist to enable scientists to make a meaningful assessment of blue marlin and white marlin stocks. Nevertheless, based on the data available, NMFS scientists have conceded that marlins have been fully exploited or overexploited for a number of years. Other scientists believe that marlin stocks are poised for a collapse. Bluefin tuna, swordfish, and marlins are under increasing pressure from U.S. fishermen as well as from growing fleets of vessels flying the flags of South Korea, Taiwan, Cuba, and Mexico. On the basis of the foregoing, therefore, one must conclude by almost any measure that existing mechanisms for managing highly migratory pelagic species in the Atlantic Ocean have not been effective. That is not to say, however, that the mechanisms could not be made to work. For example, ICCAT would be more effective if all of the nations fishing for tunas and billfishes became signatories and bound themselves to honor the recommendations of the Commission. Moreover, ICCAT would quickly become more effective if it were provided with funds to ensure that data are collected and analyzed in timely fashion. Lack of funding for scientific and statistical research has seriously undermined the effectiveness of both ICCAT and MFCMA.

The obvious change required to make the MFCMA more effective as a billfish management mechanism is the elimination of the exclusion of tunas from the jurisdiction of the Act. By doing that, Congress would bring U.S. practice into line with the rest of the world and put an end to the 'ugly Americanism' of our selectively managing highly migratory species while denying the same right to other nations.

The United States should sign and ratify the Law of the Seas Convention or, in the alternative, propose a new treaty incorporating those parts of the LOSC that are acceptable to it. The purpose of doing so from a fisheries perspective would be to lend weight to those provisions of the treaty that seek to impose conservation and management responsibilities upon coastal nations. Finally, careful consideration should be given to pursuing a regional treaty covering the fisheries of the Caribbean. To date, tuna conservation in the western Atlantic has been the result of negotiations among Canada, Japan, and the United States, in the context of ICCAT. Mexico, Venezuela, and Cuba were left out of the resulting arrangements on the grounds that the harvests taken by those nations were insignificant.

**Editors Note.* An Atlantic billfish plan was subsequently approved by the Secretary of Commerce, effective October 18, 1988. It is being challenged in court on behalf of one or more groups of commercial fishermen.

This circumstance will not prevail forever, and it fails to take into account the impact of foreign fleets based upon such nations.

Summary

The principal mechanisms for the management of billfishes and other highly migratory fish species, including sharks and tunas, in the Atlantic Ocean are the International Convention for the Conservation of Atlantic Tunas (ICCAT) and the Magnuson Fishery Conservation and Management Act of 1976 (MFCMA). ICCAT pertains to the management of tunas and billfishes in the high seas and MFCMA to the management of billfishes and sharks — but not tunas — in the U.S. Exclusive Economic Zone (EEZ). In the EEZ, tuna fishing by domestic fishermen is regulated under the Atlantic Tunas Act, foreign fishing for tunas in the EEZ is controlled through bilateral agreements. During the period in which these mechanisms have been in existence, stocks of bluefin tuna, swordfish, blue marlin and white marlin have diminished, some to the point where scientists and fishermen have become concerned. In this sense, it must be said that the pertinent management mechanisms have not been effective. The problem, however, is one of politics, not mechanics. The U.S. clings to a tuna policy that is clearly invalid in terms of prevailing international practice and makes impossible effective management of billfishes and tunas in its EEZ. Conservation of billfishes and tunas in the high seas would be made more effective with stronger financial and scientific support of ICCAT.

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Billfish Management In The Pacific And Indian Oceans

Joseph W. Greenough and Barbara K. Rothschild

Within the tropical, subtropical, and temperate waters of the Pacific and Indian oceans, lying between roughly 45°N and 45°S latitude, are found six species of billfishes: the sailfish *(Istiophorus platypterus),* the black marlin *(Makaira indica),* the Pacific blue marlin *(M. mazara),* the shortbill spearfish *(Tetrapturus angustirostris),* the striped marlin *(T. audax),* and the swordfish *(Xiphias gladius).*

The blue marlin and shortbill spearfish are primarily creatures of the open ocean; sailfish and black marlin are often found closer to shore. Striped marlin and swordfish seem to prefer cooler and more temperate waters; the blue marlin prefers warmer tropical waters. These species are all superbly adapted for highly migratory modes of existence, and journeys of many hundreds or even thousands of miles are commonplace. In some cases, these movements appear to be associated with spawning; at other times, varying oceanic conditions such as temperature or food availability may play an important role.

Billfishes are captured in both sport and commercial fisheries. By far the most important fishery in terms of numbers caught, particularly in offshore high-seas areas, is the longline fishery. Japan, Korea, and Nationalist China are the most important longlining nations. In recent years, the United States, Mexico, and Australia have also begun to participate on a more significant scale. In most cases, longline vessels target on various species of tunas rather than billfishes, but there are still significant bycatches of billfishes, especially striped marlin and swordfish which are also the most prized species in the marketplace. Billfishes are also taken commercially by other types of gear including drift gillnets, setnets, harpoons, and trolling gear. These fisheries are usually carried out within national 200-mile zones. Unlike longline fishing, these more inshore fisheries often target on one or another species of billfish, especially swordfish and striped marlin. Billfishes are also taken incidentally in tuna purse-seining operations, but this bycatch is generally not marketed.

It is sport fishing for billfishes that has focussed much attention on these species in recent decades. Few sporting experiences can match that of hooking, fighting, and landing a trophy-sized marlin, sailfish or, much less frequently, a swordfish or spearfish. Sport fishermen from all over the world congregate during the height of the run in such famous Pacific region centers as Cairns, Australia (especially for black marlin); Bay of Islands, New Zealand (striped marlin); Kailua-Kona, Hawaii (blue marlin); Cabo San Lucas, Mexico (striped marlin); and Cabo Blanco, Peru (black marlin). In these areas and others like them, sport fishing (and all of the ancillary activities associated with it) constitutes a major element in the local economy, providing both jobs and an often much needed input of capital. One of several things can happen to a sport-caught billfish. A few wind up as mounted trophies, some are retained for personal consumption, and many are released, often after being tagged by the sportsmen who captured them. In certain areas, for example in Hawaii, a large percentage of the sport-caught billfish are sold commercially in local markets. In such areas the distinction between sport fishing and commercial fishing is not always clear-cut.

The highly migratory mode of existence of the various billfish species makes difficult the job of defining stocks for management purposes and assessing their status. Much work remains to be done in this area, but some tentative conclusions regarding stocks in the Pacific and Indian oceans have been reached, based primarily on data from the Japanese longline fishery dur-

ing the 1952-1976 period. Blue marlin appears to be the species most impacted by fishing. Declining catch-per-unit-of-effort and related population analysis suggest that this species has been over-exploited, at least in the Pacific Ocean. Stocks of other billfish species are believed to be in generally good shape. Caution is advisable in the area of stock assessment, however, in part because a transition has taken place in the longline fishery. In more recent years, gear has generally been set at a greater depth than was the case in earlier years, in order to target on the more valuable bigeye tuna *(Thunnus obesus)*. Since billfishes are usually taken in shallower waters (normally above the thermocline), trends in catch-per-unit-of-effort and conclusions concerning stock condition could be affected.

Billfishes commonly move from the 200-mile zone of one nation to that of another nation or back and forth between 200-mile zones and high-seas waters beyond 200 miles. The big-game fishermen who pursue billfish constitute an international community of sportsmen. The commercial harvesting of billfish is likewise often international in scope, a good example being the distant-water longline operations of Japan, Taiwan, and Korea. Thus, both the biology of the species involved and the nature of the fisheries that exploit them point to the importance of international cooperation in the management of these unique and important resources.

Law Of The Sea

The first meeting of the Convention on the Law of the Sea (LOS) was convened in 1958 in Geneva, Switzerland, to establish a legal order for the seas and oceans with due regard for the sovereign rights of all nations. Following one of the most complex and far reaching negotiations in history, a final Convention was ready for signature in 1982. This Convention embodies the most global perspective on management of world billfish resources and mandates that such management should be on a cooperative international basis.

Articles 56, 61, 62, and 64 of Part V of the LOS are the most pertinent to the problems of utilizing and managing billfishes and other highly migratory species. Article 56 is the basic article dealing with the scope of coastal state authority within the extended economic zone (EEZ). This article assigns to the coastal state, "sovereign rights for the purpose of exploring and exploiting, conserving and managing the natural resources, whether living or non-living, of the sea-bed and subsoil and the superjacent waters." Articles 61 and 62 amplify upon how coastal states are to exercise their sovereign rights with regard to conservation (Article 61) and utilization (Article 62) of living resources.

Articles 56, 61, and 62 apply to all species of fish occurring within the EEZ, with no distinction made between highly migratory species and other species. Article 64, on the other hand, applies specifically to highly migratory species as listed in Annex I of the Convention. This list includes all species of billfishes and tunas that are of commercial or recreational importance. The first paragraph of Article 64 mandates that, "the coastal states and other states whose nationals fish in the region for the highly migratory species . . . shall co-operate directly or through appropriate international organizations with a view to ensuring conservation and promoting the objective of optimum utilization of such species throughout the region, both within and beyond the exclusive economic zone." The Article goes on to say that, in regions where no appropriate international organization exists, the states involved shall cooperate to establish and participate in the work of such an organization. While Article 64 broadens the scope of conservation responsibility to include the high seas area beyond the EEZ, paragraph 2 explicitly states that its provisions "apply in addition to the other provisions of [Part V]." Thus, it would appear that Article 64's mandate for international cooperation in the management of highly migratory species over broad ocean areas in no way diminishes the sovereignty claimed by coastal states over those resources within their respective EEZs.

As of October 31, 1987, LOS had been signed by 155 out of 176 member states and others but had been formally ratified by only 35 such members. Because the Convention will not enter into force until 12 months after the date of the sixtieth instrument of ratification or accession, it is not clear when (or even if) its provisions will ultimately take effect. Most of the nations making significant commercial catches of tunas and billfishes (or having significant catches taken in their EEZs) have signed the Convention including Japan, the leading nation in terms of catch. Presumably, therefore, they accept its provisions insofar as they apply to highly migratory species. The major exception is the United States which has declined to sign the Convention based

largely on its objections to provisions pertaining to utilization of seabed mineral resources. LOS articles dealing with fisheries matters were not involved in the U.S. decision, because these articles do not, in the U.S. view, conflict with its domestic laws pertaining to fisheries within its EEZ.

International Management Regimes

A number of regional organizations exist in the Pacific and Indian oceans which have mandates to address issues related to the conservation of billfish stocks. In most cases, the authority of these organizations with regard to billfishes is implicit in that they generally focus on tuna fisheries but also include tuna-like species among their responsibilities. Except in isolated instances, little prominence is currently given to billfishes and, in these cases, the incentive stems from commercial rather than recreational fisheries. Awareness of the importance of the billfish stocks, and of their interaction with tuna fisheries, appears to be growing.

Despite their authority to make recommendations on the management and conservation of tuna stocks, only the Inter-American Tropical Tuna Commission (IATTC) has made any such recommendations for tunas. None has recommended such measures for billfishes. Only the IATTC even has the authority to formulate potentially binding management regulations concerning billfish. Thus, any consideration currently being given to billfish stocks is only in the form of limited collection of biological data. The future role of international bodies in the conservation and management of billfish stocks in the Pacific and Indian oceans may very well expand. It is appropriate, therefore, to examine existing international organizations that have authority in this area.

Inter-American Tropical Tuna Commission (IATTC)

The IATTC was established by a Convention signed in May 1949 between the United States and Costa Rica, which entered into force in March, 1950. Membership currently includes the United States, Nicaragua, Panama, Japan, and France. The area covered by the Convention is the eastern Pacific Ocean which, although not formally defined, is generally considered to include waters lying east of 150°W.

The Commission is mandated to conduct scientific studies of yellowfin tuna *Thunnus albacares)* and skipjack tuna *(Katsuwonus pelamis)* as well as, ". . . other kinds of fish taken by tuna fishing vessels . . . [and] the populations of fishes supporting all of these fisheries." Based on these studies, the Commission is to recommend measures designed to maintain these populations at levels that can support maximum sustainable yields. The fundamental work of the Commission in carrying out its mandate is the collection of statistical and biological data. On the basis of such data, the Commission staff has made recommendations to member governments to regulate the catches of yellowfin tuna since 1961. These recommendations have been discussed apart from the Commission meetings in intergovernmental meetings where non-member governments can also participate. Agreements reached in these meetings are referred to the Commission in the form of resolutions for its consideration and adoption. Recommendations adopted by the Commission are then referred to both member and cooperating governments for implementation.

The Commission collects and compiles data on commercial billfish fisheries in the eastern Pacific Ocean. Most of this information relates to the Japanese longline fishery. Catch statistics are analyzed for the purpose of monitoring trends in abundance and assessing the impact of fishing on the stocks. The Commission also routinely conducts other research related to the biology of billfishes and carries out confidential studies for member governments to aid in evaluating possible national management regimes. Such studies have been undertaken as a result of increasing conflict between sport and commercial fisheries.

Although the Commission has never made management recommendations regarding billfishes, it is felt that more research on the stocks would be desirable. Specifically, the Commission would like to increase the collection of statistical and biological data from longline vessels fishing out of ports in Central and South America. Current sampling efforts are considered inadequate with respect to assessing the impact of fishing on billfish stocks.

Permanent Commission of the South Pacific (CPPS)

The CPPS, which currently includes Chile, Ecuador, Peru, and Colombia, was established in 1952 to advance principles of sovereignty and jurisdiction set forth in the Declaration on the

Maritime Zone. It was also to coordinate and standardize development of general regulations governing fishing and the use and control of other marine resources of common interest in their respective maritime zones.

Among other authorities, the CPPS is empowered, (1) to determine upon a specific request from a member country, protected species, open and closed seasons and areas, fishing times, methods and equipment, prohibited gear and methods, and general regulations for fishing; (2) to study and propose to the Parties such measures as it considers suitable for the protection, defense, conservation and use of marine resources; (3) to encourage scientific and technical study of and research into biological phenomena in the south Pacific; (4) and to ensure that the fishing quotas fixed annually by each Party in the exercise of its exclusive rights do not endanger the preservation of the marine resources of the south Pacific.

Pending Agreements in the Eastern Pacific

In 1979, the CPPS created a new entity known as the Meeting of Ministers of Foreign Affairs of the CPPS Member Countries. At their meeting in 1984, the ministers issued the Declaration of Viña del Mar in which they agreed upon the need to establish an Agreement for the Conservation, Protection, and Optimal Utilization of Tuna Fishes in the Eastern Pacific, and approved guidelines for such an Agreement. The CPPS joined forces with the Latin American Fisheries Development Organization (OLDEPESCA) to produce a Convention Creating the Eastern Pacific Tuna Organization. Under this agreement, individual nations would be responsible for determining the amount of tuna available for foreign harvest within their respective 200-mile zones and they would license the foreign vessels. International licenses would be issued for fishing in convention waters beyond 200 miles. The Convention, which has not yet come into effect, does not cover billfishes, and there is no indication that the CPPS has specifically addressed the question of billfish stocks.

Another pending agreement in the eastern Pacific is the Eastern Pacific Ocean Tuna Fishing Agreement (EPOTFA), which was signed in 1983 by the United States, Costa Rica, Panama, Guatemala, and Honduras but still lacks the five ratifications required for it to take effect. Under EPOTFA regional licensing arrangements would be established for a specified convention area with no national licensing. The agreement covers various species of tuna but does not include billfishes.

South Pacific Commission (SPC)

The SPC was established by an Agreement signed at Canberra, Australia, in 1947. It originally included the territories of all the acceding governments, and those territories administered by them, which, "lie wholly or in part south of the Equator and east from and including the Australian territory of Papua and the trust territory of New Guinea and Guam and the Trust Territory of the Pacific Islands." The SPC is a consultative and advisory body to the participating governments in matters affecting economic and social development of the territories within the scope of the Commission.

The mandate of the SPC includes providing for and facilitating research in technical, scientific, economic, and social fields. Consistent with this mandate, in 1981, the 12th Regional Technical Meeting on Fisheries adopted the Tuna and Billfish Assessment Program (TBAP), a proposal that evolved out of the Skipjack Survey and Assessment Program. The inclusion of the billfish stocks in the TBAP was considered high priority because of the increasing impact of the Japanese-Korean-Taiwanese longline fishery on the stocks and because of the expansion of the purse-seine fishery, which was also believed to be impacting billfish stocks. Monitoring of longline fishing effort had not been included in the Skipjack Survey and Assessment Program.

The objective of the TBAP is to conduct scientific research on the tuna and billfish stocks that support fisheries in the SPC region, as well as on the environmental factors that affect them. Activities of the TBAP include assessing and monitoring the exploitation of commercially important tuna and billfish species, and study of the biology and ecology of commercially important tuna, billfish, and bait species. In this regard, a food chain analysis based on billfish stomach contents has shown that huge quantities of skipjack are consumed. However, the data were not considered adequate to draw conclusions about a linkage between the skipjack fishery and billfish abundance. Despite the relatively high priority attached to the research on billfishes, the focus of the TBAP remains largely on skipjack and yellowfin tuna, with billfish data reviewed as time permits.

The Fisheries Statistics Project, a part of the TBAP, includes maintaining a regional oceanic fisheries data base consisting of information submitted to the SPC by member countries on local and foreign vessels fishing for tuna and billfish. Such information, which comes largely from logsheets including position of the vessel and catch by species, is entered and stored on computer and updated on an ongoing basis.

Forum Fisheries Agency (FFA)

The FFA was established by a Convention adopted in 1979 by the governments comprising the South Pacific Forum. Based in Honiara, Solomon Islands, the FFA was created to assist member countries in the coherent and coordinated development and management of their fisheries resources.

Subject to the direction of its governing Committee, the Agency's functions are to collect, analyze, and evaluate marine resource data, particularly data relating to highly migratory species; to collect and disseminate management and legislative information, including fisheries agreements adopted by other countries; to collect and disseminate market information; to provide technical advice and information in the development of fisheries policies and agreements; and to develop cooperative arrangements with relevant regional and international organizations.

Serving as an advisory body, the FFA focuses on administrative, legal, and economic aspects of policy issues in fisheries management and development as opposed to resource assessment and control. In this regard, the FFA has assisted in expanding and restructuring domestic fishing industries of member governments, securing markets for marine products, improving artisanal fishing capabilities, enhancing fisheries administrative and legislative services, implementing a regional fisheries surveillance program, and developing a training program for fisheries personnel.

The Agency also served as coordinator of negotiations held over a 3-year period with the United States, which led to the signing in October, 1986, of the Treaty on Fisheries Between the Governments of Certain Pacific Island States and the Government of the United States of America. Implemented in June, 1988, the agreement provides access for U.S. purse-seine vessels to some 10 million square miles of ocean within and beyond the zones of FFA member governments under specified terms and conditions. With the exception of southern bluefin tuna *(Thunnus maccoyii),* all tunas and fish caught incidental to the catch of tunas are covered by the agreement and will be reported under provisions of the agreement to the FFA. The TBAP of the SPC has been asked by the FFA to assist in processing the data, principally contained in logsheets, and from the data to prepare a description of fishing effort. The information remains confidential to the member governments of the FFA.

The FFA continues to serve in an administrative capacity with regard to negotiations and agreements between FFA member governments and other distant-water fishing nations, particularly Japan. Since these fisheries primarily involve longline vessels, billfishes are also covered under terms of these access agreements.

Indo-Pacific Fisheries Commission (IPFC)

Created by international agreement among FAO member nations, under Article XIV of the FAO Constitution, in 1948, the IPFC constitutes an entity distinct from FAO but which functions within the FAO framework. The IPFC was established to promote full and proper utilization of living aquatic resources in the Indo-Pacific area (undefined) through development and management of both marine and inland fishing operations and related processing and marketing activities. The Commission is empowered to formulate and recommend measures to carry out programs to create new fisheries and increase the efficiency and productivity of existing fisheries; to conserve and manage resources; and to protect resources from pollution. The Commission is also charged to encourage, recommend, coordinate and, as appropriate, undertake research and development activities. Other than metropolitan governments, nations which acceded to the agreement lie within the Pakistan-New Zealand-Japan triangle. Unlike the IOFC (see following), the IPFC could adopt a procedure by which its recommendations would become binding upon member nations if not objected to within a certain period. At its 21st Session, in 1984, the establishment of such a procedure was discussed but not agreed to by Commission members.

The IPFC has a Special Committee on Management of Indo-Pacific Tuna. Between 1971 and 1980, this Committee met jointly on six occasions with the Indian Ocean Fisheries Commission's (see following) Committee on Man-

agement of Indian Ocean Tuna. In 1984, the IPFC decided that its Tuna Management Committee should henceforth meet separately but, due largely to financial constraints, no further meetings have been held. Research and data collection activities are not undertaken by IPFC although one of the functions of its Standing Committee on Resources Research and Development (SCORRAD) is to encourage research. In this regard, at its 1987 meeting, the IPFC recommended that SCORRAD focus its attention on development of a collaborative program on tuna tagging. This program is expected to be discussed at SCORRAD's 6th Session, scheduled for early 1990.

Indian Ocean Fisheries Commission (IOFC)

The IOFC was established by a Resolution of the Council of FAO at its 48th Session, in 1967, under Article VI.1 of the FAO Constitution. Its area of competence includes the Indian Ocean and adjacent seas, excluding Antarctica. As a subsidiary body of FAO, the Commission is open to all FAO members. Its Secretariat is provided by FAO and its expenses covered by the FAO Regular Program. Under its terms of reference, the Commission is responsible for promoting, assisting, and coordinating national programs of fishery development and conservation; promoting research and development activities through international resources; and examining management problems with particular reference to the management of offshore resources. The Commission may make recommendations, which are transmitted to the Director-General of FAO; he then communicates them to member nations of the Commission for appropriate action. Under its legal framework, the adoption of an objection procedure, under which management measures could be implemented, is not possible. No management recommendations have ever been transmitted by IOFC.

At its first session, in 1968, the IOFC established the Committee on the Management of Indian Ocean Tuna to review the state of tuna stocks, consider boundaries of the area that have to be taken into account in any management and development of tuna fisheries, and arrange for coordination of necessary research. Within the committee, the Expert Consultation on the Stock Assessement of Tuna in the Indian Ocean reports catch trends for blue marlin, black marlin, striped marlin, sailfish, and swordfish. While noting improvement in Sri Lanka, the Expert Consultation has indicated that billfish statistics in general are far from satisfactory, and has recommended that collection of catch-and-effort data by species and gear be improved. The Expert Consultation has also identified a need to improve the identification of species within the catch; introduce sampling programs in countries with major artisanal fisheries that do not currently provide data; undertake studies on stock structure; and prepare standardized maps showing distribution of fishing effort, catch, and major fishing grounds.

The Indo-Pacific Tuna Development and Management Program (IPTP)

The IPTP was initiated upon the recommendation of the fifth joint meeting of the IPFC and IOFC tuna management committees, held in Manila in 1978. The project was designed to meet the urgent need for a reliable source of statistical data for tuna and tuna-like species upon which governments in the Indo-Pacific area could base their management and development decisions. Approved in 1981, the project is headquartered in Colombo, Sri Lanka. As originally conceived, the program was supposed to cover both the Pacific and the Indian oceans. Subsequently, it was agreed that the program should concentrate its activities in the Indian Ocean and in southeast Asia to the exclusion of the central and western Pacific.

Since its inception, the IPTP has been assisting government research organizations in the initial design and implementation or improvement of statistical and biological sampling programs, implementing tagging projects and biological studies, and reviewing information on stock structure and abundance under the Japan Trust Fund project. The IPTP has also been holding annual regional meetings to exchange information on the status of fisheries, resources, statistics, and research on tuna and tuna-like species.

The project has been extended through 1989. It is expected by that time to have developed a self-sustaining regional data center that will provide participating countries with adequate information for plan development and management of tuna fisheries, technical advice on resources, and a forum for the exchange and review of data and information on the status of tuna and tuna-like stocks. The IPTP collects data on billfishes routinely from participating countries. Its Manual for Collecting Statistics and Sampling covers

blue marlin, black marlin, striped marlin, shortbill spearfish, sailfish, and swordfish. It also covers all types of gear involved in tuna fishing, including sport fishing carried out with no intention of selling fish for profit.

Participating governments and the European Economic Community are required to provide annual catch statistics by species and type of gear within 6 months after the end of the year; catch-and-effort statistics by species, type of gear, and 5-degree-square fishing area; and size-frequency sampling data by species, type of gear, and 5-degree-square. In a program to assist selected countries in implementing sampling programs on tuna and tuna-like species, the IPTP started its sampling program at 3 landing centers on the west coast of Sri Lanka in August, 1986. Data on catch/effort and size-frequency are collected every other day on billfishes. A Workshop on Small Tuna, Seerfish*, and Billfish in the Indian Ocean was held in December, 1987, in Colombo. The IPTP may recommend management measures for tuna fisheries to the IOFC and IPFC tuna management committees if statistical and biological data warrant, but no such measures have thus far been recommended.

General Conclusions on International Management Regimes

The international mechanisms in the Pacific and Indian Ocean regions have implicit authority to study and to recommend management measures for billfish stocks, but none has a specific mandate to do so. Only the SPC's Tuna and Billfish Assessment Program incorporates a clearly stated research objective with regard to billfishes. Programs such as the IPTP, however, have assumed among their responsibilities a mandate to include billfishes in their activities related to tuna-like species and, thus, include billfishes in their collection of biological data. Research is also encouraged on billfish stocks and, within the IPTP, some research on the billfish stocks has occurred in Sri Lanka where there is a multispecies/multiple-gear domestic fishery that includes an increasingly important billfish component. Being the IPTP headquarters, and having certain infrastructure capabilities and scientific resources, appear to be major factors supporting this research interest.

Little consideration at the political level is being given to revising these authorities or strengthening the mandates to include the management of billfish stocks, except in the case of the IOFC where, within the Committee for the Management of Indian Ocean Tuna, discussions are under way on long-term institutional arrangements. Any new organization to emerge would absorb both the IOFC and the IPTP. Two Government Consultations on Long-Term Institutional Arrangements for the Management of Indian Ocean Tuna have been held, the most recent in March, 1988. In these two meetings, delegations have considered three options:

1. Continuation and strengthening of the present arrangements, i.e., a subsidiary body of an FAO commission receiving support from field projects financed by extra-budgetary funds;
2. Creation of a new structure within the framework of FAO, either under Article VI.1 or under Article XIV of the FAO Constitution;
3. Establishment of a new body by a treaty concluded outside the framework of FAO.

The majority of the delegations supported the need to establish a new and more management-oriented body after the termination of the ongoing field projects, although strong support continues within developing nations for any new organization to assist in fisheries development. Most participants agreed that future institutional arrangements should include the power to formulate recommendations of a potentially binding nature consistent with an objection procedure. With regard to the list of species to be covered by a new organization, all delegations except Japan preferred to include all the tuna and associated species listed in Annex I to the UN Convention on the Law of the Sea which are found in the Indian Ocean. This list would include marlins, sailfishes, and swordfish. Japan suggested that the list be limited to skipjack and yellowfin tuna.

National Management Of Distant-Water Fisheries

Management of highly-migratory species at the international level can encompass vast ocean areas that ideally should include the entire ranges of the billfish and tuna species under exploitation. National management is obviously limited to much more restricted areas lying within 200-mile zones. A form of regulation that provides a conceptual bridge between these alternatives arises out of the fact that most tuna and billfish

*Various mackerels of the genus *Scomberomorus*.

are taken by fleets that are as mobile as their quarries are migratory. Because nations retain jurisdiction over their flag vessels regardless of where they operate, regulation of distant-water fishing fleets can be a factor in overall management of highly-migratory species. A number of nations have distant-water fishing fleets that participate in the tuna purse-seine fisheries of the Pacific and Indian oceans, but three nations dominate the distant-water longline fisheries in which are taken by far the greatest catches of billfishes. These three are Japan, the Republic of Korea, and Taiwan. In considering national management of distant-water fishing activities, the history of Japan's longline fishery provides an interesting case study.

Japan first developed longline fishing techniques around the turn of the century. Although the fishery developed somewhat prior to World War II, it was a seasonal activity using vessels designed primarily for pole-and-line fishing and was confined to Japan's coastal and offshore waters. The fishing fleet was greatly reduced during World War II but recovered rapidly following the war. Distant-water longline vessels equipped with freezing equipment enabled the area of operations to expand rapidly. Through the late 1940s and early 1950s, there were explicit boundary lines for the Japanese fishery which were enlarged in several stages. The last of these so-called MacArthur lines was lifted in 1952. By the late 1960s, longline fleets were operating throughout the tropical and temperate oceans of the world. Operations of smaller vessels have been limited to so-called offshore waters within the western Pacific which as of 1981 were, roughly speaking, west of 180° and north of 5°S. Larger vessels (over 120 gross registered tons) are licensed for distant-water operations, which encompass all of the rest of the world oceans.

The rapid expansion of Japan's longlining activities, during the 1950s and early 1960s, was facilitated in part by development of mothership operations and establishment of overseas fishing bases on a number of Pacific islands, including American Samoa, Vanuatu, and Fiji. Much of the catch during this period went to the international canned-tuna market but, by the mid-1960s, a major restructuring of Japan's distant-water tuna fishing was taking place. Mothership operations for tuna ceased as these vessels transferred to the north Pacific where non-tuna species were being harvested. An important market for high-quality *sashimi* was also developing rapidly during the 1960s in Japan as a result of the development of ultra-low-temperature freezing equipment. Large new modernly-equipped longliners were built to supply this market and, because *sashimi* landings had to be brought to Japan for sale, it made economic sense to base the *sashimi* longline fleet in Japan. This resulted in a rapid reduction of Japan's foreign-based longline operations. As this transition was taking place, Korean and Taiwanese longline fleets developed rapidly (in part through transfer of older Japanese vessels) as they replaced Japan as a supplier for the canned-tuna market.

During the 1970s, the Japanese longline fleet declined somewhat in size (from about 2,100 vessels in 1970 to about 1,800 in 1980), with most of the reduction being in the category of vessels whose operations were limited to specified offshore areas. The number of unrestricted distant-water vessels remained relatively constant (between 900 and 1,000 vessels). During this period, however, Japan's tuna fleets suffered financial problems due to factors such as increased fuel costs, rising crew costs, declining catch rates — which resulted in longer trips, competition due to the entry of Korea and Taiwan into the *sashimi* fishery (often using secondhand Japanese vessels and with financial support from Japanese trading companies), and, towards the end of the decade, costs associated with the establishment of 200-mile fishing zones by the many nations in whose waters Japan had traditionally fished.

As a result of the financial problems of the 1970s, the Japanese tuna industry, in consultation with the government, decided to streamline their distant-water tuna longlining operations by reducing the fleet by about 20%. The portion of the fleet restricted to offshore areas was also reduced. By 1984, the overall fleet was down to about 1,400 vessels (from about 1,800 in 1980). Some of the vessels that were decommissioned were, however, replaced by modern vessels with greater carrying capacities. The end result, in 1984, was a longline fleet made up of fewer but more efficient vessels, and annual catches that had remained more or less constant in the 300 to 350-thousand ton range. Catches by the *sashimi* fleet operating in the Pacific Islands area give a rough idea of the relative importance of billfish in Japan's longlining operations. This fishery takes about 90,000 tons annually, which

is broken down as follows: yellowfin 40,000, bigeye 30,000, northern bluefin 10,000, billfishes and other species 10,000.

During the late 1970s and 1980s, the extension of jurisdication over tunas and billfishes to 200 miles by most nations has had a major impact on Japan's tuna fisheries. For example, it has been estimated that in 1977 about 41% of Japan's catch of skipjack and about 18% of her catch of other species of tuna came from within the 200-mile zones of 54 other nations. To maintain access to these traditional fishing grounds, Japan has been forced either to enter into joint-venture agreements or to negotiate access-fee arrangements with individual nations such as the Federated States of Micronesia, Marshall Islands, Kiribati, Solomon Islands, Papua-New Guinea, France, Australia, New Zealand, and the Republic of Belau. The terms of such agreements, in addition to access or royalty fees, can include quotas, excess catch fees, provisions for expanded imports of agricultural products to Japan, and provisions for developmental assistance.

From this brief account, it can be seen that Japan's longline fisheries are under a certain degree of management in an economic and political sense. Regulations and policies concerning type of gear to be used, vessel sizes and fleet composition, fishing areas, and type of product have characterized this fishery over the last four decades. Both government and the fishing industry have been involved in decision-making processes. Also, regulations have been imposed governing fishing activities within 200-mile zones of other nations, which has added an international dimension to Japan's longlining activites. Regulations have not in general, however, focussed on conservation of resources, and there has been little or no focus specifically on billfishes, except within the 200-mile zones of nations such as Australia, and New Zealand, where host governments have restricted billfish catches.

National Management Within 200-Mile Zones

Management of a fishery, in the broad sense of the term, encompasses a number of related activities, including monitoring of the fishery (effort, catch composition, etc.), assessment of stock conditions, regulation, and enforcement. From this point of view, most billfish management within the Pacific and Indian oceans takes place at the national level within 200-mile jurisdictional zones. Two case studies of billfish management at the national level will now be considered in some detail. The areas chosen are the east coast of Australia and U.S. waters surrounding Hawaii. Each of these areas is famous for its billfish resources, which have historically supported important recreational and commercial billfish fisheries. Space limitations preclude consideration of other important and interesting areas such as New Zealand, Panama, Mexico, and U.S. waters off California where the local state government plays an important role in billfish management.

Australia — East Coast

Some of the most productive billfish waters in the world are found off the east coast Australian states of Queensland and New South Wales. In the south, off New South Wales, the best marlin fishing occurs early in the year (January through March) with black marlin and, especially, striped marlin being most frequently taken by sportsmen at fishing centers such as Bermagui, Sydney, and Port Stephans. The first black marlin taken anywhere in the world on rod and reel was apparently one taken off Port Stephans in 1910.

To the north of New South Wales, in southern Queensland, lies Moreton Island, an area known especially for its sailfish fishing. Farther up the coast, lies the southern end of the Great Barrier Reef, which extends northwest for about 1,200 miles. The generally broad continental shelf underlying this enormous living structure, and the currents of the Coral Sea running along its outer edge, attract a wide range of billfishes. The giant black marlin is "king" in these waters, especially in the vicinity of Cairns. Here, the reef is somewhat narrower than elsewhere, and the outer banks are more accessible to sport fishermen.

The first black marlin from Australian waters to surpass 1,000 pounds was taken in 1966, just one year after the formation of the Cairns Games Fishing Club, an event that initiated the modern era of big-game fishing in northern Queensland waters. Since then, many line-class world records have been broken and rebroken in these waters, and more 1,000-pounders are taken here than anyplace else in the world. The peak season for these giants runs from September to mid-December. The waters of the Coral Sea are warming during these southern spring months,

and the concentrations of black marlin apparently represent a spawning aggregation. (This interpretation is supported by the fact that small black marlin, the progeny from the previous year's spawning, are abundant in northern inshore reef areas during the third quarter of the following year.) Also concentrating in the Cairns area during the giant marlin season are sportsmen from around the world, who make a major contribution (estimated at Aus$20 million annually) to the regional economy.

Big-game sport fishermen in Australia are not subject to any form of regulation, and there are no licensing or catch reporting requirements. However, catch records are kept by the many sport fishing clubs in Queensland and New South Wales, so that estimates of the sport catches can be made. A program for tagging and releasing sport-caught billfishes is also well established along the east coast (and elsewhere in Australia), so that much of the catch is released alive. (Sport-caught tunas are also sometimes tagged and released.) This conservation ethic of Australian sport fishermen is further reflected in the strong interest and influence that they have in regulation of commercial fishing activities that impact on billfish stocks.

Commercial catches of billfishes in Australian waters were minimal in the years prior to, during, and immediately following World War II. Throughout this period, domestic fisheries for offshore pelagic species such as tunas and billfishes were essentially non-existent along the east coast. This situation began to change in the early 1950s, when the growing Japanese tuna fleets extended their range of operation into Australian waters. By the early 1960s, Japanese longliners were operating regularly off the east coast. Generally, these operations targeted on tunas, with billfishes constituting a small but valuable bycatch. At times they would target on billfish, especially in the Coral Sea, a key area in the view of sport fishing interests.

This exploitation pattern continued (with virtually no domestic fishing for pelagic species) through the 1970s, until 1979, when Australia extended its jurisdication to 200 miles by creating the Australian Fisheries Zone or AFZ (Fig. 1). Beginning in that year, and in every year since, Australia has entered into a bilateral agreement with Japan concerning their longline operations in the AFZ. These agreements spell out specifics relating to such matters as issuance of licenses, areas of operation, access fees (Aus$2.8 million for the 1987-1988 agreement), and reporting requirements. Typically, Japanese fleets now operate in the offshore area around Lord Howe Island during early southern winter months, where they take albacore *(Thunnus alalunga)* and northern bluefin tuna *(T. thynnus)*. In August, they move inshore and begin to operate off northern New South Wales, where they concentrate on yellowfin and bigeye along the edge of the continental shelf. By September, they have moved northward to waters off Queensland. Fishing well offshore, they take swordfish, striped marlin, and black marlin in addition to tunas. Australia monitors catches through a logbook program and by placing observers on Japanese vessels.

Waters inside 12 miles are closed to Japanese longlining as are east coast waters south of 34°S (i.e., south of Sydney). North of Sydney, there is a January through March closure that extends well offshore and north almost to the Queensland/New South Wales border. The reason for excluding Japanese longliners from these areas has been primarily to limit the impact of competition on the developing Australian longline fishery rather than to protect billfishes and benefit sport fishermen. Off northern Queensland, however, a good-sized area has been closed to foreign longlining, specifically to protect billfishes and eliminate conflicts with sport fishing operations. (The Japanese continue to handline for tunas within this area from October to December.) In addition to the protection provided to billfishes by closed areas, the Japanese have agreed to release black marlin that are alive at the time of longline retrieval throughout all east coast waters. This agreement was on an informal basis until 1986 but, in the 1986-1987 intergovernmental agreement, this provision was formalized and broadened to include blue marlin everywhere and striped marlin within the seasonal open area (April through December) extending northward along the coast from Sydney.

Only since about 1983 have Australian fishermen, operating primarily in New South Wales, harvested significant quantities of tunas and billfishes from the east coast waters. The key to the development of this fishery has been the successful penetration of the high-value Japanese *sashimi* market by the Australian-caught product. Australian longliners, with a very few exceptions, are considerably smaller than their Japanese counterparts, and the longline gear that they set is considerably scaled down



Figure 1. Management zones for Australia's east coast tuna fishery.

in length. These vessels have so far largely concentrated their efforts in relativley near-shore waters, but the scope of their operations will almost certainly continue to expand. Because of the new and lucrative export market in Japan, the domestic longline fishery has grown very rapidly. By 1986, over 180 vessels were active in the fishery, producing about 600 tons of yellowfin and bigeye tunas for the Japanese *sashimi* market. A much smaller quantity of tunas was marketed in Australia along with the bycatches of other species, including swordfish and striped marlin. Notwithstanding this expansion in domestic operations, the Japanese longline fleet is still dominant off the east coast, in part because it ranges over a much broader area within the AFZ. The total annual yellowfin catch from the AFZ off the east coast has recently been about 2,600 tons, with 20 to 25% being made by Australian longliners.

The rapid development of the east coast longline fishery that began in 1983 soon raised concerns over possible over-expansion of the fleet. The Australian government has moved quickly to control entry into the fishery in order to prevent this from happening. In December, 1985, following a meeting between representatives of the fishing industry and state and commonwealth officials, a decision was made by the Australian Fisheries Council (AFC) to develop a management plan for the fishery. At the time this intention was announced (December 7, 1985), concerned parties were also warned that, as of the announcement date, they should not invest in the fishery on the misapprehension that this would entitle them to continue to participate after finalization of the plan. The next major step was taken by the AFC in July, 1986, with the creation of the East Coast Tuna Management Advisory Committee, or ECTUNAMAC. ECTUNAMAC has broad terms of reference which encompass provision of advice to the AFC on management, research, and development of the fishery. It is made up of representatives from commonwealth and state governments, the harvesting and processing sectors of the commercial fishing industry, and recreational fishing organizations. ECTUNAMAC held its first meeting in August, 1986, and has met several times a year since then. It is clear that its recommendations carry a great deal of weight, even though it is an advisory body. In fact, regarding the east coast tuna fishery plan, ECTUNAMAC's proposals have generally been subsequently adopted by the AFC, so that, in this area at least, ECTUNAMAC could almost be considered a policy-making body.

In September, 1986, the AFC, with the endorsement of ECTUNAMAC, established a register of interest for all fishermen wanting to operate in the east coast yellowfin and bigeye tuna fishery. The object was to compile information on interest, investment, and activity in the fishery that could be used in developing a management plan. Additional official warnings were circulated while the register of interest was open. Fishermen were advised that entry into the fishery would definitely be controlled under forthcoming interim management arrangements. They were also advised that boats should not be replaced after February 26, 1987, and that endorsement to other fisheries for which boats were eligible should be retained. The register of interest was closed in late May, 1987, with well over 500 registrations.

During the period that the register of interest was open, and thereafter, ECTUNAMAC continued with development of the east coast management plan. These efforts were well publicized, and meetings with interested fishermen were held at a number of ports in NSW and Queensland. The end product of these efforts, an interim 3-year management plan, was announced by the AFC on November 4, 1987. The plan calls for the east coast tuna fishery to be managed as a limited entry, pelagic longline fishery. The area of coverage is the AFZ between Cape York in the north to Cape Howe (on the border between NSW and Victoria) in the south. This large expanse of water is subdivided into 5 types of areas (Fig. 1), and 3 categories of access into these areas are established.

Area A lies off southern NSW and extends out to a distance of 50 nautical miles. This area is considered a developed fishery and only individuals with an established history in the fishery are permitted to operate there. These established fishermen can also operate in areas B, C, and E. Areas B and E are considered parts of an inshore developmental fishery that consists of coastal waters lying off northern NSW and Queensland (except for area D in the vicinity of Cairns in northern Queensland). Area E waters are within the Great Barrier Reef Marine Park, which has its own additional system of zones, some of which prohibit longlining. Fishermen who lack a history of longline activity but who

were on the register of intent by its closing date are allowed to fish in areas B and E as well as area C, but are excluded from area A. Area C, the remainder of the east coast AFZ, is a large offshore developmental zone that is currently exploited by Japanese longliners. Fishermen not qualifying in the historical or inshore developmental categories can still receive an offshore developmental entitlement that allows them to operate in area C only. In Queensland, management plan waters (areas B, D, and E) extend inshore all the way to the shoreline, itself, as a result of what is known as the Offshore Constitutional Settlement (OCS) agreement reached between the state and the commonwealth in 1987. Under this agreement, inshore tuna fisheries (inside of 3 miles) were transferred to commonwealth jurisdication. The OCS process has not yet been completed in NSW, so that state still retains jurisdiction over tuna out to 3 miles.

Area D includes all of the foreign longline closure area lying off the Great Barrier Reef in the vicinity of Cairns and, in addition, includes the Great Barrier Reef Marine Park waters inshore of the closure. All of what is now known as area D was closed to domestic longlining by Fisheries Notice 93 in 1980 in order to protect the black marlin and other billfish that are so important to the area's sport fishing industry. Australian access to the Japanese *sashimi* market in the mid-1980s led to a reassessment of this position. In 1986, Fisheries Notice 171 reopened the closed area to domestic longlining, on a very limited exploratory basis, in order to investigate the potential for a *sashimi*-based fishery. Fishermen operating in the restricted area under special permits were required to return all billfish, dead or alive, to the sea. With adoption of the east coast tuna management plan, this area, now known as area D, will continue to be managed under the provisions of Fisheries Notice 171. In addition, as in the case of area E, the portion of area D lying within the Great Barrier Reef Marine Park is subject to further restrictions on longlining.

Besides protecting billfishes in area D, further important agreements relating to billfishes have been reached as a result of ECTUNAMAC discussions. In the December, 1986, meeting, representatives of commercial longline fishing interests, recognizing the recreational importance of marlins, particularly black marlin and blue marlin, agreed to regard these two species as non-commercial. If taken in longlining operations, these two species are returned to the sea regardless of their condition when caught. For their part, representatives of recreational fishing interests, recognizing the importance to commercial fishermen of the strong Japanese market for air-freighted chilled striped marlin, agreed that this species could be retained for export with the proviso that further discussions would be held on establishing specific areas that would be closed to the taking of striped marlin. At a subsequent ECTUNAMAC meeting, sport fishing representatives proposed that waters off NSW out to 50 miles should be closed to commercial taking of marlin during the January through June period.

ECTUNAMAC finalized the details for its proposed plan for managing the east coast tuna fishery at its August, 1987, meeting and submitted the proposal to the AFC. In November, the AFC announced that it had endorsed ECTUNAMAC's proposed plan. Details of the plan were circulated to all interested fishermen, industry associations, fishermen's cooperatives, and fisheries inspectors. In December and January, 1988, application forms for endorsement into the three categories of access (historical, inshore developmental, offshore developmental) were circulated. It was noted on the endorsement application form that applications should be lodged by February 24 and that pelagic longlining under the new permit system would commence on May 20. That date was later changed to July 1. Endorsement fees for the historical and inshore developmental categories were set at Aus$2,000 per annum, while the fee in the offshore developmental category was set at Aus$1,000 per annum.

On July 1, a total of 288 endorsements were offered (112 historical, 162 inshore developmental, 14 offshore developmental). As of early November, 186 of these offers had been accepted (102 historical, 73 inshore developmental, 11 offshore developmental), and December 31, 1988, had tentatively been set as a cutoff date for acceptance of an endorsement offer. It is also anticiapted that a few of those who accept offers will not actually participate in the east coast tuna fishery.

The entire ECTUNAMAC process, from its inception to implementation of a management program, was completed in about 2-1/2 years (from December, 1985, to July, 1988). The decisive manner in which the Australian government, with the cooperation of both the recrea-

tional and commercial fishing communities, has dealt with the issue of tuna and billfish management on the east coast can serve as an example of effective resource management for other nations to emulate.

United States — Hawaiian Islands

The area around the Hawaiian Islands stands out as one of the premier spots in the world for big-game fishing. The principal billfish species here is the blue marlin, with striped marlin, black marlin, sailfish, and spearfish being taken less frequently. Swordfish are plentiful but not commonly taken in the sport fishery. The highlight of each year, the Hawaiian International Billfish Tournament, attracts participants from throughout the world and is one of sport fishing's most prestigious events. A number of commercial fisheries that take billfishes and various other pelagic species are also prosecuted in Hawaiian waters. These fisheries are dealt with in the Fisheries Management Plan (FMP) for the Pelagic Fisheries of the Western Pacific Region, which covers all species of billfishes [as well as wahoo *(Acanthocybium solanderi),* mahimahi or dolphin *(Coryphaena hippurus)* and ocean sharks] taken within the U.S. Fisheries Conservation Zone (FCZ) around Hawaii and other U.S. possessions in the Pacific. The present discussion will focus on the waters surrounding the main Hawaiian Islands (i.e., waters east of 161°W longitude).

Perhaps the most striking aspect of the fisheries for pelagic species in Hawaiian waters and surrounding areas is their diversity. The FMP breaks these fisheries down into no less than 12 categories: foreign longline, baitboat, drift-gillnet, and purse-seine fisheries; domestic longline, baitboat, and purse-seine fisheries; day and night handline fisheries; commercial and quasi-commercial troll fisheries, and the charter sport fishery).

These fisheries vary greatly in terms of their impact on billfishes. Baitfishing takes virtually no billfish. Purse-seining operations take some billfish (none to a few per set) but, because they have not historically operated in or near Hawaii's FCZ, the impact is slight. Drift gillnetting utilizes a non-selective type of gear that is very effective in capturing billfish. The Japanese drift gillnet fishery was developed in the 1970s and now extends as far east as Hawaii. Operating in waters beyond the FCZ, and targeting on tuna and billfish, drift gillnetting could impact on nearshore domestic fisheries. The day and night handline fisheries, which use two distinct fishing techniques, both target on tunas which make up by far the greatest share of their catch. Nevertheless, significant quantities of billfish are also taken, mostly swordfish and blue marlin. The U.S. longline fleet based in Hawaii has expanded significantly in the 1980s, and many of the more modern vessels routinely operate well outside of the FCZ. The foreign longline fishery is dominated by Japan, with Taiwan and South Korea also participating. This fishery operates throughout the Pacific Ocean and undoubtedly competes with domestic Hawaiian fisheries for billfishes. Tunas dominate the catches in both U.S. and foreign longline operations, but meaningful amounts of billfish are also taken. Because foreign longline operations are so extensive, this fishery is probably the primary determinant of billfish stock conditions, both in Hawaiian waters and throughout most of the Pacific.

The charter, commercial troll, and quasi-commercial troll fisheries can be considered together since they all employ more or less similar fishing methods. The quasi-commercial troll category includes fishermen motivated by many blends of commercial, recreational, and subsistence considerations. They fish from small boats and a significant amount of their catch is sold. Charter vessels are generally larger and a higher percentage of the client-catch is sold commercially by the vessel operators. Billfishes dominate the charter vessels catch, tunas dominate the commercial troll catch, and tunas and billfishes both make substantial contributions in the quasi-commercial category. Few billfish are released after capture in Hawaii although, in recent years, the rules of the Hawaiian International Billfish Tournament have encouraged this practice.

Directly comparable catch statistics are not readily available for the various domestic fisheries operating in Hawaiian waters. Nevertheless, based on data contained in the pelagic fisheries FMP, one can conclude that during the early 1980s the domestic billfish catch amounted to about 3 million pounds annually with roughly 80% being blue marlin. Quasi-commercial operations took roughly 50% of this catch while charter operations took another 30%. Longlining, which took mostly striped marlin and swordfish, accounted for about 10% of the total billfish catch. These crude figures point to the

importance of recreational fishing in the overall Hawaiian billfish picture. Assuming that the quasi-commercial category catch can be split 50-50 between recreationally and commercially caught fish, and combining this component of the recreational catch with the charter catch, one concludes that over half of the total Hawaiian billfish catch results from recreational fishing. The predominance of blue marlin in the catch made by the various categories of trollers is also noteworthy.

To understand the motivation for the existing billfish management regime in Hawaiian waters, one must go back to 1976, the year when the Magnuson Fishery Conservation and Management Act (MFCMA) became law. This Act asserted U.S. jurisdiction over fisheries resources within a fisheries conservation zone (FCZ) that extended 200 nautical miles seaward from its coastline. All fish species were covered by the MFCMA, with one important exception — the so-called highly migratory species which were narrowly defined to consist of the various species of tunas. The tunas, according to the MFCMA, were to be managed by international bodies established for that purpose. Billfishes, which are as migratory as at least some species of tunas, were not treated as highly migratory under the MFCMA.

The U.S., in taking this approach, remained cognizant of the interests of its distant-water fleet of tuna purse-seiners. The U.S. had pioneered the purse-seining method of fishing, and its highly modern fleet had traditionally fished extensively in waters that were within the 200-mile zones established by the Pacific coast nations of Latin America. When the U.S. extended its fisheries jurisdictions in 1976, it exempted tunas. The presumption appeared to be that if the U.S. allowed foreign vessels to fish on an unrestricted basis for tunas (but on a controlled basis for other species) within its 200-mile zone, then no precedent would be established for other nations to limit access of U.S. vessels seeking to fish for tuna within their respective 200-mile zones.

With this philosophy in mind, the U.S. faced a dilemma in dealing with the foreign longline fishery in the Pacific Ocean. This fishery had traditionally operated in the 200-mile zones established with the passage of the MFCMA around Hawaii and various other U.S. possessions in the Pacific. However, these longliners took both tunas and billfishes. The problem was to provide continued access to the tuna resources while at the same time exercising management authority over billfishes and other pelagic species. The solution arrived at by the U.S. in 1980 was to implement a Preliminary Management Plan (PMP) that dealt specifically with foreign longlining. This plan applied to U.S. waters in the Pacific, including the FCZ off the west coast of the contiguous 48 states but excluding Alaskan waters.

Under this provision of the PMP, any foreign longline vesel desiring to operate in the FCZ first had to acquire a permit by paying a nominal fee. Then, a vessel had to notify U.S. authorities of its intent to enter the FCZ to commence fishing operations. At that point the U.S. had the option of requiring the vessel to enter port to pick up a U.S. observer before beginning to fish. (It should be noted that the observer provision was not unique to the PMP. Rather it is an integral requirement of the MFCMA itself and must be incorporated into all management plans developed under the Act). Retention zones and non-retention zones were established within the FCZ. For the main Hawaiian Islands, the non-retention zone extended out to 100 nautical miles. In the non-retention zone, all hooked billfish, dead or alive, had to be released without being removed from the water. In retention zones, an allowable catch was established for each billfish species. In Hawaiian waters, the allowable catch ranged from 0 for blue marlin and black marlin to 139.8 metric tons for striped marlin. Small increases were possible if domestic catches fell short of expectations.

In principle, the requirements outlined, preceding, left the FCZ open for tuna longlining operations, but with conditions imposed that were quite restrictive. As it turned out, foreign longlining in the FCZ was totally inhibited. During the 1980-1982 period, hundreds of longline vessels from Japan, Taiwan, and Korea obtained permits, but none actually entered any part of the FCZ to fish. No vessel even applied for a permit in 1983. In subsequent years, vessels from Taiwan and Korea that intended to land tuna in American Samoa once again applied for permits but none fished. Thus, the PMP had the effect of excluding foreign longliners from U.S. waters.

When the PMP went into effect, it was considered a temporary means for controlling foreign longlining in the FCZ until a final fisheries management plan (FMP) could be de-

veloped to take its place, presumably in a relatively short period of time. As it turned out, this optimism was not justified. As the years passed, it became increasingly evident that the PMP, although maximizing benefits to domestic fishermen, was failing in its primary goal. That goal was to provide foreign longliners with an opportunity to continue tuna fishing in the FCZ while, at the same time, providing some degree of management control on their bycatches of billfish. Actually foreign longliners were being effectively shut out of the entire FCZ by the complex requirements relating to permits, non-retention, species quotas, observers, reporting, and checking in and out. With this in mind, the Western Pacific Fishery Management Council prepared an FMP for the Pelagic Fisheries of the Western Pacific Region.

The final draft of the proposed FMP was dated July, 1986, and differed significantly from the PMP. To begin with, the area of coverage excluded waters off the west coast of the contiguous 48 states and the northern Marianas Islands, which had been included under the PMP. Also, although provisions relating to permits, notification of intent to fish, and carrying observers were similar to those contained in the PMP, the delimitation of fishing zones was very different. Instead of billfish non-retention zones, closed areas were established where no foreign longlining could take place. Off the main Hawaiian Islands, this area extended out to 150 nautical miles (versus 100 miles for the PMP non-retention zone). In the 150 to 200-mile retention zone, there would be no restrictions on longline catches whereas, under the PMP, species limits had been imposed. The rationale for these changes was that, by eliminating non-retention provisions and billfish catch limits, foreign longliners would be less encumbered in the billfish retention zones and therefore more likely to operate there. At the same time, the broad closed zone around Hawaii would adequately protect the interests of U.S. sport and commercial fishermen.

The July, 1986, draft FMP was subjected to further significant change before being officially adopted in March, 1987. The U.S. FCZ, which had become the Exclusive Economic Zone (EEZ) as a result of Presidential Proclamation 5030 in March 1983, was now divided into three types of management areas. Around the main Hawaiian Islands, there was a 12-mile closed area, a 12 to 100-mile non-retention zone, and a 100 to 200-mile retention zone. The final regulations also provided for the closed area to be extended seaward to as far as 150 miles if it is determined that foreign longlining activities are having an adverse impact on billfish stocks or U.S. domestic interests. Thus, the outcome of this long process, which involved several revisions of the draft FMP, numerous public hearings, and many individual contacts, was to adopt a FMP that is similar in many of its provisions to the PMP that it replaced. In particular, the permit, notification of intent, observer, and catch reporting requirements, which are required by the MFCMA itself, are retained in the FMP. Hence, it is not surprising that there has been no foreign longlining activity in the EEZ up to the present time, although Korean and Taiwanese longliners landing tuna in American Samoa have continued to obtain permits.

As noted earlier, the PMP addressed only longlining activities. The FMP covers other types of gear, as well. Because purse-seining and baitfishing can be targeted exclusively on tunas (or nearly so), fishing by either of these methods is allowed on an unrestricted basis under the FMP. On the other hand, drift gillnetting is considered to be an indiscriminate method of fishing with regard to species taken, and one that also threatens marine mammals and turtles. Therefore, foreign drift gillnetting is prohibited. Domestic fishermen are also prohibited from using drift gillnet gear unless they have first obtained an experimental fishing permit. The procedures for obtaining such a permit are spelled out in detail in the domestic FMP regulations. The FMP also required domestic fishermen to cooperate in enforcement and inspection procedures and, in the case of fishermen who sell any parts of their catches, to comply with State of Hawaii licensing and catch reporting requirements.

In evaluating the success of the Western Pacific FMP (and the PMP that preceded it) as a management vehicle, one must think in terms of its major objectives. In terms of protecting and furthering the interests of the U.S. fishing community, the PMP/FMP approach has been an unqualified success in that foreign competition has been kept out of the EEZ. In terms of minimizing interference with foreign fleets wishing to harvest tunas in U.S. waters, a stated objective, the degree of success is unclear. The opportunity to fish exists in theory, but no foreign longliners have done so, apparently because they may be required to carry observers and to comply with

other notification and reporting procedures. It is doubtful, however, that these requirements are so onerous as to preclude entry because foreign vessels of various types, including longliners, have complied with similar requirements in other U.S. fisheries. It may well be the case that entry into the U.S. EEZ is not particularly important for foreign longline fleets operating in the vast expanse of the Pacific Ocean.

Requirements For Future Billfish Management

Management of billfish resources in the Pacific and Indian oceans should meet at least four general requirements in order to be fully effective. First, a management regime must have the capability of focussing its efforts on billfish as a primary area of responsibility. This does not mean that a management body's sphere of responsibility must be limited exclusively to billfish (i.e., separate from management of tunas and other pelagic species) but, rather, that billfish must be placed on equal footing with other species groups that may also be under management.

A second key requirement is that management (which in the broad sense of the term includes research, monitoring of the fishery, regulation, and enforcement) must be effectively implemented throughout the entire range of the stock under consideration. This requirement is essential, not just because of the highly migratory nature of the species, also because of the mobility of the fleets that harvest billfish and the multinational nature of the fishery and the marketing networks.

Because stock ranges include waters of many jurisdictional zones, as well as the high seas, a third basic requirement is that management must be broad in scope and that all political and commercial entities having interests in the conservation and harvesting of billfish must become involved. Cooperation is required of entities ranging from national governments down to individual fishing vessels and responsibility levels ranging from broad policy-making down to providing routine information on catches.

A fourth requirement is that appropriate mechanisms must exist for implementing an effective management program. Provisions must exist for funding and staffing that is adequate to carry out data collection, fleet monitoring, and research activities; the authority must exist to impose regulations when necessary; and appropriate enforcement procedures must be formulated. All of this infrastructure will obviously require the support and cooperation of national governments.

Finally, the management program must reflect an appropriate balance between the interests of both recreational and commercial fishermen. This balancing is particularly important in the case of billfishes because they are so highly esteemed throughout the world by sportsmen and commercial fishermen, alike. In countries that have both commercial and sport fisheries, these groups are often well organized (at the national level, at least) and speak with powerful political voices which underscore the importance of achieving balanced management.

With these broad requirements in mind, current billfish management arrangements at both the national and international level can be evaluated. In the case of national initiatives, it is clear that nations with well developed recreational fisheries for billfishes, such as the United States and Australia, have placed strong emphasis on maintenance of these resources, and that a balance of some sort exists between recreational and commercial interests. There is ample room for disagreement over how appropriate that balance may be in any given case, but there must be general agreement that no single nation's 200-mile zone comes close to encompassing the full range of any billfish stock. Since a nation cannot exercise control over commercial fishing beyond its own 200-mile zone, except perhaps over its own flag vessels, effective billfish management at the national level is severely restricted. Obviously, nothing can be done to overcome this inherent limitation on a nation-by-nation approach to billfish management. However, it should be stressed that individual nations will almost certainly play an active and important role in any effective international billfish management system.

In the case of international management, it seems clear that existing bodies in the Pacific and Indian ocean area, as they are presently constituted, are either not adequate for managing billfish resources or are not directing enough of their resources toward that goal.

In the eastern Pacific, the IATTC has never placed high priority on its role with respect to billfishes, and a number of important nations in the region are not members. The CPPS has shown little interest in billfishes. Finally, the organizations that would be created if either EPOTFA

or OLDEPESCA initiative were to enter into force would have no jurisdiction over billfish resources and would represent only a subset of the nations of the eastern Pacific. All of these eastern Pacific bodies, existing or proposed, share the common shortcoming that their authority is or would be limited within the 200-mile zones of non-member nations where important billfish resources are found.

In the western Pacific, the SPC does not cover the full range of the region's billfish stocks nor does it have management responsibility, while the FFA is not involved in research or biological assessment of the stocks.

In the Indian Ocean and Indo-Pacific regions, neither of the existing organizations, the IOFC and IPFC, has shown an inclination to exert its limited authority to make management recommendations on billfishes or any of the tunas. At least within the IOFC, however, there is increasing awareness and movement toward the development of long-term institutional arrangements for the management of tuna and tuna-like species.

The conclusion that none of the existing bodies in the Pacific and Indian ocean region is adequately addressing billfish conservation and management issues should not be construed as criticism of these organizations. When many of these bodies were created, the general level of concern over billfish resources was far below what it is today. They generally tended to focus on tunas, with billfishes and recreational fishing being of only peripheral interest or of no concern at all. Thus, it is not surprising that their present mode of operation falls short of what is needed for effective future management of billfish resources.

Various scenarios for overcoming present shortcomings in the management of billfish in the Pacific and Indian oceans can be imagined. Whatever pathway is chosen to the end result, a general approach to international billfish management can be outlined. Overall catch quotas should be established on a stock-by-stock basis. An overall quota would represent the target catch over the entire range of a given stock to be taken by all types of fishing activity. This overall quota, especially in the case of an important recreational stock, would not necessarily be that associated with the maximum biomass or economic yield. The overall catch quota could be subdivided or allocated among those participating in the fishery. If this were done on a nation-by-nation basis, the high seas share representing catch beyond 200 miles could be left unallocated or, alternatively, perhaps be divided among nations with high-seas harvesting capability. Criteria to be considered in making national allocations could include area of a nation's 200-mile zone, concentration of resource in that zone, historical catches, harvesting capability, etc.

Each nation should have some control over how its allocation is to be used. To enhance recreational fishing and associated tourism, sport fishing enclaves could be established around key sport fishing areas, as has been done historically in certain Australian, New Zealand, and Mexican waters. A nation would also have a choice as to whether to have its own flag vessels harvest its allocation or to license foreign vessels to do the harvesting. To further protect the resources, nations might agree to restrict fishing in areas where billfishes are known to form spawning concentrations at certain times of year. Gear limitations would also be possible, for example, limitations on use of drift gillnets or requirements that longline gear be designed to fish deep so as to target more specifically on tunas. Some sort of international licensing system might also be considered.

The preceding discussion gives only the barest outline of how an international management system for billfishes might be structured. Perhaps the most important point is that many major problems will have to be surmounted if success is to be achieved. This implies a serious commitment to negotiating in good faith and a willingness to compromise. Recreational and commercial fishing interests must be willing to recognize that each has a legitimate interest in and claim to its fair share of a limited resource. This also applies to nations with diverse views on how they can best derive benefits from utilization of billfish resources.

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Panel 4

Debate
Varying Approaches to Management

John Gulland, Chairman

Tuna: An International Citizen

August Felando

I want to give you a little historical perspective about a task that I feel is extremely important, defending an American experiment that was started after the Truman Proclamation in 1945. This experiment is reflected in the present tuna position of the United States.

Imagine yourself back in those days when most of the data collection on tuna was by the state of California, recognizing that the canned tuna industry was started in 1903 in San Pedro, California. Basically, it was an albacore fishery, with some bluefin taken off southern California. Recall the position that the United States took following the Truman Proclamation, which was a unilateral declaration by the United States of sovereignty over the continental shelf, looking at the oil resources. At that particular time there were also declarations that the United States would unilaterally establish a fisheries conservation zone or join with other participants in doing so.

In 1945, I was fishing for albacore in waters off Oregon, California, and Washington. During 1945-1949, the critical years, I was fishing for tropical tunas off Latin America. The American Tunaboat Association (ATA) involvement at that time, along with other segments of the industry, was to support the position of the United States. The decision was made, based on what was known about tuna biology and life history at that time, that a single coastal nation like the United States could not effectively regulate tuna by itself. Now, that's still the position and all of the science that has been collected through the following years justifies that position. We're dealing with an animal that is a restless international citizen, a reality that governments and people must deal with. If you want to regulate tuna, you must implement management measures, as much as possible, throughout the entire range of the resource.

More importantly, the United States recognized its own limitations. The reality that we must face today is that there are limitations on however small or great a country claims its sovereignty to be in the world's oceans. We are definitely in the age of nationalism in the ocean, and my defense of what I call the American experiment has fallen on hard times. But look at the results, with respect to tuna. I lived from 1966 to 1979 with the difficulties of allocating a limited resource, of making adjustments, recognizing that our fishermen, who conducted the dominant fishery of that time, were regulated, in the beginning years, for about nine months. In 1967, we had a fishery that lasted effectively for about nine months. By 1970, it was squeezed down to an open season of three months, forcing adjustments. It was suggested in 1961-1962 that the resource was limited to about 79,000 mt at the maximum. The latest recommendation of the tuna commission is that a minimum catch should be 190,000 mt, but could go as high as 210,000 mt. The important thing is that we supported this approach of delegating regulatory authority to a commission in this region because it gave us hopeful objectivity. It could perhaps even resolve the politics of gear conflicts within the United States at that time, between the seiners in San Pedro and the bait-boat fleet in San Diego. We support this commission because it has the facts and, we think, the objectivity, based on experience; where there is an error, they're willing to correct it.

The suggestion, today, is that we should eliminate this approach. Really, we're not eliminating this, we'll still have the United States government in support of this, but what

is the perception? The experiment is over with. How do you provide the incentive to countries who exercise sovereignty to agree on a treaty to limit catches? What has been the experience in the past? We have coastal nations of Latin America who claim extensive economic zones, 200 nautical miles — they're even talking about going farther offshore. What has been their record with respect to conservation of tuna? What has been the record even of a coalition of those States with respect to the conservation of tuna? The question I want to stress here, is whether we are going to return to a period where each and every coastal state will claim the capacity, the competency to regulate tuna. Are we going to turn back the clock without even recognizing the problems that are involved in allocation under that situation?

There is an analogy and I'd like to play it before you. In the United States we have the doctrine of federalism. We are strong states' rightists, and each and every state claims a bit of sovereignty. But we have the concept of intrastate commerce and the concept of interstate commerce. Tuna can be likened, I suggest to you, to interstate commerce. It is the federalism in our country that makes commerce possible among the states. There must be some relinquishment of control of sovereignty by those states to make it work. For instance, if we wanted to build a railroad from San Diego to Boston, how would it work, if each and every state could regulate that railroad? We would have chaos.

Therefore, one of the underpinnings for our support of this position is the fact that we believe it recognizes the economic reality of commercial fishing for tuna. In order to be successful, we have to be as migratory as the tuna. We believe this experiment of the Unitd States, which was started in 1949 and has evolved into the Inter-American Tropical Tuna Commission, is the way to go. As you've heard, today, the IATTC is the only commission which has the authority to commit the member governments to implement conservation recommendations.

I assume that you know about the activities of the IATTC with respect to the implementation of the global quota on yellowfin. I assume you know about the activities of the International Commission for the Conservation of Atlantic Tunas (ICCAT). I believe there are more than just political reasons for this position of the United States. In the years past, in preparation for the Law of the Sea conferences in 1958 and 1960, this position was thoroughly reviewed by both industry and government. Again, in the amendments to the Tuna Conventions Act of 1950, in which enhanced powers of regulation were delegated to the Department of the Interior at that time, and during the discussions supporting the ICCAT treaty in 1965-1966, the question was whether we were on the right track. That question was reviewed again throughout the Law of the Sea negotiations in 1971 and 1981.

It is difficult to be a leader, but I say we are on the right track. Whether it's a U.S. fleet out there, or another fleet, the willingness to delegate, to give up political sovereignty to this approach, makes it possible for us to have a renewable resource. I did not reach this conclusion easily; it is a personal conviction based on extensive experience.

The biological characteristics of the tuna require a regional approach to obtain the goals of rational conservation and optimum utlization. Article 64, of the UN Law of the Sea Convention clearly establishes this premise, and it is this international obligation that conditions the Coastal States' claims of exclusive jurisdiction over tuna within a region. The tuna policy of the United States is correct because it takes into account the reality that dictates the economics of man's harvesting such resource. To foster the policy that each and every coastal State has the exclusive competence to conserve the tunas and to regulate their harvest is to ignore such reality. Such policy would promote world-wide chaos in the production, processing, and consumption of such ocean food resource, because in time it would create a system of access for fishermen that promised only unacceptable monetary risks. Without sources of reliable supply, the processing and marketing of tuna would fail economically. Such policy would also destroy the will and power of Nations to negotiate regional arrangements, effectively frustrating the clear intent of Article 64 and the primary purposes of fishery management of the UN Law of the Sea Convention.

The American Tunaboat Association (ATA) believes that without the present tuna policy of the United States as expressed in the MFCMA, treaties, and executive pronouncements, it would be impossible to negotiate agreements or treaties dealing with regional tuna arrangements on licensing and conservation. This conclusion is based upon the many negotiations that have

occurred since 1976. In particular, the South Pacific Tuna Treaty which went into force on 15 June 1988, and the 1983 Eastern Pacific Tuna Fishing Agreement. Both treaties establish regional licensing arrangements.

Should the tuna position of the MFCMA be changed, the U.S. tuna fleet would no longer be protected under the provisions of the Fishermen's Protective Act. The removal of such protection would adversely impact the access of U.S. tuna vessels to essential fishing grounds, would severely impact the market value of U.S. tuna vessels, and impair the ability of vessel owners to use the vessels as reliable security for first preferred ship mortgages. Along with the change in the tuna position of the MFCMA would come application of the Lacey Act, subjecting U.S. tuna vessels to prosecution by both foreign and U.S. Government agencies. The ATA strongly believes that the resulting changes in other U.S. laws caused by a reversal in the tuna policy as provided by the MFCMA would leave the U.S. tuna fleet totally unprotected and subject to economic harrassment and uncertainty.

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Needed Changes In Regional Management

James F. McHugh

I am a member of the Mid-Atlantic Fishery Management Council but the opinions I express today are mine and do not necessarily reflect the position of the Mid-Atlantic Fisheries Management Council. Our Council is on record supporting changes to Section 102 of the Magnuson Act, but has not yet defined the specifics for inclusion in those changes.

The mandate of the Magnuson Act requires that management of a fishery, or fisheries, be designed to assure both a continuing supply of food and a continuing recreational fishing opportunity in a manner which will avoid irreversible and long-term adverse impacts on the resources and their environment while providing a variety of options to future users of these resources. Experience over the last eleven years has demonstrated that this seemingly simple agenda is much more easily stated than accomplished. The difficulty in its implementation arises from the human failures to recognize its necessity and its inherent equity.

The first of these failures is the refusal by some to recognize the basic needs for effective resource management. The second is the refusal by some to accept the fact that there are significant variances in the needs, objectives, and methods of the users of the resources. The third, rather than a failure, is a positive and continuing effort to politicize the process of forestalling any attempt to achieve a reasonable conservation program and an equitable access scheme.

As this indictment relates to the wide ranging pelagic species, of which billfishes and sharks are significant and valuable segments, the proposition is readily supported by the current provisions of the Magnuson Act which exclude the highly migratory species of tuna from management jurisdiction by the United States in its own EEZ. No one will deny that this provision was totally political at the time of its inclusion, in 1976. There may have been some understandable necessity for the provision at that time, but experience has proven it to be worthless in accomplishing its intention. Despite its demonstrated failure to serve its purpose, its original proponents continue to insist on its preservation without any regard for its prevention of effective resource management, or for the needs of other resource users.

Before making my case for necessary changes, and for the particular benefit of my international audience, let me make eminently clear several potential points for misunderstanding. The first of these is that the advocates of necessary changes to the Magnuson Act do not suggest that such changes contemplate the cessation of the United States from its international commitments, or from its participation in their continued efforts. To the contrary, the advocates of changes believe that the beneficial results would include programs of greater value to the international effort.

The second potential for misunderstanding is a concern that the advocates of change fail, or will fail, to discriminate among the uses of the various species of pelagics. Insurance against such an eventuality may be found in the National Standards of the Magnuson Act. The economic value of tunas, of swordfish, and of marlins arise from different user needs, and the Act requires that these varying needs be adequately considered.

Again for the benefit of my international friends, the changes that I contend are necessary must be Congressionally legislated changes to Section 102 of the Magnuson Act. In its present text, that section prohibits any assertion of man-

agement authority by the United States over the "highly migratory species," these being defined as five species of tunas. At the time the Act was passed, it was thought that the inclusion of this provision would generate reciprocal access to the territorial seas and extended jurisdictional zones of coastal nations where those tunas abounded. Time has proven this proposition to be futile. To the best of my understanding, the United States is, today, the only coastal nation not exercising management jurisdication over the tunas found, or passing through, their extended economic zones.

If the provisions of Section 102 of the Act did not seriously inhibit adequate management of those species of pelagics for which the fisheries management councils do have responsibility under the Act, I suppose that a lengthy discussion of the needs for change would be both academic and unnecessary. However, since a significant segment of U.S. commercial fishing effort employs longlining, which indiscriminantly captures any pelagic fish taking a bait, essential species management and conservation efforts are critically impaired.

As has been done in other parts of the world, the economic value to the nation of the billfishes, as recreational target species, has been well established in the United States. It is documentable, particularly in considering the marlins, that this recreational value far exceeds their value in the market place.

Other countries with greater management flexibility have imposed harvesting regulations calculated to preserve and enhance this value. Under the much more restrictive management plan development procedures required by the Magnuson Act, the Atlantic, Gulf, and Caribbean fishery management councils have submitted a management plan for billfish to the Secretary of Commerce for review and approval. In general, the plan prohibits retention by commercial longliners; with a single exception to protect an historic artisanal fishery, prohibits the sale of billfish taken in U.S. waters; and regulates the minimum sizes for possession by recreational fishermen.*

Rather than recognize the relative economic values, and acknowledge the equity in the requirements of the Act for recreational benefits on a continuing basis, the plan is being vehemently opposed by commercial interests for primarily philosophical and, therefore, selfish interests. In stating their case, they find comfort in the exclusionary interpretations of Section 102, contending that the provisions of the Billfish Plan will inhibit their directed efforts for tunas, and that they are being denied a right to retain whatever they take as by-catch.

These are the same arguments, by the same people, which totally aborted council efforts to establish reasonable management measures in the swordfish fishery. Their successful nine-year "stonewalling" of proposals for necessary seasonal closures have driven that fishery into an advanced state of growth overfishing in the western Atlantic. In so doing, they have so significantly reduced average sizes that the historic north Atlantic harpoon fishery fleet is tied to the dock for lack of viable targets.

In my opinion, until such time as there are amendments to Section 102 the United States efforts to address the problems of reckless overharvesting of the pelagic resources will continue to be an exercise in futility. If there were any demonstrable benefit to be derived from retaining Section 102, in its present form, I might be persuaded to moderate my position. The recently implemented Southwest Pacific Tuna Treaty is a clear example of the fact that it has failed in its purpose. Persistence in its retention militates against any U.S. efforts to conserve and manage pelagic resources within its jurisdiction. As an added but not insignificant impact it is economically damaging to all of the smaller U.S. commercial tuna interests, and particularly those of the western Pacific.

My position does not imply that I harbor any objection to that treaty. In fact, I supported its adoption, believing that it encompassed the salvation of our distant-water tuna activity. In so doing, however, I had hoped, and still do, that the beneficiaries of that Congressional bonanza would finally "see the light." They obtained what they wanted at the cost of millions of dollars to themselves, and to the federal government, despite the provisions of Section 102. Now it is time to reconsider their archaic and worthless position that is so militantly, selfishly, and unrealisticly opposing any consideration of amendments. Suggestions that they participate in the drafting of necessary changes have gone unanswered. Unfortunately, it has been, all too clearly, a position which conveys a total lack of concern for conservation of the resource, and

**Editor's Note: The U.S.Secretary of Commerce has since approved the Billfish Plan, effective 18 October 1988.*

a selfish disregard for the needs of other fishermen.

I would hope that the sunshine of their successful and virtually unopposed gains in the southwest Pacific would melt the glacial rigidity of their long standing opposition into a pristine mirror lake upon which all could paddle in the same canoe toward a common happy hunting ground.

James F. McHugh earned the BA degree in 1938 and the MBA degree in 1947. He is a fire protection engineering consultant. At one time or another, he has been an associate commissioner of marine resources; a member of the Virginia Governor's Land Use Roundtable; director, United States Atlantic Tuna Tournament; secretary, Interstate Striped Bass Advisory Board; chairman Large Pelagics Committee of the Mid-Atlantic Fisheries Management Council (MAFMC); local fishing club president; and director of state marine recreational fisheries organization. Currently, he is chairman of the Mid-Atlantic Fisheries Management Council; board member of the National Coalition for Marine Conservation; an observer at annual meeting of the International Commission for the Conservation of Atlantic Tunas (ICCAT) in Madrid; member of 5 fishing clubs. He has fished most of the U.S. East Coast as well as Alaska, Mexico, Mariannas, and Polynesia.

Blending of International and Coastal State Management

Carmen J. Blondin

The views expressed hereinafter are those of the author and do not necessarily reflect the views of the National Oceanic and Atmospheric Administration.

The management of highly migratory species has been debated for more than 30 years. This debate has grown more intense in recent years, as more and more countries extended jurisdiction. Advocates of international management argue that a single regime throughout the range is the only logical way to manage these species. On the other hand, advocates of extended jurisdiction point out that international management has failed to take into account coastal State considerations and has failed, in many instances, to manage these species successfully.

The fact remains that there is a mixture of management regimes around the world. The majority of the countries have shifted to a fragmented coastal State management approach. They participate in some kind of an international arrangement, some providing for access and some setting quotas and other related management measures. In any event, the systems are in a state of evolution with active negotiations and legislative developments happening continually.

As all are well aware, even in the United States there is diversity. Not all highly migratory species, as defined by the Law-of-the-Sea Convention, are handled similarly. Tunas are outside the 200-mile EEZ jurisdiction, while billfish and other species are within the 200-mile EEZ jurisdiction.

From an academic sense, in my view, the management of highly migratory species is best carried out under one regime, throughout the range of the species, and with the full authorities needed to implement needed measures effectively.

International management, alone, has failed to gain the support of the majority of the countries of the world. It has failed to be supported because the perception has been — I emphasize "perception" — that coastal State interests have not been adequately dealt with or have been ignored, and that management measures have not been addressed in a timely manner.

The list of concerns is long. It includes: interference with other coastal fisheries; intense local effort, with removals often resulting in local depletions; the loss of potential revenues because of distant-water fleet activities — which is critical for some island nations because the sources of revenue are generally limited to ocean related activities. I could go on — and I'm confident that others could add their own thoughts to the list.

Earlier, I emphasized that perceptions about international management shortcomings explain the lack of support. When the reasons are analyzed, one must conclude that all of these concerns could have been addressed internationally.

Obviously, for one reason or another, these concerns were neither pursued thoroughly, nor supported with a well though-out strategy at the international level, on a worldwide basis.

As a result, we are now faced with growing coastal State management authority over highly migratory species. This approach is also doomed to failure unless international concerns are dealt with adequately. For example: placing too heavy a license or access-fee burden could render fish-

ing revenues marginal or unprofitable; the multiplicity of such fees by many countries would also have the same effect; cumbersome regulations such as required observers, mandatory reporting, or landing requirements would also make the operations less efficient. Such regulations could even be termed as restraint of trade and as inconsistent with GATT obligations. Further, coastal State regulations on size, quotas, seasons, areas, vessel limitations, and gear limitations could be inconsistent or conflicting with agreed upon minimum international standards. Certainly in the mix of management measures, it would be possible for a coastal State to have more stringent measures than the international standards, as long as they are compatible with the overall international objectives.

Coastal State management as it exists today in the world is rarely well coordinated with international management. In the United States, we have tried to minimize inconsistencies by taking legislative steps that require participation by concerned groups.

For example, the ICCAT implementing legislation has been amended to require participation on the ICCAT Advisory Committee by representatives of the five Atlantic regional fisheries management councils. The U.S. Commissioners for ICCAT have also taken the position that the U.S. would avoid making international recommendations that are out-of-step with the announced objectives of the regional fisheries management councils.

Another problem that some have criticized is that the current arrangements in the U.S. are a slow and cumbersome process. For example, insofar as Atlantic billfishes are concerned, the process involves a large number of people with voting authority on the five fisheries management councils, many of whom have absolutely no interest in or understanding of highly migratory species management needs. The process also involves the ICCAT Advisory Committee, the U.S. Commissioners, and ultimately the entire body of ICCAT Commissioners. All of these people must march in step so to speak to achieve coordinated results in a limited time frame if they are to be effective. Past experience has shown that one or more years of lead time is/are required to place needed regulations in effect and that this kind of time delay is usually unacceptable.

In order to make the current systems more responsive, some commentators have suggested that we should begin by renegotiating the existing international regimes to provide for sufficient authority to act responsively to:

1. provide for adequate collection and central analysis of data;
2. set overall quotas, seasons, size limits, or other needed measures;
3. maintain an equitable and reasonable single licensing scheme throughout the area;
4. establish country quotas based on a fair and equitable formulation which takes into account such factors as the traditional fishing power of each of the countries concerned, the dependence of coastal States on the species concerned, and the best mix of economic and humanitarian needs of each country concerned;
5. formulate enforcement measures which address the interests of the coastal States within 200 miles, and an effective system throughout the area of jurisdiction, involving national enforcement, mutual enforcement, and international enforcement; and
6. provide for adequate and reliable funding, based upon a fair and equitable assessment on the part of governments, that would include a measure of the benefit from resources removed, processed, and/or utilized.

Some commentators have also suggested that a single worldwide international body be set up to manage highly migratory species. This approach would be ideal, but negotiating such an arrangement would be highly complex, and require a well thought-out negotiating strategy to avoid polarizing countries with a small or nonexistent recreational constituency or interest. Perhaps, as a part of the overall strategy, it would be better to select an area that would allow the development of an ideal regime for certain species and geographic areas and, once having achieved this regime, to extend the concept to other species and geographic areas as supportable precedence is achieved.

On the domestic side, the suggestions go on to address a very complicated management scheme that currently exists with eight regional fisheries management councils having responsibility for some species of highly migratory fish. Commentators have recommended that a single highly migratory species management council be set up in the United States through new legislation. This council would have the authority to

recommend domestic regulations within the 200-mile zone to the Secretary of Commerce, and would also have the authority to function as an international commission advisory committee, and some of its members could be designated by the President to serve as U.S. Commissioners. Such an arrangement, it is felt, would go a long way toward solving the most serious of the problems that exist today.

I shall close by saying that I believe the future of highly migratory species management will be the result of the committment and influence that people around the world will devote to meeting the challenge. If we meet the current problems head on, and deal with the issues in a rational and fair approach, taking into account island nations and coastal State interests, as well as international obligations, and make the necessary committments, we will develop the regimes needed to ensure conservation of highly migratory species. In the process we must keep in mind that time is running out for us to avert a total crisis. While crises sometimes force rapid decisionmaking, they rarely result in fair and equitable dealings for all concerned.

Future efforts will require serious committment, and this translates into determination and the making available of human and fiscal resources to make it happen.

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Panel 4 Discussion

John Guilland, London, England (Moderator):

First, it would be useful to go back to those assumptions that James Joseph mentioned, the first being that fishing can have a clear impact on billfishes. One can have differing definitions of overfishing, but it's quite clear that, with respect to abundance of the stocks, the ability of fishermen to go out and get good catches can clearly be affected by the activities of other fishermen.

The second thing about billfishes is that they clearly move over large distances. I don't fully agree with James Joseph that all tunas, such as yellowfin, are necessarily highly migratory. Certainly, as far as the normal biological definition of migrations is concerned, there are stocks of cods and herring that are more clearly migratory, moving from one area to another and then back again, than perhaps are yellowfin. I think the point so far as billfishes is concerned, looking at the tag returns of several of the species, notably swordfish, is that the success of fishing in one area can, indeed, be affected by the amount of fishing in areas quite some distance away. I think this has some bearing on the points made earlier, the degree to which a coastal state can impose management regulations on billfishes, and it might be useful for James McHugh to explain the degree to which he hopes, if the U.S. alone put on regulations to control billfishes in its 200 miles, that this could be effective and maintain good fishing, unless there was some international action controlling what was happening outside 200 miles. If we agree that the latter might be necessary, it sets the scene for discussions on international management. On the other hand, if it would be possible for a coastal state to ensure good fishing in its own zone, purely by actions within that zone, then you are in a different situation. I would like to have a few comments on that one.

James McHugh:

In my view, there is no question but that the international considerations are a preeminent part of an overall climate. Within the context of that position, I further believe that there are a number of various driving forces prompting the U.S. to adopt the role and the measures that I support. Leadership is required in accomplishing these ultimate objectives and, unless we have our own house in order and some game plan established, we are hardly in a position to go into an international forum and make recommendations.

Beyond that, particularly with regard to the east coast, there is no question that tunas and the other pelagics mix. You should be aware that we have an unpermitted longline fishing fleet exceeding 500 boats on the east coast and in the Gulf of Mexico. The migratory track of all these animals, whether they be tunas or billfishes, are highly predictable. The fishing patterns are very compliant. Consequently, if we don't take some immediate albeit recognizably crude action, we stand in jeopardy of seeing billfish stocks depleted in the same manner as swordfish. Bear in mind, again, that we distinguish between swordfish and billfish, those species having different user interests.

I don't have any problem, as I said early on in my statement, with international participation. At the present time, and the way our law reads, there is no way that any regulatory or administrative agency can establish any regulations over either yellowfin or bigeye tuna in the Atlantic. Consequently, there is no opportunity other than on a voluntary basis to collect data. I believe, if nothing else were accomplished, the formulation of authority over tuna in the EEZ would greatly enhance the capabilities of the U.S. to support international associations in formalized data collection.

John Guilland:

As I understand it, then, you're not questioning the need for international action, you're suggesting that national action might help and strengthen international action.

August Felando:

Just as our vessels are obligated, under the Atlantic Tuna Convention Act, to maintain logbooks, we assume that other vessels engaged in longline effort or what have you are obligated to maintain logbooks, too. That obligation is clearly in the law. What the regulations say with respect to longlining, I don't know, but to me it's astounding for anyone to suggest that there isn't authority under the existing law to require vessel owners, commercial or sport, who are engaged in the tuna fishery, or the billfish fishery, certainly the tuna fishery, to provide logbooks.

In the Magnuson Act, the decision was made politically that we're going to act like a coastal state with respect to all fish other than tuna. You have, therefore, the regulatory power, a blanket authority under the Magnuson Act, given to the Department of Commerce, to regulate those who engage in fisheries other than tuna. I think the question is what the position is of the Department of Commerce with respect to domestic fishermen who employ longline gear. We are faced with the fact that the U.S. claims coastal state authority over swordfish, however they are not in a position to implement the conservation measures throughout the range of this fishery. In fact, U.S. fishermen are heading towards the middle of the Atlantic, meeting with the Spaniards, and perhaps moving to the south. How would you provide the incentive for others to obligate themselves to catch quotas or whatever measures are required, if in fact the U.S. takes the position that, 'we will do what we want with respect to swordfish, even though we can regulate our citizens but not the others beyond the EEZ.'

The swordfish problem illustrates the difficulty with respect to the U.S. position in this area. Do you or do you not support the ICCAT? To what extent are you willing to sacrifice your sovereignty, your control over swordfish, as an example, to make sure that the resource flourishes throughout the Atlantic, north or south, east or west? There has to be some commitment by the U.S. to relinquish sovereignty, in my opinion, to provide the incentive for others to do the same in order to protect the renewable nature of swordfish or other billfishes. It's fine to talk about a debating society in which we say, 'we want to cooperate, we want to participate internationally,' but if there is no commitment to relinquish sovereignty to make it work where are you?

Carmen Blondin:

I can't help but remember what I heard back in 1971 when I was a student at the National War College and attended a seminar at the University of Rhode Island. I listened to a number of people talk about what was going to happen, about the extended jurisdictions that were going to occur, but I remember well the words of a professor from the University of Tokyo. His point was that he didn't visualize the people of the world, as these extensions occurred, giving up their national jurisdictions. He foresaw that what you are going to have is a carving up of the oceans, different kinds of commissions with different kinds of extended jurisdictional authority. In fact, some of his graphs even showed extended jurisdiction going beyond 200 miles. There's no doubt that's not the way to manage highly migratory species. His point was that we've had to learn lessons in this world. It was through failures that we then began to give up this authority, and work together in unity. I'm not suggesting that we have to do that, I guess what we need to do is embark on some kind of an effort to have people understand what's needed.

I think we're in the middle of a transition, that we are in fact faced with a mixture of things. Again, looking at the ICCAT management of billfishes. How do we mesh domestically with those international efforts? As a commissioner, this problem has plagued me for some time. It's plagued the other commissioners. We've even adopted a rule, and I guess it'll apply so long as we serve as commissioners, that we would not take any premature steps internationally in advance of the development of a direction by the five regional management councils. We could see we'd be in deep trouble. Those are some of the complications you have by a mixture of effort. It can work, but it requires a great deal of coordination so that these gears of international and domestic management are not stripped as you begin shifting.

James McHugh:

I want to preface my comment by stating that I don't know anybody who represents his people better than does Mr. Felando. I have a high regard for him. Following up on his last comments, however, I think his international travels have taken him out of touch with reality as far as these problems are concerned. On this question of sovereignty and giving up sovereignty, I have here a copy of "Pacific Magazine," July/August 1988. On page 48 there's an article on the tuna milestone in the Paupua-New Guinea area, what's referred to as the Southwest Treaty, and the comments of the minister of fisheries for Papua-New Guinea upon signing the treaty. he said that the treaty should foster closer ties between the United States and countries of the south Pacific and, in doing so, that the United States recognizes the sovereign rights of the south Pacific countries over their fisheries resources. Our perception in this country might be that we should sacrifice sovereignty, but it doesn't appear from what I read in an area magazine that the beneficiaries of these treaties have the same perception of sovereignty.

Beyond that, if somebody can tell me, with the history to back it up, how you can manage billfishes, or swordfish, or any of the species which the councils are mandated to manage, without some authority over the total fleet, I'd like to know about it. We haven't yet learned how to do so, with the possible exception of a prohibition on the use of longlines in the fishery. That's the only way you can do it. Furthermore, I don't know where there is authority to require American vessels in the EEZ in the Atlantic, Gulf, and Caribbean, to file mandatory logbooks on bigeye and yellowfin tunas.

Christopher Weld:

The point I've tried to make is that we have nothing, in fact, to relinquish in the way of sovereignty because we haven't exercised sovereignty. That's the bottom line of what our management effort has been within the EEZ. We have not exerted management authority over billfishes, tunas, swordfish, sharks — any of the highly migratory species. So, what are we giving up? In addition to this, I was really quite disappointed, although I suppose I shouldn't have been, to hear absolutely no evidence that the American Tunaboat Association was in any way willing to reconsider this policy. I would hope that they would be a little bit more open minded about this in view of the fact that it seems to us, as outsiders, that many of the industry's objectives are being realized under this very elaborate treaty network.

John Gulland:

I hope it is clear, in relation to species like billfishes that move over long distances, that the success of management actions within one country's EEZ must also depend on what is happening outside. We need to look at the whole international scene on the high seas and in other countries. There's one other point that Mr. McHugh mentioned, that you can talk about billfishes, but you have to bring tunas into that ambit if you want to be effective.

Edward Wolfe, U.S. State Department:

Since we've been talking about the South Pacific Treaty for a while, I'd like to make one or two brief points. First, I have no axe to grind one way or the other on this issue. We operate under a statute until that is changed. The South Pacific Treaty, the result of two years of negotiations, is historic, complex, and the most difficult treaty we've ever negotiated. It's my opinion, lacking the leverage we had — the Magnuson Act exclusion of tuna — that we would not have had success in this arrangement. We're going into the eastern tropical Pacific to try and do the same thing.

If we're going to get anything out of this meeting this week, I think we should be considering working together and start moving in a direction where we can conserve the species. If we come out of this meeting with an agreement to work together for scientific data and information for better management of billfish, at least we've agreed on something in a positive direction, as opposed to adversarial posturing.

John Gulland:

My personal experience with all international fisheries commissions is, once the U.S. has managed to resolve its internal conflicts, the rest of the negotiations are simple. I'd now like us to turn and look rather briefly at the sorts of things you need to do if you are going to manage through an international organization. Dr. Shima showed you some charts of international bodies of extraordinary complexity. If you looked at those bodies, with the exception of some of the FAO bodies which were never funded and supported, all the ones that really

got going and did the work did an extremely good job of getting the data and analyzing the data through their scientific groups. When I say they did a good job of getting the data, I don't necessarily mean the data were absolutely wonderful. Anyone familiar with any fishery data anywhere would echo Richard Shomura's comment that the data are "lousy," but some are less lousy than others. I think the international commissions on the whole have managed to get data that are fairly reliable.

What is also interesting in many of the areas Dr. Shima showed you was the degree to which the statistics and science were kept separate from the implementation decision on management and enforcement. This is particularly true in the north Atlantic, where the old ICNAF has been dissolved in the northwest and a three-part body has been set up, one dealing with the scientific council which can look at all stocks, and the international management action dealing only with those stocks outside 200 miles. Similarly, in the northeast Atlantic, ICES does all the work collecting statistics and providing the biological and scientific advice into their stock assessment working groups, but the management decisions are taken by the coastal states, either in the consortium of European Communities, or between the two or three countries involved in the particular stock. I'd like some comments from the panel on the merit in keeping some of these separate.

Carmen Blondin:

Most of the international commissions lack the full authority. I'm not going to get into the statistics and analysis, because I think in most areas that's been recognized as a basis to get started, and we do quite well in most commissions. It's in the implementation phase where the failure occurs. It's in the support phase, in budgeting, that the failure occurs. Here, we need to look at re-negotiating those agreements that don't have this authority in order to bring them up to speed. It's going to be difficult.

We've talked about adequate data collection. I tried to put down what I thought were the most important elements. Obviously, these commissions have got to act responsibly, meaning that they must act in a timely fashion, not one to several years after the needed action happens. We need mechanisms that can operate quickly, in collecting the data and in analyzing them, and there should be central analysis of those data, as well. There should be authority to set overall quotas, seasons, size limits, and other needed measures. If there is to be a licensing scheme, an equitable and reasonable single licensing scheme should apply throughout the area. Fourth, the establishment of country quotas is needed based on fair and equitable formulation which takes into account such factors as the traditional fishing power of each of the countries concerned, the dependence of coastal states on the species concerned, and the best mix of economic and humanitarian needs of each of the countries concerned. Fifth, enforcement is required which must address the interests of the coastal states, and an effective system throughout the area of jurisdiction should be formulated involving national enforcement, mutual enforcement (where countries have the right to board other vessels as well as their own), and international enforcement. Six, provide adequate and reliable funding on a fair and equitable assessment basis on the party countries, based upon the resources removed, processed, utilized, or other benefits that would accrue

Christopher Weld:

One of the difficulties in trying to structure any kind of an international agreement, particularly one that would involve many different nations with many different interests, is the problem of trying to address the various values of the various societies involved. To talk about the power to board other vessels, to ask for reasonable fees — as a practical matter, you're really covering tremendous issues. Of course, with the kind of leverage that Edward Wolfe is talking about, if you throw enough money at the problem it will probably be solved. What did it cost, $50 million or so to get into the western Pacific? I just don't see that kind of money coming from anywhere. I think you're talking about problems of resources, whether financial, diplomatic, or scientific. You're calling for a tremendous amount of resources, and as a practical matter I think you're biting off more than you can chew. I think these things have to be built by regional blocks, by multi-lateral agreements among nations sharing more or less the same values. Over time, these multilateral agreements can be merged or increased, at the least a 25 year project.

August Felando:

I've had experience since 1961 as a member of the Advisory Committee to the U.S. Commis-

sioners to the Inter-American Tropical Tuna Commission. I am also a member of the ICCAT Advisory Committee. To me, it's been a very interesting experience, in so far as I've been able to compare the difference in approaches, and that's been valuable. As we're going down the line here, I see where there'd be maybe a third commission, whether for the Indian Ocean or the western Pacific, designed to take the best features of both existing commissions. We have to recognize the national approaches; the U.S. and other countries have their own capabilities for providing statistics. In my opinion, however, the best approach is the IATTC. That's because the funding is different, the convention is different. The funding's largely from the U.S. They have the money to support the scientific staff to go out and get the numbers. And they have the commitments by the governments to regulate the fisheries, to provide the logbook data. I like the IATTC approach.

Dr. Shima stated that the 1978-1979 negotiations with the south Pacific countries resulted in agreement. In my opinion, it was a landmark agreement because that agreement established an open end arrangement, the same type of open arrangment that is available in the IATTC. If you don't get all the participants feeling that they're part of an organization, how can you expect them to contribute to it? One of the essentials to making a new commission in other areas would be a necessity of having an open end arrangement that certain rights and rewards goes with contributing data. Rather than a global approach, I see at the present time a regional approach, and it all basically resides in the commitment. I also agree with Christopher Weld that the benefits to participants vary; not everyone is interested in receiving a benefit with respect to an allocation of the resource. There's a limit to the amount of money that can be generated by fees.

James McHugh:

How many boats are involved under the Southwest Pacific Treaty, and how many U.S. flag vessels are in the eastern Pacific?

August Felando:

Basically, we're talking about 70 seiners that provided about 280,000 tons of catch last year. If you're talking about numbers, we're a very small fleet, yet we're the largest purse-seine fleet in operation in the world today. We have about 345 vessels operating in the eastern Pacific, about 30 vessels in the western Pacific.

Peter Goadby, New South Wales Recreational Fishing Advisory Council:

I was very interested to hear the tie-in between the Magnuson Act and the two commissions, which we all acknowledge do a fine job. Being a humble fisherman from a small country, I can assure you there's another provision in the Magnuson Act which our countries take into account in negotiations. It is that if our country or any other small country moves against a U.S. tuna boat, that country could lose the value of its exports to the U.S.

Peter Miyake, ICCAT:

We have a lot of problems in the Pacific because there is no oceanwide organization to gather statistics. We have so many different interests — commercial fisheries, recreational fisheries, government, scientists — but we agree more or less that we must know basic statistics to work from, and everybody says the data are poor. Yes, they are poor but they're better than they were 20 years ago. The problem is now much more complex, and the improvements are not catching up with the increasing complexity of the problems. My recommendation is that this symposium pass some kind of resolution to express our true concern over the lack of basic data, and how to improve them, particularly in the area where there's no mechanism to obtain it.

John Gulland:

We have general agreement that we're looking for some sort of international arrangement. Carmen Blondin set out requirements for this which are rather imposing, but I hope we could see our way as moving towards them. I'll pose the question: Should our first priority be to establish some international arrangement whereby somebody, some organization and individuals, should have immediate responsibility for improving, collecting, tabulating, and making the statistics available on perhaps an oceanwide basis, for the Pacific Ocean and for the Indian Ocean, and use that organization as a way forward towards one that has much more direct authority over the stocks and over the fishing activities?

Barbara Rothschild:

I want to make the point with regard to man-

agement issues that, when I look at the IOFC in the Indian Ocean, in fact it's very unusual that a group of countries in the Indian Ocean have acknowledged publicly that they want a body with management authority just for the Indian Ocean. If we go back to Mr. Felando's point, where he mentioned he did not know why the agreement in 1978 fell apart — I think he really does. That was because they were afraid that any organization that had management authority, in which the U.S. was a member, would be skewed in the direction of U.S. interests. So, while you can acknowledge that international data collection is a valid objective, once you step off into the management issue you're into a hornet's nest. I might emphasize that the treaty between the U.S. and the Pacific Island states does not in any include management authority for that region.

Christopher Weld:

I feel the focus of this convention is slipping more and more away from the do-able to very large scale projects which may be beyond the realm of the do-able. If something is going to come out of this meeting in the way of a practicable program, I would like to have some sense that that program is something that we can achieve within my lifetime.

Brian Rothschild:

Speaking of what is do-able, we should perhaps lower our sights a little bit and decide what we want to come out of this meeting and this so-called debate. The first thing we might think about is the question of what principles we might adopt as a group. I think the first principle has to deal with the conservation of the stocks of concern; after all, this is a billfish meeting and we are concerned with the future of billfishes. Of course, it's difficult to separate billfishes and tunas, as a practical matter; nevertheless, we have to be concerned with the conservation of the billfish stocks. That's a very different issue from allocation of the stocks, and it's a very different issue from the allocation of stocks within the U.S. 200-mile zone. So, let's just stop for a minute and talk about conservation. The conservation of the stocks has a lot to do with how much fishing effort is applied to stocks, and it's very difficult if not impossible to determine effort if we don't have the data. Of all the suggestions that have been made, Peter Miyake's suggestion of a follow-up technical conference is perhaps the most do-able. So, I'd like to see us come away from this meeting with adopting a suggestion like Peter Miyake's. We need as a community to go a lot farther than that, but I don't think this is the place to do it. I'd like to propose another idea, and it relates to something like having a technical conference. Both interested parties to look to reexamine the issues relating to management of high-seas resources. I think this is an imperative, and we should do that, and while we're doing that, the folks in the U.S. can worry about the important problems of the billfish catch in their conservation zone and the Magnuson Act. I think we need to look at the bigger picture. People have talked about these ideas of technical conferences before, but they've never come to pass. I would think that Secretary Blondin in his key role in this area in the United States would be one of the key guys to propose such a conference and get together with the other interests around the world to do that.

Carmen Blondin:

The comments made by everyone about where we're going are certainly correct. We can't get there too rapidly, as Chris Weld said, and I hope I didn't give the perception that I was trying to drive the system there rapidly. I think the point that Brian Rothschild has made is a good one. I certainly carry that kind of thought back home. But I think it really takes a joint effort, just as this symposium is an effort jointly between private interests and governmental interests. I think that's what we need to look at. I think those initiatives that start off being purely governmental are perhaps doomed by an inability to do and say the things that one must in order to be forward looking. I think it's a joint effort.

Peter Fithian, Hawaiian International Billfish Association:

I heard what Brian Rothschild said, I heard what everybody said up here, and I get the feeling it's agreed that there's got to be some kind of mechanism. Some like one kind, others like another kind, but I think reasonable men would figure out that the best parts would be taken from each. Frankly, in the Pacific, I want the best out here. I know what a technical meeting is, but if it's only bureaucrats, it'll never work. The engine that's driving this concept is not a bureaucracy. So, if a technical conference is how to get to the place to decide what kind of

a mechanism we need, then let's do it. But let's do what Carmen Blondin advocates and involve some of the rest of us. If a technical meeting is it, let's involve both sides and find the right process we can live with and let's get this job done. I looked at what we said in 1972 and it's not very different from what we're saying today.

Gregory McIntosh, South Atlantic Fishery Management Council:

Some remarks made by Mr. Blondin and Mr. Felando implied that if the U.S., can't manage swordfish domestically, we can not possibly manage on an international basis. Let me point out that five Atlantic councils, including the Gulf and Caribbean, and the fishermen represented on those councils, were unanimous in their resolve to conserve swordfish resources, and proposed specific implementing management measures to the Secretary of Commerce. Those measures were rejected by the Secretary because of a lawsuit filed by the Japanese stating that the proposed management measures would not provide a reasonable opportunity for them to fish for tuna. The second rationale for rejection was that the proposed measures would inflict unnecessary burden on the developing U.S. tuna fishery. The councils reconsidered all the management objectives, all the management opportunities and options available to them, and concluded, again unanimously, that the variable season closure originally submitted was the only viable way to conserve and manage Atlantic swordfish. The measures were again rejected by the Secretary of Commerce for the same reasons. I use this example, to point out that tunas and billfishes are inextricably woven together, and we must either amend Section 102 of the Magnuson Act to get rid of swordfish and billfishes, and go international, or we must amend 102 to include tunas. Until then, and that's a decision the Congress will have to make, pelagic resources management in the Atlantic Ocean will be seriously impaired.

M. Okuno, Japan Fisheries Agency:

What is the relationship between amending the Magnuson Act to permit the management of tunas, and the pending billfish management plan?

Christopher Weld:

The pending plan contains measures that have been found to be objectionable by the State Department and representatives of foreign fishing interests fishing in the EEZ. Their standing to object to those measures is founded entirely upon their entitlement to fish in the EEZ. Now if you amend the FCMA to include tunas, you remove that right to fish. Thereafter, under an amended Act, foreign fishing for tunas or any other species would be on the same basis. In other words, you're not necessarily excluding foreign fishing, you're saying that if you're going to fish for tunas, then you're going to fish subject to the provisions of the billfish and/or swordfish or shark, or any other management plan. That might include no fishing at night, it might include area and seasonal closing where tunas and billfishes coincide and, to be perfectly frank, it might ultimately result in the exclusion of all foreign tuna fishing from the EEZ. I would think, nevertheless, that any foreign nation with entitlement to a quota in the western Atlantic under ICCAT, could not be excluded from the EEZ. They would, however, be subject to the conservation and management provisions of other plans.

M. Okuno:

It seems to me that the billfish plan's proposed prohibition on the sale of billfish and the importation of billfish for sale is inconsistent with the National Standards of the Magnuson Act, which forbid discrimination against one group of users.

Carmen Blondin:

The point is an interesting one, and we can certainly look at it. It is not inconsistent to develop landing laws or sale restrictions where, in fact, they are tied in with the conservation of fish. When it becomes a violation of GATT (General Agreements on Tariffs and Trade), and when it's not, is a rather difficult determination. Often times, the matter ends up before the panel of GATT. In any event, the U.S. has looked at this.

Winthrop Rockefeller, The Billfish Foundation:

I've sat here for four days hearing scientific population studies indicating that a real problem exists, not just as regards the future but the current status of billfish populations. I heard Dr. Miyake's comment and recommendation, and I

concur very strongly. Something must be done in terms of developing an international body; an international cooperative effort must be achieved as soon as possible.

Panel 5

The Future — Prognosis and Recommendations

Pierre Closterman, Chairman

Future Trends in the Fisheries (Panel 1 Summary)

Peter Goadby

The subject of today's summarizing session is, "Future Prognosis and Recommendations." It cannot help be wondered, following papers, information, and opinions expressed here at Billfish II, whether the subject should be changed to "Billfish: Is There a Future?".

The opinion is expressed that this meeting will give hope and plans to provide a future. If we fail to act quickly, positively, and overcome difficulties and blocking delays, then there may be no need for management plans because there will be few billfish to manage.

In our lifetimes, we have all experienced the sad and frightening stories of the bluefin tuna in the Atlantic and Pacific Oceans and the southern bluefin tuna in the Indian Ocean. These are living cases of competition between countries, of political decisions, of stocks in trouble and the trouble not recognized, and of what happens as a result of over-exploitation, poor data, and the mistaken interpretation that the stocks can cope.

The history of the brief span of the Atlantic swordfish recreational fishery is even shorter in its establishment, decline, and demise. Most of us in our billfish fisheries have experienced the declines in strike rate, in day-to-day action in fish at boat or tag-and-release, despite improved knowledge, equipment on boats, tackles, and technique.

The future dictates further improvement in all these factors for the recreational fishing industry to survive. Recreational fishing is an industry shown in many areas and recognized by some governments for the fish to be worth more recreationally than commercially.

There will continue to be a close relationship between billfish and ocean tuna fisheries.

Looking to the future, there is an incredible and immediate need for a data base on all information relating to billfish. Collection and dissemination of this information could be accomplished by an international data collection and dissemination organization. The data collection zones may overlap, but the Atlantic, eastern Pacific, western Pacific and Indian Ocean areas would seem a logical break up of the world fisheries. The international billfish (and related fisheries) data should be disseminated to all fisheries, managers, scientists, governments, and all facets of offshore fisheries involving billfish to provide a basis for sound decision making.

Two representatives from each of the four areas could meet annually to review the data and make recommendations. The meeting of all represented scientific and management authorities should meet in a planned wider meeting of all involved billfish groups each five years. All catching and using nations, including Korea, Taiwan, USA and Japan (the world leader in billfish catch, usage, and market acceptance) among 25 other nations, should supply data for dissemination.

The USSR does not supply catch data at present, yet could affect the result. It is frightening to be part of a fishery, where a major influencing country has not released its data and where others are slow to do so or release incomplete data. An international billfish management data base, by its information and interpretation, could ease fishing pressure where and when necessary before stocks come to the brink of depletion.

The international data collection and dissemination should cover catch, effort, and all other data and developments from all world fisheries, commercial, recreational, artisanal, and indigenous.

There is immediate and future need for billfish

stock identification to establish as a start whether there are local, or one or more stocks of each species in each ocean. Electropheretic and morphometric studies could give indications on this. The recreational tag-and-release programs should be continued and expanded to increase knowledge and conserve stocks.

There is concern that the term, "Highly Migratory Species" in future could become, "Highly Migratory Fishing Fleets" as boats cross the oceans and travel to fish at or near other nations' back doors just outside their EEZs and so influence recruitment and stock size into the EEZ of other countries.

There is concern now that, in the future, the fish scientists and the fisheries scientists may continue on ever more diverging courses of interest and study. This problem should be acknowledged and recognized and both schools of thought in science, plus the economists, should plan studies so as to yield improved knowledge of billfish biology, of the fisheries, of the factors of demand and acceptance of billfish as food. These are important factors that affect the fast-growing tourist industry — and the fish.

There have been some surveys on the economic value of a tournament of recreational fishing, of the fish themselves in recreation, whether as captures or tagged releases, and of the commercial fisheries. Utilization of billfish resources should generate maximum socioeconomic benefits.

In the future, there must be factual surveys of the values and all the socioeconomic factors in the various fisheries. Employment and associated benefits in the involved industries must be researched and this knowledge disseminated. The value of a billfish should be established for its various fisheries, in various localities, in a normal life cycle and growth of the fish.

The location of many of the billfish spawning areas are known to various nations along with the time of spawning, its duration and direction. Coastal nations will never own the offshore billfish stocks; but nations may own the spawning concentrations in their EEZs.

In the future, to assist the species, every encouragement, even national government decisions in an international interest, should be made to minimize kill of billfish of all sizes in spawning time, in spawning areas, and to maximize stocks survival during tag-and-release operations.

All fishing for billfish, whether commercial, recreational, artisanal, or indigenous, affects the stocks. When assessed on the basis of take by one vessel, the incidental billfish by-catch may seem insigificant but, when multiplied to fishing fleets, the by-catch can be major and frightening. Billfish stocks are not inexhaustable resources.

It has been shown that the billfish — marlins, sailfish, swordfish — are indeed target species in some fisheries. When they are, by-catch studies must be made in the future to minimize billfish captures (particularly in multi-species fisheries) before commercial fishermen in both developed and emerging nations come to depend on income from their catches of billfish for livelihood and boat and gear expansion.

There is future need in artisanal and indigneous fisheries for training and guidance, through international education, in the least wasteful methods of fishing. Expansion of driftnet fisheries by island and developing countries around some oceans perpetuates both the many problems associated with this wasteful method of take, not only of multi-species fish and sharks, and the unnecessary and unpalatable take of mammals, turtles, and other marine life. An active international organization should assist emerging nations and island states in the control and reporting of data as well as economic (i.e., cost-effective) fishing methods.

In the future, there will be a continuing market pressure and acceptance of billfish products for their apparent health benefits and other reasons of choice and desirability. Increased prices for billfish products mean increased returns and additional incentive for fishermen to target on these species.

Swordfish are popular in the United States and other countries. Striped marlin are popular sashimi fish in Japan. The Japanese market for billfish has increased dramatically, with 25 countries shipping billfish to Japan. Because of price and demand, the future will be one of further technical development in an industry where many boats and their equipment are already over-capitalized. These boats therefore need more billfish products to continue their profitability through increased utilization of modern methods and to improve acceptance of products by trying to change from frozen product supply to fresh.

It is wondered how long it will be before fast all-weather boats and even big helicopters in near coastal waters will be picking up fish from

freezer-type boats so the catch can be sold as chilled fresh and command higher price and acceptability. Again, availability of improved products will ensure continuation of the demand. At present, despite the data on price of various billfish species presented at this symposium, there is considerable variation in price of each species at different times.

In most areas and countries, surveys show that recreational fishing for billfish brings in the most dollars and most socio-economic benefits. The exploding tourism industry, important in most coastal countries, has spotlighted the benefits of recreational fishing with its minimal effect on stocks and life cycles — particularly when combined with tag-and-release programs — a case of fish, fishermen, and industry combined in optimum use of a resource.

In the future despite the reported growing trend to deep long lines to take bigeye tuna, and the apparent stabilization from the Japanese scientists in take of billfish by the longline industry, the fact remains that marlin in the upper water layers will continue to hook themselves on unused baits as the line is retrieved unless some practical preventive measure can be adopted.

There is no doubt that this problem should be researched and that, in other major ways, all aspects relative to the future take of billfish will undergo change. This change will come from the concern, real or created, on the part of the commercial conservationists, the genuinely concerned animal "libbers," the "greenies," and other vocal groups, in regard to the take of billfish.

It is very evident that there is an immediate need for the commercial and recreational industries to prepare to work together, to plan and, in fact, actively to offset and negate the attack that will surely come on use of the billfish resources. In some areas, attack and planning is already evident in the media and to governments.

There has already been a court case in Germany where the tournament organization was fined a substantial amount for organizing cruelty and inflicting pain on the fish. Plans should be made now for recreational and commercial fisheries and fishing media and writers to be careful in their relations with "greenies" and rabid conservationists, who do not believe in any use of a resource, and in descriptions of fish captures and photographs. A mutually benefitial united front with data and facts from an International Data Bank could prove invaluable in countering extreme non-utlization pressure.

Despite the sorry history of the world's bluefin tuna species and the repeated assurance that this *won't* and *can't* happen again, it has done so. The current factor and evidence of growth overfishing in the Atlantic swordfish fishery is already just one more example. For the future, one recommendation from this world symposium to meet the worrying prognosis could be strong consideration for a limitation on the take of billfish, a freeze at the levels of 1979-1980, the last year for which detailed data from major billfish harvesting countries were freely available. For the immediate future, those harvesting levels could be held until an up-to-date evaluation of stock and recruitment into the fishery can be made.

Many folk at this meeting have said and believe that billfish are already on the "brink." There are those who believe a limitation on take at 1980 levels, a freeze, is a logical decision. There are those who believe a further 5 years of delay in decision making may be too late.

There are here those who believe that the speedy establishment of an International Billfish Data Bank by all nations, for all nations, could provide the necessary data that should make possible future management decisions to manage the billfish resources equitably and safely. The alternative, if billfish are to be managed and survive internationally, appears to lie between an immediate freeze at 1979-1980 levels, and the speedy creation of the data bank and subsequent management decisions to ensure stock survival. Other alternatives that may have to be considered are gear restrictions on length of line, on number of hooks, on length and depth of nets, and the establishment of international limited-entry fisheries on the high seas.

In the future, the need to bring technical efficiency and socioeconomic benefits closer together to gain the impact of mixed stock fisheries is important. Allied to this is the need for positive study and evaluation of the food chain. What are the effects of the efficient fisheries for squid, for small tuna, and other baitfish? These fisheries may have short-term socioeconomic benefits, but consideration must be given to the way they affect the billfish, their wanderings, the strike rate, size of the stock, even the survival in breeding numbers of those peak predators.

There would seem to be international and

U.S. benefits from speedy review and amendment of the Magnuson Act in some clauses and penalty provisions in this Act.

Looking into the future, for recreational fishermen, success with billfish lies with the trend of fishing farther offshore with bigger fish being sought. The improvement in boat speed, in electronic gadgetry, in aids to navigation will facilitate the move towards the fishing of offshore seamounts — again with possible gear conflict with commercial fisheries looking to those same natural features.

Historically, it has been easy and logical for government to identify and assist commercial fisheries. The industry is visible and obviously provides food supply. Now, finally, in many countries there is government acknowledgement of the socioeconomic value of the recreational fishing industry and in encouraging growth of the tourism industry which utilizes recreational fishing and recognizes this is a reason for people to travel and visit and spend money.

It is important that conflict between the various fishing groups and industries be minimized and avoided. The future must be a time for cooperation and consensus rather than confrontation. We are at the stage in time when the late U.S. President Kennedy might have said, "We must ask what we can do for the billfish, not what the billfish can do for us." The future must see a change.

The prognosis for the billfish is not good unless strong preventive medicine is taken as directed, whether this be an immediate freeze at 1980 levels or international collection and dissemination of data and speedily agreed management plans.

All nations taking billfish in any quantity must report their data for there to be a sound data base. It is indeed worrying and unnecessary that in this 1988 fishery there are few or no up-to-date data available.

To ensure there is a future, the world needs the international giving and collection of data, international data analysis, international dissemination of data. There is need for a single international authority, one commission with management responsibility to be adopted by all nations. Let everyone acknowledge that, like other species, billfishes are a limited resource.

Let us acknowledge the problems of the past and present, let us all plan, agree, and work to ensure the future for billfish so that our children and our children's children may experience and derive benefits from these great ocean fishes.

Let us have an International Commission for the Conservation and Management of Billfish.

Peter Goadby is a freelance magazine contributor and lecturer, having fished much of the Pacific Ocean, and author of *Big Fish and Blue Water*. He has served as governor and chief judge for the Hawaiian International Billfish Association. He was the first angler to weigh billfish and shark over 1,000 pounds, with a black marlin of 1,137 pounds and a white shark of 1,139 pounds. He is the Australian representative for the International Game Fish Association, and has captained Australian game fishing teams in tournaments in Hawaii, Tahiti, and Nova Scotia. He holds memberships in various game fishing clubs and associations in Belgium and Japan, as well as in Australia.

Assessing The Status Of The Stocks (Panel 2 Summary)

Gordon Broadhead

Stock assessment, in itself, is not a particularly difficult technical task for a trained fishery scientist equipped with an adequate data base. Data acquisition and management of the resource are more difficult than the analysis and stock assessment phase. However, the perfect or near perfect situation never occurs. The fishery scientist is usually faced with a mediocre data base and models that may not fit the situation. Thus, in practice, providing useful advice to resource managers on the status of large pelagic species is not easy.

When I listened to the papers on population status of the various billfish species, I thought of the comment, "this is *deja vue* all over again." This is not a criticism of the papers or of their presenters but, rather, of the state of the art and our progress toward a more acceptable result for management purposes. With few exceptions, we are examining flawed, incomplete, and/or biased data sets. The models are most sensitive to the parameters that we don't know or don't consider (natural mortality and environment impacts). Further, even the best of methods lack the currency often required for management action. We find out about declines long after they have occurred, the fishing structures have been established, and dollars have been invested. Change is then difficult and painful.

The use of an age-structured model tuned to an apparent abundance series is a good example of an excellent method that has decreasing accuracy as present time is approached. This is compounded by the difficulty in obtaining catch, effort, and age data on a current basis. Thus, the closer we get to when we need to know the status of the stock for management purposes, the less reliable are the answers. In terms of forecasting the future, the situation is compounded by the difficulty of also anticipating the reactions of the fishermen to the regulations. The general production model suffers from some of the same difficulties. In average conditions, it estimates average maximum sustainable yield under average conditions. A single year of fishing can be affected by major environmental components such as El Nino.

Next, let's turn to the people element. Panel Two was composed of well educated and very experienced fishery scientists. However, they were all people with reputations as tuna scientists. Not one was a full-time billfish scientist. The reason is simple. At this time there are insufficient incentives to attract experienced population dynamics people to work on billfish stocks. The full-time, dedicated billfish biologists are mostly younger scientists with local area assignments or working on the periphery of the assessment issues. Good enough data and funds are simply not available. Research on large pelagic species is expensive. We have spent in excess of 100 million dollars on tuna research over the last forty years. Billfish work has been funded at a much lower level and only in recent years. There is not a lot of glory involved in the management issues (even if you are correct technically), especially when the data are questionable.

So, what can be done? The data problems have been well covered by Raymon Conser and others, so I'll pass over this item for now. Some of the best assessment work has been done in the marine mammal area, where public pressure has provided the legal, political, and financial support necessary to attract top scientists to the research work. Perhaps billfish cannot achieve the public relations status of marine mammals, but certainly major improvements in awareness

and funding are possible. If the data base is improved and funding provided, there will not be a problem in attracting people to do the analyses.

The problem of models is more difficult. Perhaps they can be improved or simplified to fit the data sets available. At least, we can set priorities and concentrate efforts on the species most impacted presently or likely to be impacted seriously in the near future.

Peter Miyake raised the issue of developing a mechanism for improvement of the collection and organization of the billfish data. In the Atlantic, significant progress is being made through an expanded billfish program under ICCAT, financed by private funds supplemented by government efforts. An expansion of this type of program to the Pacific and Indian Ocean areas is needed. It's clear that some organizational leadership is required to get things started. We ought to build on the existing agencies in the Pacific because the formation of a new billfish research organization is probably too expensive and politically difficult at this time. An informal meeting of representatives of existing organizations to discuss ways and means of implementing a coordinated program for the entire Pacific is a first step. This might be spearheaded by the symposium sponsors, or by one of the existing organizations.

The future of the billfish stocks is dependent upon action now. It will take at least 10 years to develop the data base necessary for management. There is still time to do so, however, as it is difficult to deplete the stocks of large pelagic species.

Gordon C. Broadhead received the B.A. degree (zoology and chemistry) from the University of British Columbia in 1949, and the M.S. degree (zoology and fisheries) in 1955 at the University of Miami; and has since undertaken additional studies at San Diego State College (geology) and at the University of California (business management). In 1949-1950, he was a salmon research biologist with the Fisheries Research Board of Canada at Nanaimo, B.C. Since 1950, he has worked continuously in marine biology, studying both small and large pelagic fish species. From 1955-1963, he was a senior scientist with the Inter-American Tropical Tuna Commission; from 1963-1969, he was director of marine science, then research vice president for Van Camp Sea Food Co. He then founded the consulting firm of Living Marine Resources, Inc. serving as its chief executive officer until 1987. Currently he is an associate with LMR Fisheries Research, Inc., and a member of the U.S. Advisory Committee to U.S. Commissioners to IATTC and ICCAT.

Meeting Critical Information Needs (Panel 3 Summary)

David B. Grobecker

Following is a list of biological and fishery management objectives aimed at obtaining the information that seems to be most needed to support billfish stock assessments and to evaluate the impact and effectiveness of proposed management measures. For convenience, critical information needs may be placed in two very general categories: (1) biological and (2) fisheries management.

Broadly defined, biology is the science of life in all its phases and underlies the applied science of fisheries management.

Fisheries management, in general, seeks the wisest use (including harvesting) of a natural resource, considering human (socio-economic) and non-human impacts. It is realized that many of the following objectives are overlapping and depend on each other in order to obtain clear results.

Taxonomy

Objective: Investigate the taxonomy of billfishes at the species level, which is the fundamental unit of classification. In order for billfishes to be dealt with accurately, each one must have one universally used name. Taxonomy utilizes genetic relationships discovered through various methods of study, including morphometrics, meristics, and molecular biology (i.e., utilizing m.t. DNA). Without a universally recognized classification of billfishes, all other studies will be fraught with uncertainty.

Early Life History

Objective: Achieve a better understanding of billfish early life histories (the most critical stages concerning survivorship). Information should include the roles of environmental factors required for productive nursery grounds. Changes in adult populations may reflect environmental alterations (e.g., pollution, etc.) of the nursery grounds, in addition to adult mortality.

Age and Growth

Objective: Validate current methods of aging billfishes (i.e., injection of oxytetracyclene in billfishes, which marks the hard-parts) and develop international standardization for measuring sizes of billfish growth. Information on age and growth is among the most critical factors concerning the assessment of billfish stocks.

Movement and Distribution Patterns

Objective: Determine the distribution of billfishes at both the species and the individual stock levels. Telemetric studies shed light on both vertical and horizontal movement patterns. Such studies also reveal information on: (1) the survivorship of released billfishes and methods to increase the assurance of a healthy release, and (2) specific aspects of the physiology of the billfishes.

Eventually, archival or "smart" tags will become cost effective, making it feasible to record data for biological factors over relatively long periods of time.

The recapture of billfishes tagged and released by sport fishermen will provide information regarding migratory patterns, age and growth, and stock structure while returning fish back to the population for potential reproduction.

Behavioral Ecology

Objective: Obtain information concerning bionomics and life history not otherwise covered in this summation. The term "Behavioral Ecology" is here defined in a liberal sense to include such diverse and overlapping topics as reproduc-

tion, predator-prey interactions, food chain dynamics, inter-and-intra-specific competition, habitat selection, sexual dimorphism, and schooling behavior.

Fisheries

Catch Statistics

Objective: Improve catch statistics, which will rely upon better kept log books from all nations, including both the recreational and commercial sectors of the fishing industry.

Necessary records include complete descriptions of gear type, how each type is fished (depth, number of hooks, etc.), and the amount of effort (time) in specific areas. The log book must eliminate species lumping, and report data on sizes of the catch. A universal standard of size measurements for each species must become institutionalized.

Socio-economics

Objective: Complete a profile of the socio-economics of all types of fisheries (recreational, commercial, and artisanal) from all countries concerned. Socio-economics is a key factor in effective fisheries management. It is paramount when considering resource allocations and helps resolve user-group conflicts.

Stock Identification

Objective: Use methodologies of taxonomy (noted preceding) to determine which portions of billfish populations are being utilized by the fisheries. These include studies which examine billfish parasites as potential "natural tags," meristics, and morphometrics.

Population Models

Objective: Improve population models by inclusion of information gained from implementing the objectives noted preceding. Better information helps to assess billfish stocks more accurately.

Pacific Centralized Data Source

Objective: Establish a data collection center for the Pacific Basin. Once biological information and fisheries data are acquired, the establishment of a Pacific Data Collection center would be beneficial to all concerned. This data center would be responsible for maintaining a comprehensive collection of information and data, both historical and recent, on an all-inclusive international scale.

Conclusion

In order to accomplish the foregoing list of objectives, in reaching information needs, more adequate funding must be provided to support research projects and their investigators. This support should arise from individuals, representative groups, and all governments concerned.

Results from biological and fishery studies must be published in timely fashion in as scientific a manner as possible (both reviewed and refereed), and multiple publication of these results is to be discouraged. In order to achieve long-term future information objectives, investigators must be encouraged, stimulated, and supported to pursue careers in the management field.

With the initial momentum generated by this second International Billfish Symposium, many needed information objectives can benefit from closer liaison among professionals involved with billfish management and conservation.

This liaison may be accomplished by establishing a regularly scheduled series of technical meetings at which: (1) research would be updated, (2) ideas would be exchanged, and (3) unnecessary duplication of work would be eliminated. It will be possible to manage successfully one of our "greatest" natural resources only with appropriate funding and fostering of cooperation and effort among researchers, policy-makers, and users of the billfish resource, toward a mutual interest in billfish conservation.

David B. Grobecker received the B.S. & M.Sc. degrees in zoology and marine biology (1976) from California State University, Long Beach, and the Ph.D. (1983) from the College of Ocean and Fishery Sciences, University of Washington. In 1983, he was awarded the Achievement Reward for College Scientists and a post-doctorate position, Department of Zoology, University of Washington. His research has taken him to China, Central America, Baja California, and Australia. He is currently employed as scientific director for the Pacific Gamefish Research Foundation, Kailua-Kona, Hawaii, with particular current emphasis on the biology and management of Pacific blue marlin. He also serves both on the Scientific and Statistical Committee and on the Plan Monitoring Team for Pelagics of the Western Pacific Fishery Management Council. He has published numerous scientific and popular articles on fishes, includ-

ing co-authorship (with Theodore W. Pietsch) of a book concerning angler fish, *Frogfishes of the World,* published by Stanford University Press.

Strategies For Successful Management (Panel 4 Summary)

James Joseph

I would like to highlight some of the major points raised during the symposium on the management of highly migratory species, particularly the discussion during the management panel. My remarks refer to tunas as well as billfishes: they are so similar in their biology, their behavior, and in the way they are harvested that they can be treated as a single group. Indeed, from a management point of view, there are advantages to doing so.

Each of us has his own definition of the term "management," which implies different things to different people. It is generally taken to mean an effort to make the best use of a resource, in this case fish. Management implies a degree of conservation of the resource; again, the term "conservation" means something different to each of us. Dr. Shima stated that conserving populations of fish usually means maintaining them at levels which can support maximum harvests on a sustained basis. He noted that MSY is the stated objective of both the Inter-American Tropical Tuna Commission (IATTC) and the International Commission for the Conservation of Atlantic Tunas (ICCAT), the two major international bodies responsible for the management of highly migratory species. More recently, some alternative views of the aims of conservation have been put forward. These alternatives include maximizing employment or economic returns, and, as with the great whales, an end to all harvesting.

A good example of differing objectives came up in the discussions of recreational and commercial fishing, held during this Symposium. Commercial fishermen are interested in extracting the maximum sustainable yield from the stocks of tunas and billfishes; recreational fishermen want to maximize the strike rate and the chances of catching a large fish. These differing objectives require different management strategies. In order to get the maximum physical yield from a stock of fish on a sustained basis, the abundance of that stock must be reduced to the level at which it replaces itself most rapidly. As stock abundance decreases, the density of the population and the average size of the individual fish decrease; inevitably, so does the strike rate, and with it the probability of catching a giant fish. Increasing the sportsman's chances of getting into the record books, therefore, requires a reduction in commercial fishing effort. Fortunately, the outcome of this situation does not have to be the total ascendancy of one set of interests over the other, since management schemes can accommodate both of them. One such scheme involves establishing recreational fishing enclaves within commercial fishing areas, and this measure has been adopted in some places.

A question arose, about whether it was possible to overfish the stocks of billfishes or tunas. "Overfishing," like "management," is a very subjective term. Where you draw the dividing line between exploitation and overfishing depends on your objectives: the charter boat captain in search of a record marlin for his client sportsman and the captain of a seiner with wells to fill, both with livings to make, would have very different definitions of overfishing.

John Gulland expressed doubt that tunas or billfishes could be fished to the extent that their survival would be jeopardized, and I tend to agree. Most of the fisheries are directed toward one particular species, and it would not be economically feasible to continue fishing it to the point of extinction. I do believe, however, that it is possible to exert enough fishing effort to reduce the abundance of a stock to a level

well below that which will sustain maximum yield. Indeed, this reduction is precisely what has happened with several species. There is ample evidence to demonstrate that a number of species have been subjected to "growth overfishing" (substantially reducing the average catch by reducing the average size of the fish in the catch). So far "recruitment overfishing" (reducing the number of animals entering the population by reducing the number of spawners through fishing) has not been directly demonstrated for any species of billfish or tuna, although there is serious concern that the southern bluefin tuna stocks may have been overfished in this manner.

Over the long term, we need to be concerned about man's effect on the abundance and survival of these stocks through more than just his involvement in fishing. Earlier Brian Rothschild stated that we are not addressing the real cause of this and many other problems, which is an ever-increasing human population. In the same context, Rick Gaffney mentioned the demise of the North American bison. The disappearance of the vast herds of the early 1800s was due mainly to the changes man has made in their habitat. The prairies have been tilled and fenced, and now grow food for humans and domestic animals; they are no longer capable of supporting the bison. The passenger pigeon suffered a similar fate, because man destroyed the hardwood forests where they once nested. Much the same is now happening to waterfowl; their nesting areas are being put progressively under cultivation, and their populations are at all-time lows. Let's not repeat our mistakes; let's not foul the ocean and destroy the fragile habitat of billfishes and tunas. At the rate we are polluting the ocean, it is by no means unreasonable to think that the survival of these highly sensitive species could be threatened in the future.

Before we can set about managing our billfish resources properly we need to know something about the animals. We need to know how fast they grow, and when and why they die; where they come from, where they go, and why. Much of the data on which we can base our answers to these questions can come only from the fishing industry itself. These data should include information on how much fish is caught, when and where, and the size of the individual fish in the catch. The responsibility for collecting, collating, and analyzing this information, particularly statistics of catch and effort, needs to be delegated to some entity, which then needs to be given the financial and legal support to carry out its appointed task.

Up to now, the record on collecting statistical and biological data on highly-migratory species has been mixed. The most notable successes are the two tuna commissions, the IATTC in the Pacific and the ICCAT in the Atlantic, particularly the former. Their successes are due to the fact that they were mandated to carry out specific tasks and are given the means to do it. They are accountable for their actions, but are independent of national or partisan interests.

National data collection systems are inadequate in many instances. Christofer Boggs' comments on the lack of basic catch data on the commercial tuna fishery here in Hawaii, and similar comments about the developing U.S. tuna fishery in the Gulf of Mexico, and along the eastern seaboard of the United States, demonstrate that somehow, somewhere, responsibility for collecting such information is falling through the institutional and jurisdictional cracks. It is certainly time for many nations, including the United States, to examine their laws and policies governing the collection of fisheries information.

Data are virtually non-existent for most of the recreational fisheries for billfishes and tunas, scattered around the world. These fisheries are becoming increasingly important, and it is imperative that both statistical and biological data be collected if we are to manage them properly. In fact, virtually all of our current data collection systems need to be improved if we are to fulfill our responsibilities for managing these resources. Improvement should not be too difficult if we are willing to delegate the tasks and duties involved, and those who are to carry them out are willing to accept this responsibility.

Given the highly migratory nature of billfishes and tunas, the similarity of the fisheries for them in all parts of the world, and the great mobility of the fleets that harvest them, international cooperation in the collection and analysis of data is essential. A coordinated approach will achieve far greater effectiveness and efficiency, both economic and technical.

To narrow the focus for the moment: Peter Goadby asked about the migratory nature of tunas in Australian waters. There wasn't time then to respond to Peter's questions, but I would like to do so now.

Bluefin tunas are the most migratory of the

tunas, and southern bluefin tuna are the most migratory of all. They spend a great part of their lives in Australian waters, and support that country's most important tuna fishery. Southern bluefin spawn in a restricted area west of the Australian continent, and the young move into the inshore waters of southern Australia, where they are caught as 2-, 3-, and 4-year-olds. Older fish migrate far to the east and west, so their distribution is circumpolar, or nearly so.

The other tuna species do not migrate as extensively as the bluefin, but their movements are extensive enough to require international cooperation in their management. Skipjack tuna, for example, support a major fishery in the eastern Pacific but do not even spawn there; they migrate into the area from at least as far west as the central Pacific. A recent scientific paper claims that the skipjack in the western Pacific are not migratory; even so, they cross national boundaries regularly. Tagging data for the western Pacific indicate that on average 75 percent of all skipjack tagged inside an EEZ die as emigrants from that EEZ.

Yellowfin tuna may be among the least migratory of the major tuna species. Most of the tagged specimens that are recaptured are caught within several hundred miles of their points of release. Nevertheless, their travels would take them through the EEZs of several countries during their lifetimes.

Tagging information for billfishes is much scarcer, but there are nonetheless plenty of data that attest to their mobility. We have heard during the course of this symposium that some of the major species of billfishes are as migratory as the tunas.

In view of all this, it seems realistic to conclude that most of the major species of tunas and billfishes are highly migratory, and can be overfished in one sense or another, and that international cooperation is therefore necessary for their proper management. Article 64 of the Third United Nations Conference on the Law of the Sea, which deals with the management of tunas and billfishes, recognizes their highly migratory nature, and calls for nations to cooperate in the management of such species through international bodies.

It is one thing to recognize the need for international cooperation; implementing it is quite another matter. Past attempts to manage tunas and billfishes were well discussed, as well as the current management situation worldwide. Overall, the record is not too encouraging; of the many organizations set up, only two — the ICCAT and the IATTC — appear to be successful, and those not completely so. Both commissions have done a pretty good job of collecting and analyzing data on tunas, but their records on billfishes, particularly those of the IATTC, have been less impressive.

If past and present methods of managing tunas and billfishes have not worked as well as was hoped, then is there anything that we can do to improve the situation? I am convinced that the answer is emphatically "yes." Whatever we decide to do, a number of points must be kept in mind. First, we must have reliable information about the stocks we wish to manage. We must know about the distribution and abundance of these stocks, and about the effect of man's activities upon them. Second, a mechanism must be found for allocating the resources among user groups and nations. Any such mechanism has to recognize the rights and privileges of coastal states, as well as the historical involvement of distant-water fishing nations. It must also take into account the legitimate interests of special groups such as commercial and recreational fishermen. Third, the fish must be managed over their entire range. Tunas and billfishes recognize only Nature's boundaries, and man's artificial boundaries are meaningless in this context.

In my opinion, the best way to manage these highly-migratory species is through the establishment of a broad-based management body. As most of you know, I have written and lectured on the advantages of such an approach for nearly 15 years. I base my reasoning on three facts: the fish themselves are highly mobile, and cross jurisdictional boundaries as readily as you and I cross the street; the fishing fleets are even more mobile than their prey; and the market for tuna and billfish is truly international — what happens in the market in one part of the world has an almost instantaneous effect on markets elsewhere.

Such a broad-based body would be most efficient, effective, and economical if it were established on a global basis. The prospects of such a body being set up in the near future, however, do not appear very bright. The main reason for pessimism is that extended jurisdiction is a relatively new concept for coastal states, and there is a fear of derogating this jurisdication by relinquishing management of highly-migratory species to a body whose membership includes

distant-water fishing nations as well as coastal states from all over the world. I expect that these attitudes will change with time but, in the meantime, we need to improve our institutional arrangements by building on some of the existing organizations and creating some new ones.

In the Atlantic Ocean, the ICCAT has done an admirable job of collecting statistics on the billfish and tuna fisheries in that area. It has also provided a framework for scientists of the region to meet and work on the analyses of these important fisheries. However, the ICCAT's operating capital is insufficient for the task it is mandated to do. If it is to fulfill its objectives, the member governments must provide adequate financial support.

In the Pacific Ocean, the IATTC is currently doing a satisfactory job of collecting and analyzing data on the tuna stocks of the eastern Pacific. On the basis of these analyses, the Commission staff recommend conservation measures for the tuna stocks in this area each year. Since 1979, however, the member governments have not been in a position to implement these recommendations. The IATTC does some research on billfish, but not enough. Its mandate needs to be broadened to include greater responsibility for billfish research and management. This increased responsibility naturally implies a larger budget.

Our discussions made it clear that there is no one entity in either the western Pacific or Indian Ocean which has a clear mandate for the research and management of tunas and billfishes. The various organizations currently in existence overlap in some fields and leave gaps in others, and the institutional arrangements for tuna and billfish management in these areas need to be rethought. There is a strong need to create the type of body described in Article 64 in both of these ocean areas. These bodies must have clearly assigned research and management responsibilities, and must be given the financial and political means to fulfill their objectives.

Once such entities are established or expanded, combining them into a single entity should not be too difficult. In the Pacific Ocean the transition should be fairly smooth for the scientific programs of the various institutions. Since many of the boats from which data are collected travel back and forth across the Pacific, passing from waters administered by one organization to those of another, and because the biological and analytical problems are so similar in all areas, the various organizations will naturally tend to cooperate. Getting together on scientific issues would be perceived by the coastal states as much less of a threat to their sovereignty than would be getting together on management issues.

To sum up, tunas and billfishes are of great importance to many sectors of society. Man's exploitation of these resources is increasing at an alarming rate, and it has been demonstrated both that they can be overexploited and that this may already have happened to some stocks. These developments are outpacing the existing institutional arrangements, and governments have lagged behind in the creation of new scientific and management organizations. The challenge is clear: international institutions need to be set up to ensure that these valuable resources are utilized wisely. Is there anything this symposium can or should do to further the creation of such institutions?

We have been taking stock of our present understanding of the biological and environmental processes that control the populations of tunas and billfishes. We have identified many gaps in our knowledge. We have also examined management arrangements for these species, and have identified many gaps in these as well. All of the information presented at this symposium will be combined in book form; this will be the legacy of this meeting, but it will not resolve the problem of husbanding these valuable resources. The symposium organizers have a responsibility, indeed a duty, to take the next step, which is to establish a forum in which a framework for institutional arrangements for the management of tunas and billfishes can be developed. The first step should be the setting up of a working group of knowledgeable and interested individuals who can meet as often as necessary to outline a broader forum, such as a technical conference or series of workshops, that can develop viable alternatives for the management of tunas and billfishes in the Pacific Ocean.

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Retrospection

A Symposium Overview

Kenneth Hinman

The compelling need for greater global cooperation to conserve wide-ranging species of marlins and swordfish, in the face of equally widespread uncertainty as to the health of these resources, was the overriding theme of this recently concluded International Billfish Symposium. Organized by the National Coalition for Marine Conservation, the symposium was co-sponsored by a dozen fisheries organizations from the United States, Mexico, and Japan, and held August 1-5, 1988, at Kailua-Kona, Hawaii. More research into the biology, behavior, and distribution of billfishes (marlins, sailfish, swordfish, and spearfishes), the establishment of a global network for gathering data to assess the condition of the stocks, and higher priority for billfish concerns within regional and ocean-wide management regimes, were among the recommendations highlighting the symposium.

This historic gathering of the world's foremost billfish authorities attracted 150 scientists, managers, conservationists, and fishermen from 12 countries having established or developing interests in billfishes. A total of 60 papers were delivered and discussed during the week-long conference, covering such topics as trends in the recreational and commercial fisheries, the current status of billfish populations, research needs and priorities, and management strategies. In addition, the very latest studies in growth, reproduction, stock identification, and stock movements, by scientists from every corner of the globe, were presented, as were papers on the socio-economic value of billfishing.

The status of billfishes in 1988, according to a consensus of speakers at the symposium, can be summed up this way: Fishing pressure is mounting on the world's already heavily-exploited stocks of swordfish and marlins. If present trends continue, and the fisheries remain unregulated, fishermen can expect serious declines in catches in the near future. Severely aggravating the situation is the fact that data on billfish catches in the Atlantic, Pacific, and Indian oceans are poor and generally unreliable — as speaker after speaker attested.

Efforts to manage the billfish harvest lag far behind the need to do so, or are non-existent. This is due largely to the interrelationship between the commercial tuna longline fisheries and the incidental longline catches of billfishes, and the nearly complete subordination of billfish concerns to the interests of tuna fishermen in setting management objectives for these highly migratory species.

Research

The amount and focus of research necessary to conserve billfishes was the subject of considerable discussion. A number of presentations revealed information which was not available at the time of the previous billfish symposium, in 1972, but progress in most study areas over the last 16 years has proven woefully inadequate to meet present-day needs. There was a general demand for increased levels of research across the board but, conceding limits on funding and manpower, the emphasis was placed on obtaining the information most needed to support stock assessments and to evaluate the impact and effectiveness of management measures. Stock identification, age and growth studies, mortality rates, catch rates, and length frequency data were cited as critically important information needs.

The present inadequate state of research was

blamed on, among other things, the small number of scientists engaged in full-time billfish work (many who are assigned to pelagic fisheries spend the majority of their time on tunas) which, in many countries, merely reflects the low priority and minimal funding still accorded the recreational fisheries. Private fisheries organizations must demonstrate stronger public support for billfish programs in order to promote the necessary research. Also, the recent trend among recreational fishermen toward releasing marlins and sailfish, which greatly assists tagging studies aimed at getting information on stock identification and distribution, should be encouraged and expanded in all areas of high angling activity. Finally, the scientists agreed that a follow-up conference should be convened within a year or two, to maintain the momentum of support for enhanced research generated at this year's meeting, and that regular symposia with international representation should be planned.

Data Collection

The fisheries for billfishes involve many nations and occur throughout the far-reaching oceanic ranges of these fish. More comprehensive data on the true extent of the commercial and recreational catches and effort around the world are absolutely vital to monitoring the status of the stocks. The creation of an international data bank was proposed, using existing international fisheries organizations, with unanimous support. The information collected should be widely disseminated among all nations involved in billfish management.

In this regard, the new ICCAT initiative to monitor billfish catches in the Atlantic Ocean was singled out for praise, and there was support for expanding that effort, as well as for initiating a similar effort in the Pacific Ocean. An information meeting of representatives of Pacific-Rim nations was suggested to discuss establishment of a coordinated data collection program. As for making the best of today's insufficient fisheries data sets, speakers recommended working to simplify the population models used in stock assessment work and adapting them to fit the type and quantity of numbers available for analysis.

Management

There was a clear difference of opinion between advocates of national efforts to manage billfishes and those supporting management only by international agreement, but it was evident that the two positions are not as far apart as one might think. The efforts of individual nations to conserve highly migratory species in their own 200-mile exclusive economic zones (EEZs) is an accepted reality (e.g., the U.S. Atlantic billfish plan and recent actions by Mexico and Australia), while international efforts are widely viewed as a vital component of conservation which will complement unilateral action.

Nations belonging to international fisheries conservation organizations were urged to offer more political, scientific, and financial support to billfish conservation programs within those organizations, and to explore ways of using them to control billfish harvests on the high seas, beyond national jurisdictions. At the same time, obstacles to national management of billfishes and other highly migratory species should be removed — in the U.S., for example, by amending the Magnuson Fisheries Conservation and Management Act to include regulation of tuna fishing within the EEZ. Regional fisheries agreements, in areas such as the Caribbean Sea and the Indian Ocean, should be considered in order to bring smaller, developing fishing nations into the conservation process and to give special protection to so-called fishing "hot spots."

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