

ECOLOGICAL REFERENCE POINTS FOR FORAGE SPECIES¹



The biological benchmarks, or reference points, used by fishery managers to judge the relative health of a fish population are, in the simplest terms, targets that we aim for and thresholds we aim to avoid. The conventional reference points applied to most single-species assessments, however, do not allow us to gauge the population's capacity to provide adequate prey for other species in the ecosystem. That's why, for forage species, we need "ecological reference points," the development of which is a key element of the Mid-Atlantic Fishery Management Council's Guidance Document to support Ecosystem Approaches to Fisheries Management.

It is essential to begin with the understanding that a) ecological reference points will be grounded in policy, balancing social, economic and ecological goals; and b) the process of developing and applying reference points to meet broader, ecosystem-based management goals is not so different from the process used to establish standard biological benchmarks.

The lack of clearly defined management objectives is a major impediment to establishing reference points of any kindⁱ. Typically, there are two kinds of reference points, conceptual and technical, in that order.ⁱⁱ *Conceptual* reference points first define the management goals, such as maximizing yields to fisheries (MSY) or incorporating other societal values into an optimum yield (OY). Then *technical* reference points are developed for achieving these goals, e.g., F_{MSY} or $\%F_{MSY}$.

In the conceptual stage, ecological reference points, in the case of important forage species, must articulate a goal of providing a forage set-aside for other species in the ecosystem, in order that technical reference points may be developed to achieve this ecologically sustainable yield (ESY)ⁱⁱⁱ.

Ecological target and threshold (or limit) reference points can make use of the traditional benchmarks, such as some measure of population size (abundance-based) and fishing mortality rate (mortality-based), applied to a single-species stock assessment for the forage species in question. That's because the goal of leaving a specified portion of the prey population in the water to serve predator needs can be defined in the same currency as leaving a reserve (e.g., $\%B_{MSY}$) to guard against stock depletion.

¹ Portions of this briefing paper are excerpted from **RESOURCE SHARING: The Berkeley Criterion**, by Ken Hinman, President, Wild Oceans. 2014.

So, how is this forage set-aside determined?

At this point, it's worth noting that innovative ecosystem models are being developed with the aim of quantifying the functional relationships between predators and prey.^{iv} Such models may eventually help fishery managers better understand the trade-offs among concurrent management strategies for multiple species. However, the most complex and precise ecosystem model will not, in and of itself, reveal what amount of fishing for a key forage species should be allowed or what amount to leave in the water. That is ultimately an allocation of prey between human and natural predators, a policy decision based on agreed-upon ecosystem goals.

As noted, these goals (conceptual reference points) are essential to establishing target and threshold reference points for assessing the ecological status of a forage species. But fishery managers, accustomed to looking to their stock assessment scientists to provide model-based reference points for already-established MSY-based management goals, sometimes seem at a loss as to where to begin.

Fortunately, considerable effort has been devoted over the past two decades to finding a practicable approach to establishing ecological reference points for forage species. In fact, a remarkable consensus has emerged in the scientific literature around just what those targets and limits should be, based on the ecological importance of forage species, the impacts of fishing on predator-prey relationships, and the precautionary principle. In this paper, we review what is becoming an accepted standard for conserving and managing forage species.

Managing for Higher Abundance

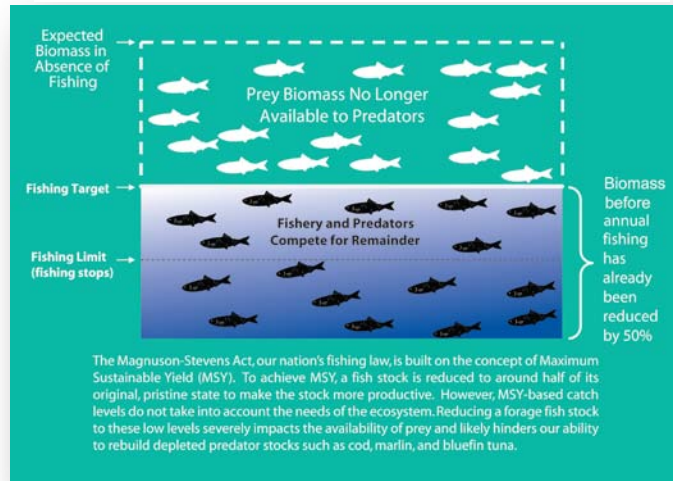
For forage species, population size – or standing biomass - constitutes the principal measure of the amount of prey available to meet the needs of dependent predators. Although other factors such as age structure of the population and geographic distribution are important to determining adequate availability of prey, this is a reasonable place to begin.

Reference points that would be responsive to the role of a species as forage would be ones which maximize population abundance, taking into regard the allocation of fish between natural mortality and fishing mortality.^v First consideration, then, should be given to how targets and limits for population abundance and fishing mortality might be established in a manner that specifies an allocation of the species as prey.^{vi}

The National Marine Fisheries Service (NMFS) in 2009 revised its federal guidelines for implementing annual catch limits consistent with the Magnuson-Stevens Fishery Conservation and Management Act's National Standard 1 (NS1). NS 1 states that "Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery..." The optimum yield is the

amount of catch that provides the greatest long-term benefit to society. It was conceived as a modifier to MSY, requiring fishery managers to consider a range of factors in setting management goals, including the effects of fishing on marine ecosystems.^{vii} But NMFS had never provided guidance and direction as to how fishery managers should take into account the protection of marine ecosystems when they set catch limits, or how MSY should be reduced by ecological factors, or even what those factors are. The predictable result - ecological factors have rarely if ever been taken into account.

PREY DEPLETION ASSOCIATED WITH MSY



Under the revised NS1 Guidelines, NMFS now

recommends setting a population target for forage species higher than the level associated with MSY "in order

to maintain adequate forage for all components of the ecosystem".^{viii} The stock size at MSY (B_{MSY}) is on average approximately 40% of the un-fished stock size, according to NMFS (citing scientific literature showing the range between 36.8% and 50% of a pristine population.)^{ix} Indeed, taking a more precautionary approach with regard to forage species abundance is well established in the scientific literature.^x NMFS does not recommend how much above B_{MSY} forage species abundance should be, but a number of other science and management institutions do.

An Emerging Consensus

The Convention on the Conservation of Antarctic Marine Living Resources

(CCAMLR) is generally credited as the first regional body to apply an ecosystems approach to fisheries management. Recognizing the key role of krill (*Euphausia superba*) as forage in the ecosystem, CCAMLR in 1991 adopted more conservative reference points than commonly used in traditional fisheries management.^{xi} The requirements of krill predators (whales, fish, seals, penguins, et al) were incorporated by establishing a level of krill escapement of 75% of the pre-exploitation (un-fished) biomass, instead of the 40-50% level normally used in single-species management.^{xii}

The Antarctic Krill policy, sometimes called the 'predator criterion', is consistent with the fact that low trophic level forage species, or prey species with high predation rates, are less resilient to intensive fishing mortality than higher trophic levels and thus merit more precaution. It establishes the optimum population level for krill as somewhere

between the MSY biomass and carrying capacity, acknowledging that choosing a point within this range is a subjective decision (as we've discussed). The choice of a target population level of 75% of the un-fished population is essentially splitting the difference between a population at or near MSY, which fails to take predator needs into account, and maintaining the population at carrying capacity, which gives complete protection for predators but allows for no fishing.^{xiii}

The **United Nations Food & Agriculture Organization, in its Technical Guidelines for Responsible Fisheries** published in 2003, suggests "maintaining selected prey populations above 75% of the un-fished biomass to allow for predator feeding."^{xiv} In fact, the "75% solution" is becoming the accepted standard for setting best practices for managing forage fish, a default target population level for forage species in the absence of detailed and explicit ecosystem analysis that identifies a more specific level.^{xv}

In 2011, the **Marine Stewardship Council**, which develops international standards for sustainable fishing, convened a Low Trophic Level Task Force to develop guidelines for assessing the sustainability of forage fisheries in order to award the MSC label. Its recommendations were released in 2011.^{xvi} The new guidelines apply to key low trophic level species, such as menhaden, herrings and sardines (family *Clupeidae*), anchovies (family *Engraulidae*), krill (family *Euphausiidae*) and other small pelagic species that form dense schools, feed mostly on planktons, and transmit a large volume of energy to higher trophic levels by serving as prey.

The "75% solution" is emerging as the consensus standard within the international scientific community.

The MSC suggests that the default recommended target reference point for these forage species is 75% of an un-fished population. After reviewing research the council funded to determine the amount of precaution necessary for forage species,^{xvii} MSC concluded that "(s)etting a target of 75% of un-fished biomass for LTL [low trophic level] species (25% depletion) reduces the impact on other species within the ecosystem by more than half while maintaining yields above 80% of the level that would be achieved with a target of 40% of un-fished biomass. Such a target is usually achieved at fishing mortality rates less than half those needed to achieve MSY."

Weighing in with its own study and report in 2012, the **Lenfest Forage Fish Task Force**, 13 ecologists representing 5 countries, suggests a "precautionary biomass target" for forage fish of $1.5 B_{MSY}$ (the biomass associated with achieving MSY), which happens to correspond to 75% of unexploited biomass.^{xviii} Clearly, a consensus is emerging within the scientific and policy-making communities.

Preventing Ecosystem Overfishing

The corollary to maintaining a higher target population for key forage species is setting a higher “overfished” threshold. The standard single-species definition of an overfished stock – the point at which fishing is curtailed and rebuilding begins – is approximately $\frac{1}{2} B_{MSY}$, a population level that may still be capable of rebuilding, but which is about $\frac{1}{4}$ or less of an un-fished population. It is clearly risk-prone to permit a forage population to be reduced to this level without significantly diminishing the ecosystem’s capacity to support healthy and abundant populations of predator species.^{xix}

Using food web models, the Lenfest Task Force^{xx} compared conventional MSY strategies - used to prevent overfishing of most forage fisheries within the United States - to more precautionary approaches and found that “the only fishing strategies that reliably prevented a decline in dependent predators were those that limited fishing to half the conventional rate.” Ecological sustainability is further improved by doubling the minimum biomass that is left in the ocean, from the conventional minimum to 40% of the un-fished biomass; that is, making B_{MSY} the limit reference point.

The information available to fishery managers is an important consideration in determining the magnitude of precaution to apply. Halving fishing rates and doubling minimum biomass from conventional levels may be sufficient when managers know enough about forage fish interactions with predators and the environment to assess the impacts of fishing. However, in data-poor situations, the Lenfest Task Force recommends maintaining a biomass floor of at least 80% of an un-fished level for existing fisheries, while prohibiting new forage fisheries from developing until information improves.

To summarize, then, target populations should be set no lower than 75% of un-fished biomass, while the overfished threshold should be set substantially higher than traditional levels, certainly no lower than the biomass level associated with MSY.

Allocating Mortality

The **NOAA Chesapeake Bay Office**, in *Fisheries Ecosystem Planning for Chesapeake Bay*, recommends that fishery managers “(c)onsider explicitly strong linkages between predators and prey in allocating fishery resources. Be precautionary by determining the needs of predators before allocating forage species to fisheries.”^{xxi} Allocating forage fish to serve ecosystem needs *first* suggests controlling total mortality by specifically allocating it between predators and fishing.

For instance, Collie and Gislason, in examining the use of single-species reference points in a multi-species or ecosystem context, conclude that such reference points are inappropriate for forage species which have natural mortality rates that fluctuate substantially. They suggest a more appropriate alternative for forage fish is to manage

for total mortality by decreasing fishing mortality when natural mortality increases.^{xxii}
Or, Z (total mortality) – M (natural mortality) = F (fishing mortality).

One type of mortality-based reference point already in use to approximate fishing at the MSY level for data poor stocks, or when there is a high degree of uncertainty about stock status, is $F=M$ or where F is a fraction of M , e.g., $F=0.75M$.^{xxiii} It is commonly assumed that when harvesting at MSY, F is roughly equal to M , so this is an F_{MSY} proxy. If the goal is to maintain a higher biomass, as in the case of forage species, then the allowable fishing mortality rate would be set no higher and preferably lower than M .^{xxiv} The **North Pacific Fishery Management Council**, which uses a tiered system for setting buffers between overfishing limits and target catch levels based on stock life history and uncertainties in the assessment, establishes an overfishing level (MSY) for walleye pollock (*Theragra chalcogramma*), an important forage fish in Alaskan waters, that is equal to M and a target F that is set at $0.75M$.^{xxv}

Managing for Availability

Ecological management of forage fish may also account for the fact that setting a more conservative target population goal does not fully protect the species' role in the ecosystem. Fishing a prey population also affects the size (age) of prey available and distribution throughout their natural range.^{xxvi} Indeed, the two are often linked, since different age classes exhibit different patterns of movement. Because spatial and temporal availability of prey of the right size is important to predators finding an adequate supply of food where and when they need it, precautionary catch limits alone cannot prevent localized effects on the ecosystem.^{xxvii}

The **Policy on Fisheries for Forage Species of Canada's Department of Fisheries and Oceans** states: "Management plans for commercial fisheries on forage species should include explicit provisions to ensure that fisheries do not unduly concentrate harvest and do not produce local depletions of the forage species...Forage species should be managed in ways which ensure local depletion of population components does not occur. Local depletion of the forage species could result in food shortage for the dependent predators, even if the overall harvest of the forage species was sustainable."^{xxviii}

To avoid localized shortages and maintain prey availability, management strategies for forage fish may establish, in addition to biomass and mortality targets and thresholds: 1) The desirable population age structure, i.e., an age distribution reflecting that of a natural, pre-exploitation population; and, 2) Population density, i.e., prey availability distributed in time and space approximating the un-fished range to avoid local or regional depletions.^{xxix}

Summary

The first principle of conserving forage species should be to adequately meet the needs of the ecosystem, that is, natural predators, before determining the allocation of fish to fishing. Fish populations do have limits and thresholds that cannot be exceeded without causing harm at the ecosystem or community level.^{xxx} For important prey or forage species, the scientific and fishery management communities are arriving at a consensus as to what these limits should be, and equally important, on what the target population should be for forage species.

The scientific literature and emerging standards in fishery policy suggest the populations of forage species should be maintained at a level approximating 75% of the un-fished population and that fishing mortality should never exceed but should preferably be significantly lower than natural mortality.

Reference Point ²	Target	Limit
Biomass (population size)	B_{MAX75%}	B_{MSY}
Mortality	F_{=.75M}	F=M

In the end, raising our standards for conserving important forage species means changing our management goal from maximizing yields to fisheries to sharing the resource, in a way that recognizes the vital ecological role of these species as prey while still providing for reasonable fishing opportunities. The concept of resource sharing is based on the best available science, it is ecologically sustainable, and it is fair to all marine predators, including humans.



*This briefing paper was prepared by **Wild Oceans**, an independent non-profit group of anglers dedicated to protecting the ocean's top predators – the billfish, tunas, swordfish, and sharks – while preserving healthy ocean food webs and critical habitats essential to the survival of all fish, marine mammals, sea turtles and seabirds. For more information visit WildOceans.org or call (703) 777-0037.*

² B is the stock biomass, B_{MAX} is the biomass in the absence of fishing, B_{MAX75%} is 75 percent of the un-fished biomass, and B_{MSY} is the biomass associated with producing the maximum sustainable yield.

Endnotes

- ⁱ Smith, S.J., Hunt, J.J., and Rivard, D. (Editors). 1993. *Risk evaluation and biological reference points for fisheries management*. Can. Spec. Publ. Fish. Aquat. Sci. No. 120.
- ⁱⁱ Caddy, J.R. and R. Mahon. 1995. *Reference points for fisheries management*. FAO Fisheries Technical Paper 347. Food and Agriculture Organization of the United Nations. Rome 1995 .
- ⁱⁱⁱ Zabel, R. et al. 2003. *Ecologically Sustainable Yield*. American Scientist. Vol. 91: 150-57.
- ^{iv} Examples of fishery ecosystem models include Ecopath with Ecosim (EwE), Atlantis and Gadget.
- ^v ASMFC 1999. *Terms of Reference & Advisory Report for the Atlantic Menhaden Stock Assessment Peer Review*. Stock Assessment Report No. 99-01. p. 5.
- ^{vi} ASMFC 2004. *Terms of Reference & Advisory Report to Atlantic Menhaden Stock Assessment Peer Review*. Stock Assessment Report No. 04-01. p. 4-5. See also Review of the Fishery Management Plan and State Compliance for the 2008 Atlantic Menhaden Fishery. Atlantic Menhaden Plan Review Team. ASMFC. May 2009.
- ^{vii} The OY is defined as “(t)he amount of fish which (A) will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities, and taking into account the protection of marine ecosystems; (B) is prescribed as such on the basis of the maximum sustainable yield from each fishery, as reduced by any relevant economic, social, or ecological factor.”
- ^{viii} NMFS. *National Standard 1 Guidelines*. 2009. 50 CFR Part 600.310(e)(3)(iv)(C).
- ^{ix} National Marine Fisheries Service (NMFS). 1998. National Standard 1 Guidelines: 63 FR 24216.
- ^x Collie, J.S. and H. Gislason. 2001. *Biological reference points for fish stocks in a multispecies context*. Canadian Journal of Fisheries and Aquatic Sciences. 58: 2167-2176.
- ^{xi} Gascon, V. and Werner, R. *CCAMLR and Antarctic Krill: Ecosystem Management Around the Great White Continent*. Sustainable Development Law & Policy. Fall 2006. p. 14-16.
- ^{xii} Gascon, V. and Werner, R. *Antarctic Krill: a case study on the ecosystem implications of fishing*. Antarctic and Southern Ocean Coalition. Puerto Madryn (Argentina), October 2005.
- ^{xiii} Constable, A.J., de la Mare, W.K., Agnew, D.J., Everson, I., and Miller, D. 2000. *Managing fisheries to conserve the Antarctic marine ecosystem: practical implementation of the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR)*. ICES Journal of Marine Science, 57: 778-791.
- ^{xiv} FAO. 2003. *The ecosystem approach to fisheries*. FAO Technical Guidelines for Responsible Fisheries. Food and Agriculture Organization of the United Nations. Rome 2003.
- ^{xv} Marine Stewardship Council. 2011. Technical Advisory Board D-036: Assessment of Low Trophic Level (LTL) Fisheries. 15 August 2011.
- ^{xvi} MSC. 2011.
- ^{xvii} Smith et al. 2011.
- ^{xviii} Pikitch et al. 2012. p. 23.
- ^{xix} T. Ragen. 2001. *Maximum sustainable yield and the protection of marine ecosystems: a fisheries controversy in Alaska*. Author’s unpublished manuscript. The author is Executive Director of the U.S. Marine Mammal Commission.
- ^{xx} Pikitch et al. 2012
- ^{xxi} *Fisheries Ecosystem Planning for Chesapeake Bay*. 2006. NOAA Chesapeake Bay Office. American Fisheries Society. Trends in Fisheries Science and Management 3.
- ^{xxii} Collie, J.S. and H. Gislason. 2001.
- ^{xxiii} Field. 2002.
- ^{xxiv} Houde, E.D. University of Maryland Center for Environmental Science. *Developing, Adopting, and Implementing EBFM in Chesapeake Bay*. A presentation to the Conference on Ecosystem Based Management: The Chesapeake and Other Systems. Baltimore, MD. March 23, 2009.
- ^{xxv} Fishery Management Plan for Groundfish of the Bering Sea and Aleutian Islands Management Area. North Pacific Fishery Management Council. April 2009. p. 15.
- ^{xxvi} Ragen. 2001.

^{xxvii} Constable et al. 2000.

^{xxviii} DFO, Canada. Policy on New Fisheries for Forage Species.

^{xxix} Hobday et al (2004) provide a limit reference point of reduction of geographical range by more than 25% of the unfished range. In Sainsbury, Keith. Best Practic Reference Points for Australian Fisheries. Australian Fisheries Management Authority. December 2008.

^{xxx} EPAP. 1999. p.15.