Ecological Reference Points for Atlantic Menhaden

Ken Hinman
National Coalition for Marine Conservation
June 2009

Among the ASMFC's tasks this year for conserving and managing Atlantic menhaden, according to the commission's 2009 Action Plan, is to "explore the development of ecological reference points."[1] To this end, the Policy Board in February tasked the Management and Science Committee (MSC) with providing advice to the Menhaden Management Board on developing new reference points; targets and limits designed to protect menhaden's vital role in the ecosystem, in accordance with the objectives of the Interstate Fishery Management Plan[2], with particular emphasis on providing adequate forage for predatory fish, marine mammals and seabirds.

The Menhaden Management Board initiated an addendum to the Atlantic Menhaden FMP in 2005 to conserve menhaden with a temporary cap on reduction harvest in Chesapeake Bay (through 2010), while addressing concerns about localized depletion in the Bay and the possibility of compromised predator-prey interactions, in particular reduced availability of forage for resident and migratory striped bass. A research program recommended by the Menhaden Technical Committee is underway to try and determine if reduced abundance of menhaden is related to observed predator deficiencies (e.g., low weight-to-length ratios and stress-related disease in striped bass) and low larval menhaden recruitment.[3]

A new benchmark stock assessment for menhaden will be conducted in 2009 and peer reviewed in 2010. This assessment, unfortunately, will employ the coast wide model used in the last assessment and biological reference points developed for stock replacement, not to preserve ecological function. [4]

---

[1] ASMFC 2009 Action Plan. p. 5
[2] ASMFC 2001. Amendment 1 to the Interstate Fishery Management Plan for Atlantic Menhaden. Fishery Management Report No. 37.
[3] ASMFC 2005. Addendum II to Amendment 1 to the Interstate Fishery Management Plan for Atlantic Menhaden. pp. 6-7
[4] The Menhaden Management Board in February asked the Stock Assessment Subcommittee to consider an alternative assessment model developed by L.B. Christensen and S.J.D. Martell of the University of British Columbia. Atlantic Menhaden Stock Status Report: New Advice (unpublished manuscript). Although this model also assumes a coast wide stock and uses existing reference points, it suggests that "the Atlantic menhaden stock is currently overfished, and that overfishing is occurring."

Current Reference Points are Insufficient For Ecosystem-Based Management

As the Peer Review Panel pointed out in its review of the last benchmark stock assessment for menhaden, the ASMFC's coast wide, single-species assessment model and the reference points established for assessing the status of the stock cannot measure the stock's capacity to provide adequate forage for other species in the ecosystem, nor can it "detect localized depletion and reduced ecological function that could occur when the fishery is concentrated in one part of the coast," such as in and near Chesapeake Bay.[5]

The biological reference points currently in use are two: a fishing mortality (F) target and threshold; and a population fecundity (number of eggs) target and threshold.[6] These reference points are intended to assure that the stock is capable of sufficient reproduction to replenish itself and that the stock is maintained at a size capable of supporting a viable fishery. As targets and thresholds linking the status of the stock to management goals and actions, they do not account for nor can they prevent the possibility that a fishery, especially one exploiting a key forage species like menhaden, could be overfished in an ecosystem context even if it is not overfished in a single-species context.[7]

Developing ecological reference points for menhaden is similar to the process used to establish the current reference points, in that both are targets and thresholds set to achieve specified management goals. Once again, the current limits are set to determine whether overfishing is occurring or the stock is overfished on a coast wide, single-species basis; that is, to ensure the rate of fishery removals does not exceed the ability of the stock to replenish itself. Ecological reference points, on the other hand, also use traditional benchmarks, such as stock biomass and mortality rate, but are set with ecosystem-based management goals in mind.

As the Peer Review Panel noted, ecological reference points require management goals that specify an allocation of menhaden as forage.[8] As an example, the Panel suggests that a reference point that would be "responsive to menhaden as a forage species would be one which maximizes population abundance taking into regard the allocation of fish between F (fishing mortality) and M (natural mortality)".[9]

---

[5] ASMFC 2004a. Terms of Reference & Advisory Report to Atlantic Menhaden Stock Assessment Peer Review. Stock Assessment Report No. 04-01. p. 4-5. *See also* 2009 Review of the Fishery Management Plan and State Compliance for the 2008 Atlantic Menhaden Fishery. Atlantic Menhaden Plan Review Team. ASMFC. May 2009.
[6] ASMFC 2004b. Addendum 1 to Amendment 1 to the Interstate Fishery Management Plan for Atlantic Menhaden.
[7] Pikitch, E.K. et al. 2004. Ecosystem-Based Fishery Management. *Science*. 305: 346-7.
[8] ASMFC 2004a. p. 5.
[9] ASMFC 1999. Terms of Reference & Advisory Report for the Atlantic Menhaden Stock Assessment Peer Review. Stock Assessment Report No. 99-01. p. 5.

First consideration, then, should be given to how targets and thresholds for menhaden population abundance and total mortality (the relationship of F to M) might be established in an ecosystem-based context. We offer the following recommendations, based on a review of the scientific literature and approaches recommended and/or implemented in fisheries for other key forage species.

Managing for Greater Abundance

The standard population, or biomass, associated with maximizing yields to fisheries is B_{MSY}. The ASMFC in 2004 opted to replace the use of a proxy for an MSY-based spawning stock biomass (SSB) with a fecundity target and threshold.[10] Aside from whether SSB or fecundity is a more accurate indicator of stock reproductivity, standing biomass - or population size - does constitute a better measure of the amount of prey available to meet the needs of dependent predators.

The National Marine Fisheries Service (NMFS) issued new Guidelines effective February 17, 2009 for implementing annual catch limits consistent with the Magnuson-Stevens Act's National Standard 1. In these Guidelines, NMFS recommends setting a population target for forage species higher than the B_{MSY} level in order to maintain adequate forage for all components of the ecosystem.[11] This more precautionary approach for forage species abundance is well established in the scientific literature.[12] How much higher than the B_{MSY} level depends on a number of factors, among them the uncertain effects of climate variability and change on fluctuations in prey populations, the uncertain effects of reduced biomass on prey distribution and availability to predators throughout the range of the prey species, and uncertainties in data and scientific advice.

Recent research on forage fish such as Atlantic herring and mackerel suggests that fully accounting for predation *demand*[13] in stock assessments and associated reference points – including expected increases in demand from predatory fish and seabirds that are the object of recovery efforts - can dramatically increase estimates of the population size needed to sustain both predators and fisheries, while lowering the yields available to the fishery.[14]

---

[10] ASMFC 2004b.

[11] 50 CFR Part 600.310(e)(3)(iv)(C).

[12] 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.

[13] Prey *demand* is the prey required to meet dynamic predator population *needs*, as opposed to merely estimating present predator consumption.

[14] W.J. Overholtz, L.D. Jacobson, and J.S. Link. An ecosystem approach for assessment advice and biological reference points for the Gulf of Maine – Georges Bank herring complex. North American Journal of Fisheries Management, 28. 2008. *and* H. Moustahfid, J.S. Link, W.J. Overholtz, and M.C. Tyrrell. The advantage of explicitly incorporating predation mortality into age-structured stock assessment models: an application for Atlantic mackerel. ICES Journal of Marine Science, January 16, 2009.

While ecosystem models under development attempt to quantify the relationship between predator and prey with the goal of enabling fishery managers to understand the precise trade-offs among various management strategies for each, their application is likely years away. Until we are able to develop assessment models to determine what some scientists call the ecologically sustainable yield[15] for forage fish such as menhaden, precautionary interim management strategies are warranted.[16]

To cite an example of an interim strategy already in practice, the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR), recognizing the key role of krill in the ecosystem, adopted more conservative reference points than the ones commonly applied in single-species fisheries management.[17] "(T)he requirements of krill predators were incorporated by establishing a level of krill escapement of 75% of the pre-exploitation biomass, instead of the 40-50% level normally used in single-species management. This has been called the 'predator criterion' and it reflects an arbitrary level that needs to be revised to take into account information on the functional relationship between abundance of prey and recruitment in predator populations as it becomes available."[18]

The corollary to maintaining a higher target population for key forage species is setting a higher overfished *threshold*. With each increment of reduction in the target prey population level, the predator population is left with less available food and its population must shrink in size in order to come into equilibrium with the amount of prey available. [19] The standard single-species definition of an overfished stock – the point at which fishing ceases and

---

[15] Zabel et al. Ecologically Sustainable Yield, American Scientist, March-April 2003. The authors, from the Northwest Fisheries Science Center of NMFS, recommend moving away from traditional single-species approaches to management to what they call ecologically sustainable yield (ESY), because "the cost of mismanaging a community might be far greater than the cost of mismanaging a fishery. Although overfished stocks have been known to recover, revival of communities that have changed states can be excruciatingly slow or even impossible."
[16] Department of Fisheries and Oceans, Canada. Policy on Fisheries for Forage Species. http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/reports-rapports/amac-ccmb/annex4-annexe4-eng.htm. Biological Pre-requisites for Commercial Fisheries on Forage Species: "It should be possible to estimate the risk that the proposed level of harvest poses to the forage species and ecologically dependent species. In situations where risk presented by a particular level of harvest and consequences of over-harvesting are especially uncertain, exceptionally risk-averse decisions are necessary."
[17] 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.
[18] 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.
[19] Rounsefell, G.A. Ecology, utilization, and management of marine fisheries. C.V. Mosby Co. 1975.

rebuilding begins – is approximately ½ B_{MSY} - a population level that may still be capable of rebuilding - but which is about ¼ or less of an un-fished population.[20]

In an ecosystems context, it is clearly risk-prone to assume that the biomass of a target forage species can be reduced to below half its pre-exploitation state without causing reduction in the ecosystem's capacity to support healthy and abundant populations of predator species.[21] Therefore, an overfished threshold should also be set substantially higher than in the traditional single-species approach, and probably no lower than B_{MSY}.

Avoiding Localized Depletion

Ecological reference points may also account for the fact that setting a more conservative target population goal does not fully account for and protect a prey fish's role in the ecosystem. Fishing a prey population down to a fraction of its un-fished level in order to increase fishery yields causes not simply a reduction in the number of prey (total population), but also a change in the type of prey available (size/age) and distribution throughout their natural range.[22] Each of these factors is important to predators finding an adequate supply of food where and when they need it.

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."[23]

To avoid localized depletion and maintain prey availability, ecological reference points for Atlantic menhaden should establish, in addition to population biomass targets and thresholds:

- Target population age structure, i.e., an age distribution reflecting that of a natural, pre-exploitation population; and,

- Target population density, i.e., prey availability distributed in time and space to avoid local or regional depletions. Time-area limits (caps) can be

[20] The National Marine Fisheries Service (NMFS) estimates the stock size at MSY at approximately 40% (range 36.8% to 50%) of the un-fished or pre-exploitation stock size. NMFS National Standard 1 Guidelines (1998): 63 FR 24216.
[21] 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.
[22] Ragen. 2001.
[23] DFO, Canada. Policy on Fisheries for Forage Species.

used to distribute catches geographically.

Allocating Prey to Predators

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.[24]

In an un-fished population at a natural equilibrium, total mortality (Z) for a species equals natural mortality, which for a forage fish like menhaden is primarily predation. In a population that is at a fishing-induced equilibrium, the amount of predation is reduced to accommodate desired fishery yields. As a result, estimates of natural mortality (M) used in single-species assessments are influenced by the fishing mortality rate (F). The M that is "determined" is therefore an *a priori* allocation to predators, rather than a determination of actual predator needs.

Some management bodies have recommended that an ecosystem-based approach to managing forage fish would be to allocate prey to predators first, before allocating to the fisheries. The NOAA Chesapeake Bay Office's FEP, *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."[25]

Following on Collie and Gislason, doing this would entail estimating an amount of prey fish to set aside to supply predators at desired levels, then determining the sustainable fishing mortality rate; or, Z – M = F. The predation mortality used in the menhaden stock assessment (M_2, a subset of M), which is estimated from the Multispecies VPA, is thought to produce a more accurate fishing mortality rate for the purpose of staying within current biological reference points. But as the ASMFC has pointed out, the MSVPA cannot provide information about the size and composition of striped bass and other predator populations a given menhaden population can support.[26]

---

[24] Collie, J.S. and H. Gislason. 2001.

[25] Fisheries Ecosystem Planning for Chesapeake Bay, NOAA Chesapeake Bay Office, 2006. pp. 320-1.

[26] Brad Spear, Senior Fishery Management Plan Coordinator for Policy, ASMFC. Coast-wide Stock Assessment of Atlantic Menhaden. Proceedings of the Menhaden Science and Policy Symposium. Narragansett, RI. November 30, 2007. p. 14. The MSVPA includes only three predators - striped bass, bluefish and weakfish – on a prey species known to be preyed on numerous fish, marine mammals and seabirds.

The natural mortality rate used in the stock assessment, based on the MSVPA, is 0.45. The current fishing mortality reference points for menhaden are an F_{TARGET} of 0.75 and an $F_{THRESHOLD}$ of 1.18.

One class of reference points used 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.[27] It is commonly assumed that when harvesting at MSY, F is roughly equal to M. If the goal is to maintain a higher biomass, as in the case of forage species, then F should be set no higher than M and preferably lower. Indeed, one author of the Chesapeake Bay FEP, referencing Collie and Gislason, has recommended that for menhaden, F should as a rule be less than or equal to M.[28] 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, an important forage fish in Alaskan waters, that is equal to M and a target F that is set at 0.75M.[29]

Summary

Ecological reference points for Atlantic menhaden used as an alternative to the commonly used single-species reference points could nonetheless use stock biomass and fishing mortality rate as reference points for setting targets and thresholds to achieve more conservative, ecosystem-based fishery management goals.

In Table 1 (below), we present what ecological reference points for menhaden might look like, based on the preceding discussion on the scientific literature and approaches used to manage forage fish elsewhere. B is the stock biomass, BMAX is the biomass in the absence of fishing, $BMAX_{75\%}$ is 75 percent of the un-fished biomass, and B_{MSY} is the biomass associated with producing the maximum sustainable yield. F is the fishing mortality rate, M is the natural mortality rate and F=.75M is a fishing mortality rate that corresponds to 75% of the natural mortality rate.

---

[27] Field, J.C. 2002. A review of the theory, application and potential ecological consequences of F40% harvest policies in the northeast Pacific. School of Aquatic and Fisheries Sciences. University of Washington. Prepared for the Alaskan Oceans Network.
[28] 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.
[29] Fishery Management Plan for Groundfish of the Bering Sea and Aleutian Islands Management Area. North Pacific Fishery Management Council. April 2009. p. 15.

Table 1. Ecological Reference Points for Atlantic Menhaden

Reference Point	***Target***	***Threshold***
Biomass	$BMAX_{75\%}$	B_{MSY}
Fishing Mortality Rate	F = .75M	F=M