A Case for Precautionary Management of Forage Fish

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Abstract

As knowledge about marine ecosystems expands, our nation's fishery management infrastructure must evolve to keep pace. Recently, marine scientists have developed new understanding about one of the ocean's most important attributes: forage fish. Forage fish provide a vital link between small protein-rich plankton and top predators that make up our marine mega-fauna. Managing forage fish to sustain the productivity and resilience of marine ecosystems, and the health of top predators, is becoming increasingly important to modern fisheries management. As single species, maximum sustainable yield (MSY)-based management has proven ineffective in managing forage fish, a paradigm shift must occur. Fishery management must move towards ecosystem-based fishery management (EBFM) with new strategies to manage forage fish acting as a sensible next step for that transition. As our knowledge evolves and fishery management follows, ideas such as incorporating forage fish as indicators of ecosystem health and the need to protect essential fish habitat will come to the forefront.

Forage Fish: Definition and Importance

Small, schooling fish that swim in ocean waters play an important role in our marine ecosystems. These "forage fish" are so-called because ocean predators, like larger fish, birds and marine mammals, rely on them as food. Recognizing the importance of forage fish for ecologically-sound fisheries management, a distinguished international group of 13 scientists formed the Lenfest Forage Fish Task Force (LFFTF) to review the impacts these species have on ecosystems. In 2012 they published a report that defined forage fish and made recommendations for how to manage them sustainably worldwide. For small fish species to meet the "forage fish" criteria, they must have several key characteristics. Forage fish:

- Transfer energy from the lower to higher levels of the food web by eating plankton, and then being eaten by larger predators;
- Are the most numerous fish by number of individuals, despite only a few forage fish species existing in any ecosystem;

- Are schooling fish that are small in size, mature early, live short lives and bear large numbers of offspring.[14]

Many species of forage fish swim the nation's oceans, coastal waters, and estuaries. Some species are managed in Federal Fishery Management Plans (FMPs). Others are managed through interstate compacts such as the Atlantic States Marine Fisheries Commission (ASMFC). Many more species go completely unmanaged. Some examples of forage fish important to our marine ecosystems include:

- ***Atlantic herring*—**Atlantic herring is a keystone species in the Gulf of Maine ecosystem, supporting commercial fishing and serving as a major food source for many of the ecosystem's predators including codfish, striped bass, bluefin tuna, and endangered whales. Recent research reveals that predators can consume 300,000 tons of herring a year—roughly three times the amount caught by fishermen.[15] Given the major role herring play in the food web, managers need to take into account the needs of predators when setting fishing limits for herring.
- ***Pacific sardines*—**Pacific sardines support a valuable commercial fishery whose U.S. scope extends from southern California to the coast of Washington. They are a key forage species in the California Current Ecosystem. Pacific salmon stocks, albacore tuna, many groundfish species, seabirds such as brown pelicans, and marine mammals from harbor seals to whales depend on Pacific sardine as a major source of food. Ensuring sufficient abundance of Pacific sardine is therefore necessary for maintaining healthy populations of these important species at the top of the food web.
- ***Atlantic menhaden*—**Atlantic menhaden play an important role in fisheries and marine ecosystems from Maine to Florida. This valuable forage species is a food source for wildlife such as whales, dolphins, ospreys and eagles, as well as valuable federally-managed fish species like tuna, cod, striped bass and tarpon. The Atlantic states recently took action to end overfishing of Atlantic menhaden, recognizing its importance to the diet of numerous valuable recreationally and commercially targeted species.

Ecological importance

Forage fish play a pivotal role in food webs of many coastal and marine ecosystems. They form an essential link between primary and secondary producers (e.g., phytoplankton and zooplankton) and top predators (e.g., large fishes, marine mammals and birds). According to the research by the LFFTF, three-quarters of marine ecosystems worldwide have predators that are highly dependent on forage fish.[16] Scientists have estimated that total consumption of forage fish

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[14] Pikitch, E. et al. 2012. Little Fish, Big Impact: Managing a Crucial Link in Ocean Food Webs. Lenfest Ocean Program. Washington, DC. 108 pp.
[15] Overholtz, W. J., and Link, J. S. 2007. Consumption impacts by marine mammals, fish, and seabirds on the Gulf of Maine–Georges Bank Atlantic herring (*Clupea harengus*) complex during the years 1977–2002. *ICES Journal of Marine Science, 64*:83-96.
[16] Pikitch, E. et al. 2012. Little Fish, Big Impact

by the world's marine mammals can amount to 20 million tons each year.[17] A single humpback whale can consume 1,000 pounds of forage a day.[18] Numerous seabird species rely on abundant forage as well, requiring roughly 12 million tons annually. Recent research suggests that keeping one-third of the forage fish biomass in the water is necessary to sustain healthy breeding populations of seabirds.[19]

In addition to their role as prey, forage fish provide other important ecological services. Most notably, researchers have discovered that forage fish can play a significant role in removing carbon dioxide from the ocean's surface by feeding on plankton and producing carbon-rich fecal pellets that sink to the ocean depths.[20] Migrating anadromous forage species, such as river herring and shad, also play a valuable role in transporting marine-derived nutrients to rivers and streams, and thus have significant impact on the productivity of freshwater systems.[21] Forage fish are also important predators, feeding on planktonic organisms, including the eggs and larvae of other fish species. Studies have suggested that forage fish predation can have important top-down effects on phytoplankton and zooplankton populations, with implications for the wider food web.[22] Given the important role forage fish play in marine ecosystems, fishery managers should be precautionary about setting catch limits for these species.

Historical role

Forage fish species have always played an essential role in America's marine ecosystems, transferring energy from plankton to predators. Native Americans and early colonists depended on forage species such as river herring, shad, and menhaden as important protein sources in their diet, and fertilizer for crops.[23] Recreational fishing in coastal rivers and the oceans has been a national pastime for centuries. As the U.S. experienced the 19th century industrial revolution and the population expanded west, new forage fisheries like the Pacific sardine industry developed. This expansion provided thousands of jobs and served as the economic engine in many coastal communities like the famed "Cannery Row" in Monterey, California. By the 1960s, industrial fishing technologies had been introduced which increased the ability to catch and process previously unimaginable quantities of forage fish, creating higher profits and fewer jobs. Today, many forage fish populations are at historic lows or have collapsed, due in large part to overfishing. Since 1976, federal management has focused on achieving conservation through single-species management with considerable success, but the system has failed to fully account

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[17] Kaschner, K., Karpouzi, V., Watson, R. and Pauly, D. 2006. Forage fish consumption by marine mammals and seabirds. pp. 33-46. *In*: Alder, J. and Pauly, D. (Eds.). On the multiple uses of forage fish: from ecosystems to markets. *Fisheries Centre Research Reports 14(3)*. Fisheries Centre, University of British Columbia

[18] Witteveen, B. H., R. J. Foy, and K. M. Wynne. 2006. The effect of predation (current and historical) by humpback whales (*Megaptera novaeangliae*) on fish abundance near Kodiak Island, Alaska. *Fishery Bulletin 104*:10-20.

[19] Cury, P.M., Boyd, L. L., Bonhommeau, S. et al. 2011. Global seabird response to forage fish depletion. *Science, 334*:1703-1706.

[20] Saba, G. and Steinberg, D. K. 2012. Abundance, composition, and sinking rates of fish fecal pellets in the Santa Barbara Channel . *Scientific Reports, 2*:716.

[21] Hall, C.J., Jordaan, A. and Frisk, M. G. 2012. Centuries of anadromous forage fish loss: consequences for ecosystem connectivity and productivity. *Bioscience, 62(8)*:723-731.

[22] Cury, P., Bakun, A., Crawford, R. J. M. et al. 2000. Small pelagics in upwelling systems: patterns of interaction and structural changes in "wasp-waist" ecosystems. *ICES Journal of Marine Science, 57*:603-618.

[23] McKenzie, M. 2010. *Clearing the Coastline*. Lebanon, NH: University Press of New England. 248 pp.

for the value of forage fish left in the ocean. New ways of accounting for the supportive value of forage fish, like the recommendations of the LFFTF, should be implemented when setting catch levels.

Economic role

Forage fish have continued to play a critical role in providing protein for humans. In 2011, the U.S. commercial fishing industry landed 9.9 billion pounds of seafood.[24] Forage fish directly or indirectly provide much of the foundation for this important industry. Americans consume roughly 15 pounds of seafood per person annually and forage fish are essential prey for some of the most valuable food fish.[25] For example, the majority of the Alaska walleye pollock diet is krill, along with other forage fish such as capelin and sandlance.[26] Without these abundant prey sources, the largest fishery in the U.S. could collapse, which is a key reason why directed commercial fishing for krill and other forage species is prohibited in federal waters off the Alaskan coast.[27] Forage fish also bring food to our tables indirectly as the primary source of bait in many of America's commercial and recreational fisheries. In the Northeast, American lobster and blue crab fisheries primarily use forage species such as herring and menhaden as bait. The domestic reduction industry lands menhaden in the Atlantic Ocean and Gulf of Mexico, which becomes protein for humans indirectly as feed for livestock and aquaculture.

The Task Force reported fluctuations in reliance on forage fish, with some ecosystems, especially areas of ocean upwelling, relying more heavily on forage fish abundance. However, in 75% of the ecosystems studied, there was at least one predator that depended on forage fish for over half of its diet, and in 29% of the cases there was a predator that was "extremely dependent," relying on forage fish for over 75% of its diet. This research creates a framework that managers can use for determining the importance of forage fish in the ecosystems they manage, and making wise choices that support all the species in the marine food web. Because of their importance as food for larger, higher-value fish, small forage fish are worth more in the water, rather than as direct commercial catch. The LFFTF studied 72 ecosystems and estimated that the value of direct landings of forage fish is $5.6 billion, whereas their "supportive value" to other commercial species is approximately double, at $11.3 billion.

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[24] National Oceanic and Atmospheric Administration (NOAA) Fisheries. August 2012. Commercial Fisheries of the United States 2011. p. ix. http://www.st.nmfs.noaa.gov/commercial-fisheries/fus/fus11/index. The majority of this increase in catch was from Gulf of Mexico menhaden, a key forage fish, which increased by 407 million pounds (42 percent) in the Gulf states, see page ix. By weight, 79 percent of these domestic landings were consumed directly as human food, 3 percent were used as bait, and the remaining 18 percent were taken by the reduction industry, see Table: "DISPOSITION OF U.S. DOMESTIC LANDINGS, 2010 AND 2011," page 6.

[25] National Oceanic and Atmospheric Administration (NOAA) Fisheries. August 2012. Commercial Fisheries of the United States 2011. p. v.

[26] National Oceanic and Atmospheric Administration (NOAA), Alaska Fisheries Science Center. December 2011. Chapter 1: Assessment of the Walleye Pollock Stock in the Gulf of Alaska. p. 72. http://www.afsc.noaa.gov/REFM/docs/2011/GOApollock.pdf. Note: Alaska walleye pollock is the largest and sixth most valuable fishery in the United States.

[27] *See* Final Environmental Assessment for Amendments 87/96 to the NPFMC Groundfish FMP's at http://alaskafisheries.noaa.gov/sustainablefisheries/amds/95-96-87/final_ea_amd96-87_0910.pdf

Deficiencies in current forage fish management

Currently, many of the nation's forage fish are entirely unmanaged. In addition, many of the managed species face overexploitation because of several factors, including the reliance on single species, maximum sustainable yield (MSY) management, and static assumptions regarding natural mortality, among other factors. Moreover, economic analysis in fishery management plans too often relies only on the costs and benefits to directed forage fisheries (and their end markets, such as bait users) rather than evaluating the value of leaving forage fish in the ocean to provide ecosystem services and feed dependent predators.

The LFFTF found that "conventional management can be risky for forage fish because it does not adequately account for their wide population swings and high catchability. It also fails to capture the critical role of forage fish as food for marine mammals, seabirds, and commercially important fish such as tuna, salmon, and cod."[28]

Pacific coast Councils: Examples of effective forage fish management

As ecosystem science has progressed and the implications for management have become clear, we have seen positive examples of ecosystem principles, like forage fish protection, being incorporated into existing management. For example, the North Pacific and Pacific regional councils are leaders in protecting the forage base and the marine food web.

Specifically, the North Pacific Fishery Management Council (NPFMC) amended the Gulf of Alaska and Bering Sea/Aleutian Islands Groundfish FMP's in 1998 to preclude directed fishing on a suite of forage species.[29] According to NMFS, this was "necessary to conserve and manage the forage fish resource off Alaska…a critical food source for many marine mammal, seabird and fish species."[30] The NPFMC amended these FMP's in 2010 to update these actions, maintaining the prohibition on directed fishing and designating these forage species as ecosystem component species (ECS), consistent with the new National Standard 1 guidelines revised in response to the 2007 reauthorization of the Magnuson Stevens Act (MSA).[31] The NPFMC also created an Arctic FMP in 2009 whose primary purpose was to preclude new commercial fisheries in the Arctic Management Area, including for forage species, unless and until robust information was available and deemed sufficient to approve a new fishery.[32]

Meanwhile, the Pacific Fishery Management Council (PFMC) amended its Coastal Pelagic Species FMP to put in place a harvest prohibition on all species of krill.[33] The PFMC is also

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[28] Pikitch, E. et al. 2012. Little Fish, Big Impact

[29] *See* Final Rule implementing Amendments 36/39 to the NPFMC Groundfish FMP's at http://www.fakr.noaa.gov/frules/3639fr.pdf. This action identified and protected over 20 important forage species in 9 scientific families by prohibiting directed fishing on those species.

[30] 50 CFR 679. *See also* June 2004 PFMC Meeting. Exhibit G.4.a Situation Summary.

[31] *See* Final Environmental Assessment for Amendments 87/96 to the NPFMC Groundfish FMP's at http://alaskafisheries.noaa.gov/sustainablefisheries/amds/95-96-87/final_ea_amd96-87_0910.pdf

[32] *See* Final Rule implementing the Arctic FMP at http://www.fakr.noaa.gov/frules/74fr56734.pdf

[33] *See* 2009 Final Rule implementing the Amendment 12 to the CPS FMP at http://www.pcouncil.org/wp-content/uploads/CPS_Am12_E9-16531.pdf

actively considering additional protections for all other unmanaged forage species, and in June 2012 adopted an objective of prohibiting new directed fisheries on unmanaged forage species.[34]

These examples of precautionary forage policy do not create winners and losers, nor do they have significant negative impacts on existing fisheries. In fact, proactive and precautionary management of the forage base can help increase both the productivity and sustainability of all fisheries. Conservation groups are not alone in this view. The NPFMC's ban on new fisheries for forage species is hailed in an industry-sponsored study as one of thirteen "best practices in ecosystem-based fishery management."[35] The use of the ECS category by the North Pacific Fishery Management Council (NPFMC) to advance an ecosystem-based approach to management through forage protection is of particular note. The NPFMC has applied the category to implement concrete measures to understand and protect the food web, recognized as one of the basic tenets of EBFM.[36,37] This approach should be undertaken by additional fishery management councils.

Existing legal and regulatory tools and authority to manage forage fish

Several MSA provisions provide authority for management of forage fish. The MSA requires every FMP to contain a number of specific provisions, all of which must be consistent with ten National Standards (NS) for conservation and management.[38] Importantly, NS 2 requires that all management measures be based on the best available scientific information.[39] The MSA also provides managers with discretion to implement additional measures that can be used to manage forage fish, including broad authority "to conserve target and non-target species and habitats, considering the variety of ecological factors affecting fishery populations; and . . . prescribe such other measures . . . necessary and appropriate for the conservation and management of the fishery."[40] While the MSA's required and discretionary provisions provide ample authority to manage forage species, and more broadly to engage in ecosystem-based management, codifying some of these provisions into requirements would create a strong framework for future management of forage fish. Several of the relevant provisions of the Act are briefly summarized below:

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[34] *See* June 2012 PFMC Decisions Summary at http://www.pcouncil.org/wp-content/uploads/0612decisions.pdf , page 4.
[35] Warren, B. 2007. Sea Change: Ecological Progress in U.S. Fishery Management. A report jointly commissioned by the Marine Conservation Alliance and the Institute for Social and Economic Research and the University of Alaska Anchorage.
[36] *See* Ecosystem Based Fishery Management: a Report to Congress by the Ecosystem Principles Advisory Panel, available at http://www.nmfs.noaa.gov/sfa/EPAPrpt.pdf at pp. 29 and 33.
[37] Christensen, V. and Maclean, J. (Eds.). 2011. *Ecosystem Approaches to Fisheries: A Global Perspective*. Cambridge, U.K.: Cambridge University Press.
[38] 16 U.S.C. §§ 1853(a), 1851(a).
[39] 16 U.S.C. § 1851(a)(2).
[40] 16 U.S.C. § 1853(b)(12)-(14).

- ***Stocks in the Fishery.*** The MSA requires that managers include any stock in need of conservation and management in an FMP.[41] In making this determination, councils are required to look to factors such as the need for
- rebuilding, restoring, or maintaining "any fishery resource and the marine environment,"
- assuring among other things, a food supply and recreational benefits, and
- avoiding long-term adverse effects on fishery resources and the marine environment.[42]
- ***NS 1: Preventing Overfishing.*** The NS 1 requirements to achieve the dual goals of preventing overfishing while achieving optimum yield on a continuing basis have primacy over all other MSA requirements.[43] "Overfished" and "overfishing" are defined as "a rate or level of fishing mortality that jeopardizes the capacity of a fishery to produce the maximum sustainable yield on a continuing basis."[44] As fisheries managers typically recognize, the Act requires that excessive mortality of any forage stock must be reduced or maintained at levels necessary to prevent overfishing of that same stock of forage fish. However, the overfished/overfishing definition does not specify that the fishery experiencing an excessive rate or level of fishing mortality, and the fishery whose capacity to produce MSY is jeopardized, be the same fishery. Thus, the MSA provides the authority to manage the mortality of forage species at levels that do not jeopardize the capacity of dependent predator species to produce MSY.[45]
- ***NS 1: Achieving Optimum Yield (OY).*** The MSA defines "optimum yield" as the amount of fish that "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," and "is prescribed as such on the basis of the maximum sustainable yield from the fishery, as reduced by any relevant economic, social, or ecological factor."[46] The NS 1 guidelines reflect this statutory emphasis on ecosystem protection, specifying that "maintaining adequate forage for all components of the ecosystem" is a key consideration relevant to OY.[47]
- ***Annual Catch Limit (ACL) Requirements.*** Setting ACLs requires establishment of a scientifically-robust acceptable biological catch (ABC) control rule.[48] An appropriate ABC control rule establishes an approach for setting catch levels that will vary as a function of where the stock is relative to an appropriate target biomass (target above B_{msy} for forage fish) and accounts for scientific

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[41] 16 U.S.C. § 1852(h)(1); 50 C.F.R. § 600.310(d), (h).
[42] See 16 U.S.C. § 1802(5).
[43] 16 U.S.C. § 1851(a)(1); 50 C.F.R. § 600.310(l).
[44] 16 U.S.C. § 1802(34).
[45] NMFS's essential fish habitat ("EFH") guidelines support this interpretation of overfishing. These regulations specify that the loss of prey species may constitute an adverse effect on EFH and note that habitat loss or degradation can contribute to a species being identified as overfished. 50 C.F.R. §§ 600.810(a), 600.815(a)(1)(C), (a)(7).
[46] 16 U.S.C. § 1802(33).
[47] 50 C.F.R. § 600.310(e)(3)(iii)(C).
[48] 16 U.S.C. § 1852(g);50 C.F.R. § 600.310(b).

uncertainty.[49] NS 2 requires that ABC control rules be based on the best available science, and several recent studies address setting ABC control rules for forage fish, and call for new approaches.[50] Thus, setting ABC control rules for forage fish based on the best available science requires management consistent with the risks associated with forage fish populations' tendency to swing dramatically, their high catchability, and the critical role of forage fish as food for commercially valuable species, marine mammals, and seabirds.

- ***Essential Fish Habitat (EFH).*** EFH includes "the waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity," and each FMP must "describe and identify [EFH] for the fishery . . ., minimize to the extent practicable adverse effects on such habitat caused by fishing, and identify other actions to encourage the conservation and enhancement of such habitat."[51] EFH regulations treat prey species as an integral component.[52]
- ***Minimizing Bycatch.*** National Standard 9, and related provisions, require that conservation and management measures minimize bycatch to the extent practicable.[53] Forage species tend to swim in large schools and sometimes mix with other species of forage fish (e.g., river herring and Atlantic herring). They are thus susceptible to becoming bycatch, because fisheries targeting forage species generally use large mid-water trawl nets or purse seines capable of indiscriminately taking entire schools of fish.
- ***Maximizing Economic and Social Benefits.*** National Standards 4 and 8 support managing forage species to maximize overall economic and social benefits to fishermen and fishing communities, consistent with the MSA's conservation provisions.[54] Conserving forage species can be crucial to these requirements because forage species provide the prey base that supports recreational and commercial fisheries.
- ***Non-Magnuson Stevens Act Authority.*** Additional authorities exist that can affect forage fish management.
- ***Interstate Fisheries Management.*** Near-shore fisheries are typically managed in coordination by states through interstate compacts with varying levels of binding authority, and in some cases an overlay of federal authority. For example, on the East Coast the ASMFC manages state fisheries pursuant to a compact and the Atlantic Coastal Fisheries Conservation and Management Act gives ASMFC plans legal force.[55] These authorities require "coastal fishery management plans" consistent with Magnuson-like standards designed to ensure that FMPs "promote the conservation of fish stocks throughout their ranges and are based on the best scientific information available"[56]

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[49] See e.g., 50 CFR § 600.310(c)(3), (f)(2)(ii)-(iii).
[50] Pikitch et al 2012; Smith et al 2011; Cury et al 2011; Tyrrell et al 2011.
[51] 16 U.S.C. §§ 1802(10), 1853(a)(7).
[52] 50 C.F.R. §§ 600.810(a), 600.815(a)(7).
[53] 16 U.S.C. §§ 1851(a)(9), 1853(a)(11).
[54] 16 U.S.C. §§ 1851(a)(4), (8).
[55] 16 U.S.C. §§ 5104 –5108.
[56] See e.g., 16 U.S.C.. § 5104(a)(2)(A).

- ***Endangered Species Act.*** The ESA provides protection for endangered and threatened species.[57] Key authorities strictly limit the take of listed species, require designation of critical habitat and plans for their recovery, and impose consultation requirements on federal agency actions affecting listed species.[58]

Improving forage fish management as a step towards ecosystem-based fishery management (EBFM)

Currently, single species management characterizes most fishery management strategies in the United States, including forage fish fisheries. Over the last several years, fishery management councils and NOAA fisheries service have begun to discuss and plan for moving away from single species management towards ecosystem-based fishery management. Changing management strategies for the nation's forage fish to precautionary management can be a useful next step in this transition.

Precautionary management

Because of the vital role forage fish play in marine ecosystems and the reliance of predators on healthy forage fish populations, a precautionary management strategy is advised. While many forage fish are currently unmanaged or managed for maximum sustainable yield, forage fish are often overexploited, negatively impacting predators and marine ecosystems in general. The LFFTF recommended specific precautionary catch levels to protect forage fish and their dependent predators. Management strategies that limited fishing rates (F) to half the conventional rate effectively headed off declines in dependent predator populations. Reducing the fishing on forage fish not only benefited predators but also reduced the risk of collapsing forage fish populations, albeit with some forgone commercial yield. This approach must be considered for future management of forage fish species.

Ecosystem-based fisheries management

Just about everyone whose livelihood depends on going to sea in search of fish understands that the fish they depend on are part of an intricate system of predators, prey, and habitat – an ecosystem. When humans first began to fish the seas close to shore, their predation was readily absorbed by thriving marine ecosystems. All this changed as the abundance of people and the power of fishing technology exploded: people became such a powerful force that they unwittingly transformed the ecosystems they depended upon, leading to the disappearance of critical fish stocks, and other unfortunate consequences. Single species management of fishing has helped, but has proven inadequate to restore marine ecosystems because it fails to account for the interactions among species that are fundamental to the food webs. Basic dependencies

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[57] 16 U.S.C. § 1531(b).

[58] 16 U.S.C. §§ 1538(a)(1)(B), 1533(a)(3)(A), 1533(f)), 1536(a)(2).

among predators and their prey, for example, continue to be perilously ignored. Entire ecological regions such as the Northeast U.S. are being subjected to ecosystem overfishing.[59]

Ecosystem-based fisheries management (EBFM) is a promising approach to fisheries management that is within reach, offering a solution to these problems, but it remains to be fully implemented in U.S. federal waters. In simple terms, EBFM is managing fisheries within an ecological region "so as to coordinate, account for, and include all factors in a holistic, synthetic, integrated fashion."[60] These broad goals of EBFM can be achieved through a range of approaches from simple steps, to the use of multi-species or full ecosystem models. Implementing management plans that take into account the unique role that key forage species (such as Atlantic herring, menhaden, sardines, and krill and other zooplankton) play in the marine ecosystem is a common sense, first step along the path to EBFM. Fisheries management has failed in many places because it has not recognized the ecosystem and has not been sufficiently precautionary. Precautionary management of forage fisheries, and protections for these key species, has not yet been applied to directed fisheries, although it is crucial to the future of a healthy U.S. fishing industry.

Lenfest Forage Fish Task Force recommendations

In reviewing various ecosystems, the Task Force considered both the impact of fishing on the forage species themselves and the consequences of removing these fish from the ocean for the predators that depend on them as food. They discovered that conventional MSY management practices when applied to forage fish are often riskier than expected because these small schooling fish are particularly vulnerable to net capture and because these fishes typically undergo relatively wide population swings. They also discovered that harvest of forage fish puts their predators at risk of collapse.

Based upon an extensive analysis of ecosystems around the world, the LFFTF recommends managing forage fish so that the biomass is kept at levels substantially above those typically used as targets for other kinds of fish. In every case, they recommend a careful evaluation of the available information for a given forage species and its dependent predators, with specifics of guidance tailored accordingly. It is generally recommended that harvest control rules be adopted that stop fishing when population biomass falls below a threshold (e.g., corresponding to 40% of the biomass expected without fishing), and that strive to keep the biomass near 75% of B_0. Fishing mortality (F) should be held below half of the traditional F_{MSY}, or to half of the natural mortality rate (M) if that is well-estimated and less than F_{MSY}. The Task Force also recommended that no new fisheries should be allowed to develop on forage stocks with limited information, a description that characterizes most currently unfished and unmanaged forage species.

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[59] Murawski, S.A. 2000. Definitions of overfishing from an ecosystem perspective. *ICES Journal of Marine Science, 57*: 649–658; Ecosystem Assessment Program (2009). Ecosystem Assessment Report for the Northeast U.S. Continental Shelf Large Marine Ecosystem. U.S. Dept Commer, Northeast Fish Sci Cent Ref Doc. 09-11.

[60] Link, J. S. 2010. *Ecosystem-Based Fisheries Management: Confronting Tradeoffs*. Cambridge, U.K.: Cambridge University Press.

In summary, the work of the Task Force shows that forage fish play a vital role supporting ecosystems and that the best available science demands a precautionary approach to managing these stocks.[61] In terms of developing new fisheries for as yet unexploited stocks of forage fish, caution is clearly warranted and the burden of proof must be on those proposing such fisheries to clearly establish that the proposed fisheries are ecologically-sound based on new scientific work on forage fishes. The U.S. should make precautionary management of its forage fishes a priority as a critical step toward EBFM, and fisheries management should move away from MSY management for these species.

Suggested requirements before new forage fish fisheries are conducted

Because of the important role forage fish play in marine ecosystems, new forage fish fisheries should be prohibited until a stock assessment has been conducted and required criteria for measuring when the stock is overfished and overfishing is occurring has been established. The stock assessment and stock status criteria must take into account:

- Ecosystem functions of the target forage fish.
- Historical, current, and future needs of predators that consume the target species.
- Variable abundance of the target species in response to fluctuating environmental conditions.

Fishing should be allowed only after a fishery management plan is developed that:

- Establishes a management program that is consistent with the recommendations of the Lenfest Forage Fish Task Force, including the harvest control rule, precautionary mortality reference points, and a biomass target closer to the biomass with no fishing (B_0) than is typical in conventional management (i.e. $B>B_{MSY}$).
- Evaluates and quantifies the bycatch and habitat impacts of the fishery.
- Implements measures to monitor and reduce bycatch and habitat impacts in the fishery.
- Analyzes the environmental consequences of target species removals and the economic costs and benefits of direct harvest compared with leaving forage fish in the water.

Developing Federal management plans for forage fish primarily caught in Federal waters

U. S. federal fisheries management has a strong record of ending overfishing and in a number of cases rebuilding depleted fish stocks.[62] However, many forage fish species that swim in the nation's Exclusive Economic Zone are currently unmanaged in federal waters, and are also either

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[61] Gerrodette, T. et al. 2002. Precautionary management of marine fisheries: Moving beyond burden of proof. *Bulletin of Marine Science, 70(2)*, 657–668.

[62] National Oceanic and Atmospheric Administration (NOAA). May 2012. Status of Stocks 2011: Annual Report to Congress on the Status of U.S. Fisheries. http://www.nmfs.noaa.gov/stories/2012/05/docs/status_of_stocks_2011_report.pdf

unmanaged or poorly managed in state waters by interstate fishery management bodies. Efforts are underway to bring additional forage fish, such as river herring and shad on the East Coast, under federal fishery management plans.[63] Improved coordination between interstate and federal management is also required. Many additional species of forage fish would benefit from the requirements outlined in the Magnuson-Stevens Act (e.g. ending overfishing, rebuilding fish stocks, minimizing bycatch, protecting habitat). This could be accomplished through joint management by federal fishery management councils, NMFS and interstate compacts like the ASMFC. Managing these forage fish by the standards of the MSA, and ultimately transitioning to EBFM, will result in a benefit to predators, the ecosystem, and the nation as a whole.

Conclusion

Forage fish play an important role in the nation's marine ecosystems and in the diets of top marine predators. For this reason, management of forage fish must be aligned with new ecosystem science and improved accordingly. The Lenfest Forage Fish Task Force report, which provides a set of robust recommendations to protect forage fish and move our nation's fishery management forward, should serve as the basis for sound management of our critically important forage species. Many more species of forage fish must be brought under precautionary, federal management as the nation transitions from single species to ecosystem-based fisheries management.

Key recommendations

- Transition from single-species to ecosystem-based fisheries management.
- Ecological role of forage fish should be accounted for when setting catch limits.
- Economic value of forage fish should be expanded to include their supportive value to other commercial and recreational fisheries, and eco-tourism industries.
- Risk of wide population swings and high catchability of forage fish should be accounted for in fishery management plans.
- Stock assessments and FMPs should be developed before forage fisheries can be expanded or initiated to maintain their vital role in marine ecosystems.
- Protections afforded in the Magnuson-Stevens Act should be given to forage fish caught in federal and state waters, through improved coordination between fisheries management authorities.
- Key recommendations

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[63] *See* MAFMC, Scoping Document for Amendment 15 to the Atlantic Mackerel, Squid and Butterfish Fishery Management Plan, available at http://www.mafmc.org/fmp/msb_files/Am15/SCOPING_DOC_MSB15_FINAL.pdf