CONSERVATION IN A FISH-EAT-FISH WORLD

Managing Related Predator and Prey Species in Marine Fisheries

by Ken Hinman

NATIONAL COALITION
FOR
MARINE CONSERVATION

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Acknowledgments

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Dedicated to the Memory of
Ellie Dorsey (1949-2000)
whose lifelong advocacy for conservation
remains an inspiration to us all

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The following individuals (listed alphabetically) leant their knowledge, experience and innovative ideas to the workshop:

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PREFACE

BY KEN HINMAN, PRESIDENT

As stewards of the ocean's living resources, we have for too long attempted to conserve each species alone, just as we fish for them. We perform assessments of fish populations on a species-by-species basis and set catch limits within the same little boxes. This narrow approach doesn't account for interactions among predators and prey or the effect that fishing one species has on others. Or fishing operations that capture a wide range of species indiscriminately. Or changes to the environment, human-induced or otherwise.

Synchronizing the conservation of related species is not a new idea in fisheries management. In fact, it's been acknowledged and discussed for many years. Yet achieving anything more than a perfunctory attempt at what is commonly called ecosystem-based management has remained an elusive goal. Meanwhile, the urgency to expand our thinking and consider the impact of fishing on the food web has increased, due to the depleted condition of so many of our marine fish populations and new, concerted efforts to restore them and thereby create truly sustainable fisheries for the future.

> ***Ecosystem-based management is a natural outflow of our increasing knowledge and our expanding circle of concern for all marine species.***

As a member of the National Marine Fisheries Service's Ecosystems Principles Advisory Panel, charged by Congress with advancing ecosystem principles in fisheries management, I saw how the panel's ambitious goal of developing "fishery ecosystem plans" to guide management decisions would come about only through an incremental strategy. Not in one giant leap, but in carefully measured steps. The first step is to understand and preserve the interdependency of key predator and prey species.

After all, ecosystem-based management is a natural outflow of our increasing knowledge of the ocean and our expanding circle of concern for all marine species. So it is also a natural progression in the evolution of fishery management. Does embarking on such a daunting challenge create the potential for misuse or even abuse, as some fear? Maybe. Change and innovation are always risky. But I've seen how management decisions are already being made based on misperceptions about ecological relationships, because there is no established process for making such decisions. That is the more dangerous course to follow.

The reality is that ecosystem-based management will occur - already *is* occurring - shaping not only perceptions about management decisions but also the decisions themselves. We are obliged to make sure that it is done correctly, based on science and agreed upon goals, adhering to a process that we can understand and believe in.

The need for predator-prey management does not arise merely from the failure of single-species management to effectively conserve ocean fish. It stems more from the fact that the species-by-species approach cannot address certain critical issues and problems that will no longer be ignored.

It is essential to understand that considering fisheries in an ecosystem context does not diminish the need to regulate fishing or downplay the effect of fishing on fish populations. It cannot be used to justify overfishing one species in order to maximize yields of another species. Nor does it diminish the need to fish selectively to avoid bycatch (the incidental capture of non-target species) and minimize bycatch mortality. In fact, ecosystem-based fishery management supports taking the precautionary approach to conserving and managing marine fisheries, especially when the ecosystem effects of fishing are uncertain or

> ***An ecosystem-based approach is not a substitute for aggressively implementing mandates to prevent overfishing, minimize bycatch and protect fish habitat.***

unknown. It is our firm belief that an ecosystem-based approach cannot and should not substitute for aggressively implementing existing mandates to prevent overfishing, minimize bycatch and protect essential fish habitat.

The National Coalition for Marine Conservation (NCMC) is committed to moving management of the nation's marine fisheries toward a broader, ecosystem-based approach. Among the first steps that fishery managers should take is to carefully consider predator-prey relationships affected by fishing allowed under existing Fishery Management Plans (FMPs). This will require determining the effects of fishing on the food web, setting optimum population levels to account for ecological factors, and justifying total allowable catches with respect to interspecies relationships.

In order to provide direction and drive to this initiative, NCMC convened an intensive 2-day workshop of fisheries scientists and managers in Annapolis, Maryland in November 1999. This report and its recommendations are a result of those discussions and our ongoing commitment to improving management of all marine species.

INTRODUCTION

Fishery scientists and managers have recognized for some time the need to expand traditional single-species fishery management planning to address ecological considerations, most notably the interactions between related predator and prey species. Indeed, ecosystem-based management is gaining increased interest and attention, especially as it relates to the conservation and management of a number of key marine fisheries.

In 1996, Congress directed the National Marine Fisheries Service (NMFS) to convene a panel of experts to review and recommend application of ecosystem principles to federal marine fisheries management. That panel's report, entitled "Ecosystem-Based Fishery Management," calls for a transition from single-species to ecosystem-oriented management of fishing activities. The panel recommends a two-stage approach, beginning with interim changes to ongoing research and management strategies and ultimately leading to development of comprehensive Fishery Ecosystem Plans for the major ecosystems in each region of coastal America. An important first step toward a more holistic approach to fisheries management, the panel concludes, is considering predator-prey interactions affected by fishing allowed under each FMP. (NMFS 1999)

> ***Sound management has been hampered by misperceptions about the nature and extent of predator-prey interactions.***

While many fishery managers, fishermen, scientists and conservationists can agree on the need to incorporate predator-prey relationships into fishery management plans *in concept*, we lack a *process* for doing this, along with some basic information on cause and effect between predator and prey species. In fact, the principal reason ecosystem relationships are not being adequately considered is a lack of guidance as to what information is needed and, most importantly, how it should be used in the real world of making fishery management decisions.

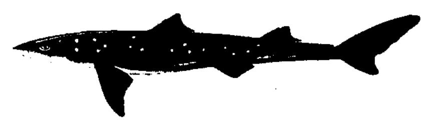
Meanwhile, because so many marine fish stocks are in a depleted state and new, concerted efforts are underway to restore them to healthy and sustainable levels - a record high of 92 stocks were listed as overfished in 2000, with 75 rebuilding plans in place, according to the government's annual review (NMFS 2001) - there is increased urgency to expand the scope of management to consider the impact of fishing one species on other, related species.

Several predator-prey interactions are receiving attention in recent fishery management debates, underscoring the urgent need for a defined process to replace anecdotal information. Foremost among these is the striped bass (*Morone saxatilis*). The resounding success in rebuilding striped bass, also known as rockfish, along the Atlantic coast has been followed by worries that the newly resurgent bass are finding too little to eat because harvests are too high on one of their most important prey species - menhaden (*Brevoortia tyrannus*). Because of the well-established inter-relationship between striped bass and menhaden and its implications for fisheries management, we provide a detailed case study in this report.

Concerns about high, unregulated harvests of horseshoe crabs (*Limulus polyphemus*) in the mid-Atlantic area, largely for use as bait in other fisheries, have been heightened by fears that depleted populations of horseshoe crabs would leave shore birds that feast on the crabs' eggs without enough fuel to complete their long migrations. State and federal agencies are moving to limit the number of horseshoe crabs commercial fishermen may land, limits that traditionally have been set according to the bait needs of the fishing industry.

Horseshoe Crab

Some New England fishermen and fishery managers have argued that the target population level in the rebuilding plan for dogfish sharks (*Squalus acanthias*) should be lowered, and thus restrictions on fishing for dogfish relaxed, because dogfish consume significant amounts of cod (*Gadus morhua*), a higher-value species that is also in need of restoration. Significant predation on cod, however, has not been supported by analyses of dogfish stomach contents. In fact, scientists advising the Regional Fishery Management Councils determined that adult cod are more significant predators of juvenile cod than are dogfish. Nevertheless, the perception of dogfish as an "undesirable" species, whose abundance jeopardizes the abundance of other, more desirable species, not only persists but may influence decisions, even if at a subliminal level.



Atlantic Dogfish

In these and other recent debates, sound management has been hampered by misperceptions about the nature and extent of predator-prey interactions, inadequate data about them, and lack of an established process for taking predator-prey interactions into consideration. This last problem is exacerbated when the related species are managed by different agencies.

The purpose of this report is to provide some guidance on what predator-prey information is needed and how it might be used in fishery management decisions, particularly in harmonizing otherwise incompatible management goals for related species. We note that fishery managers currently have the authority and discretion to consider predator-prey interactions in management planning. We strongly recommend that the National Marine Fisheries Service, Fishery Management Councils and Interstate Fisheries Commissions begin immediately to move toward an integrated, multispecies approach to fisheries management by taking advantage of existing authority under the current management system. We also recommend that Congress provide additional resources as well as new, expanded authority to apply ecosystem principles throughout the federal and interstate fishery management process.

In sum, we recommend that fishery managers: 1) make changes in existing fishery management plans to consider the effects of fishing each species on other species in the food web; 2) begin devising Fishery Ecosystem Plans to serve as overarching guidance and a context for future management decisions; and 3) amend federal law to facilitate movement of all national and regional management bodies away from single-species management toward ecosystem-based management.

For the short-term, we offer a template for a step-by-step process for synchronizing management objectives for related predator and prey species in each FMP. This process, beginning with a description of the "significant" food web, would lead to specific recommendations for conservation and management, including the setting of optimum catch levels for each species that take into account species interdependence and prevent "ecosystem overfishing." We also offer some suggestions specific to management of striped bass, menhaden and associated species, a predator-prey complex we chose for a case study because of its prominence in the current debate, the comparative wealth of scientific information available, the cross-jurisdictional nature of management, and a relatively defined (though by no means complete) ecosystem (Chesapeake Bay).

Why Predator-Prey Relationships Matter

Species play a critical role in shaping and structuring their ecosystems, inducing predictability and balance into the system. This principle argues for managers to understand, account for and address inter-relationships among species in management decisions. Relationships among keystone predators and key or "significant" prey are paramount. Fishing that reduces abundance of either affects the others (both peer predators and object prey alike) in measurable ways. Those effects must be understood and accounted for in management decisions.

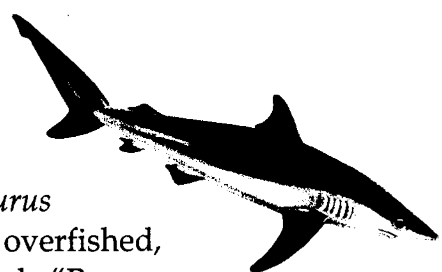
We know that the removal of one species from fishing can and does affect other species in the ocean. What we might call "ecosystem overfishing" occurs when reducing one component adversely impacts another, or precipitates unknown or unpredictable changes in the food web. Predators of the removed species may suffer from reduced growth, reproduction and survival if alternate prey are not available. Prey of the removed species may become more abundant and more long-lived because of reduced predation mortality. The size of such effects on predators and prey depends on the strength of the interaction with the removed species. Where predator-prey interactions are strong, such effects can propagate across additional trophic levels with the direction of the effect reversed at each successive level in what is known as a "trophic cascade."

Trophic cascades have been described most often in lakes, streams, and intertidal communities, but have recently been documented in a greater diversity of ecosystems, including coastal areas and the open ocean (Pace *et al* 1999). In the North Pacific, the abundance of planktivorous pink salmon (*Oncorhynchus gorbuscha*) appears to determine the biomass of zooplankton and phytoplankton. Over a ten-year time series, it has been observed that zooplankton have a higher biomass and phytoplankton have a lower biomass when salmon abundance is low; when salmon abundance is high the reverse pattern prevails (Shiomoto *et al* 1997). Thus predation by the salmon has a major effect on structuring the oceanic ecosystem that they inhabit.

> ***'Ecosystem overfishing' occurs when reducing one component adversely impacts another, or precipitates unknown or unpredictable changes in the food web.***

Another example of a trophic cascade was recently described in coastal waters of Alaska. There, populations of sea otters (*Enhydra lutris*) have recently declined in several areas, and their principal prey, sea urchins, have increased dramatically, with a resulting 10-fold decline in kelp, the urchins' forage (Estes *et al* 1998). The disappearance of kelp, which acts as a breakwater against wave action, in turn causes increased erosion of the shoreline. These changes appear to be the result of increased predation on the otters by killer whales (*Orcinus orca*). The reasons why killer whales have increased their take of otters are not certain, but are probably related to population declines in other marine mammal prey for the whales, notably Stellers sea lions and harbor seals. The pinniped decline may, in turn, have resulted from declines in stocks of their forage fish, such as Alaskan pollock, as a result of heavy fishing pressure.

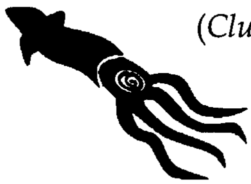
Strong effects of top predators on the ecosystems they inhabit - in particular, the removal of large predators precipitating major disruptions down to the ecosystem's foundation - have been demonstrated in a number of different ecosystem types (Pace *et al* 1999). This raises the question of what ecosystem effects have been created by the fisheries that remove some of the ocean's apex predators. In the Atlantic Ocean, for example, swordfish (*Xiphias gladius*), the large tunas (bluefin, *Thunnus thynnus*; bigeye, *Thunnus obesus*), blue and white marlin (*Makaira nigricans* and *Tetrapturus albidus*) and large coastal sharks (22 species) are overfished, with several species considered severely depleted. "By removing so many of these predators," worry some fishery scientists, "we are weakening an entire tier at the top of the food chain, which may have dire biological consequences throughout the ecosystem." (Hinman 1998) As Larkin notes, fisheries for one predator commonly take other predators (e.g., the multi-species pelagic longline fisheries), thereby decreasing overall predation in the ecosystem. Predator removal may be more disruptive than prey removal, since predators are generally longer-lived than their prey, and are thus slower to respond to changes in their environment, or to fill niches left by the disappearance of other predators. (Larkin 1979)



Dusky Shark

The question of how predator removal effects the ecosystem has been approached recently by modeling (Kitchell *et al*, in press). But in most cases the appropriate data were not collected early enough in the history of exploitation of large pelagics (tunas, billfishes and sharks) to document the effects. Still, properly developed models, with adequate data, hold promise of forecasting the strength of interactions among predators and prey.

An additional concern is the effect of increased harvest of pelagic forage species on their large pelagic predators, many of which are overfished and the object of national as well as international rebuilding programs. Increasing



Squid

harvests of squid (*Loligo pealei* and *Illex illecebrosus*) and herring (*Clupea harenus harengus*) on the northeast Atlantic shelf raise questions about how this unprecedented growth in fishing mortality might impact the effectiveness of recovery efforts for species, such as swordfish, bluefin tuna, blue and white marlin and a number of sharks, for whom squid and herring are a dominant food source. Squid and herring are labelled "under-utilized species," and in the traditional single-species sense, they may not be overfished or even fully exploited. But in the ecosystem context, it's a gross mischaracterization which does not take into account that natural mortality may be at an all-time low, or that the demand for these prey species is expected to increase substantially as rebuilding efforts succeed in repopulating coastal waters with a higher abundance of predators.

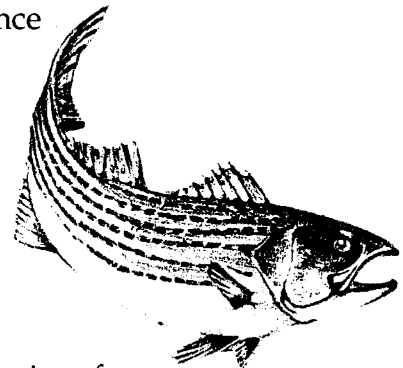
Not all trophic interactions are strong enough to produce a cascade effect across more than one trophic level. The omnivorous diet of many species - Larkin prefers to call it a "style" of feeding that constrains what the fish will eat but does not limit them to a single prey species - is believed to make trophic cascades less likely by weakening the interaction between any two species. (Larkin 1979) The significance of any single prey species to a single predator, however, increases or decreases at different life stages, as does the impact of prey availability on each predator.

Part of the challenge of managing related predators and prey is to identify which predator-prey interactions are significant. What may appear to be a less than significant part of an animal's diet, in terms of percentage of overall consumption, may in fact be quite significant in terms of how the presence or absence of that portion of the diet affects behavior, productivity, abundance and the like. Some scientists, for instance, consider a prey species significant to a predator if it makes up 5 percent of its diet.

In any case, it is clear that managers will have greater success in achieving conservation goals if fishing's effects on species that are trophically related are understood, considered and the appropriate management action taken.

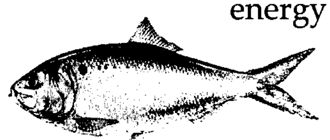
A CASE STUDY: CHESAPEAKE BAY STRIPED BASS AND MENHADEN

The interactions between striped bass and menhaden in Chesapeake Bay illustrate well the need for synchronizing management of related predators and their prey. Menhaden are important prey for striped bass in Chesapeake Bay, as well as, to a lesser extent, for two other harvested predators, bluefish (*Pomatomus saltatrix*) and weakfish (*Cynoscion regalis*). Recent developments raise questions about whether the current high harvest of menhaden is compatible with the recently restored abundance of striped bass or with the goal of rebuilding the bluefish population. Menhaden account for over 80% by weight of commercial landings from Chesapeake Bay, the nation's largest estuary, but management goals for menhaden do not acknowledge its role as prey for other harvested species.



Striped Bass

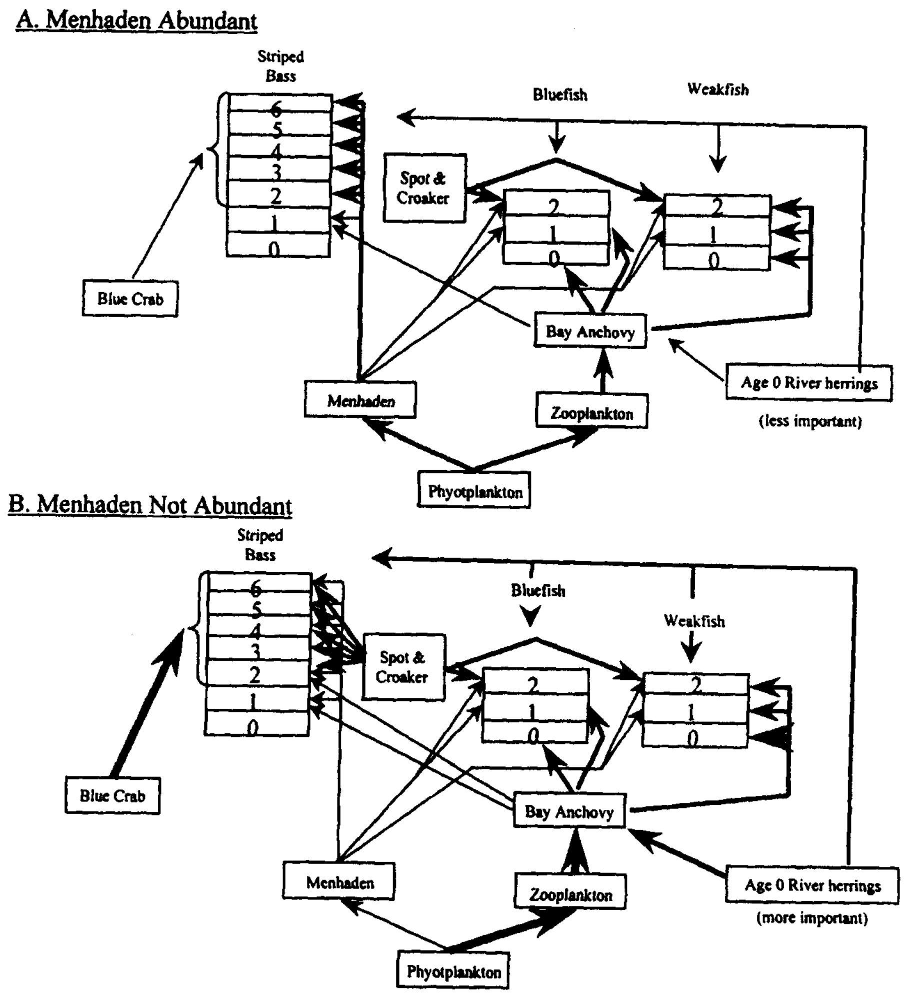
The description of the ecosystem and fisheries of Chesapeake Bay on page 13 is based on the literature review and synthesis by Miller *et al* (1996), augmented by insights of workshop participants. *Figure 1* presents a conceptual model of the interactions among the three major predators in Chesapeake Bay and their dominant prey under two different conditions. In normal years when menhaden abundance is high, menhaden are the principal prey for striped bass aged 1 year and older, while bluefish and weakfish depend more on bay anchovy (*Anchoa mitchilli*) and on two benthic feeding fish - spot (*Leiostomus xanthurus*) and croaker (*Micropogonias undulatus*) (Figure 1A). In years of low menhaden abundance, the pattern of predation and energy flow changes (Figure 1B). Striped bass aged 2 years and older feed more on spot and croaker, increasing the competition with bluefish and weakfish. Bay anchovy production may increase because of increases in zooplankton resulting from reduced grazing on phytoplankton by menhaden. More bay anchovy may increase the growth and survival of weakfish and bluefish, thus further increasing competition with striped bass. Thus, fluctuations in menhaden abundance due to fishing and natural causes have the potential to change the routes of energy flow in Chesapeake Bay and the productivity of its top predators.



Atlantic Menhaden

Menhaden are currently in reduced abundance in Chesapeake Bay. The spawning stock has declined in recent years, to nearly 20% below the long-term average. (ASMFC 2000) The availability of menhaden as prey for striped bass is even further reduced by a skewed age structure for each species. The recovery of striped bass from extremely low levels in the 1980s has been driven by several very good year classes in the 1990s. As a result, the striped bass population is heavily skewed toward fish aged 4 years and less. Stripers of this size are too small to eat menhaden older than one year. Recent menhaden year classes have

Figure 1 [modified from Miller, Houde and Watkins 1996]



Hypothesized Chesapeake Bay Predator-Prey Relationships

been poor, however, so the menhaden biomass is largely composed of older fish that are unavailable to the bulk of the striped bass. Reports of "skinny stripers" in the last few years, fish with low weights for their length, have fueled concerns that menhaden abundance and availability is too low for the recovered striped bass population. Menhaden have declined in both number and weight in the stomach contents of striped bass. A new study by the University of Maryland Eastern Shore's Cooperative Fish and Wildlife Research Unit confirms that striped bass are finding fewer menhaden to eat and, as a result, are growing more slowly. (A succession of good year classes of striped bass in the late 1990s, however, suggests that food, from whatever sources, may be adequate for strong reproduction.)

Striped bass have several potential alternate prey species to turn to when menhaden availability is low. In addition to spot and croaker, as indicated in *Figure 1*, striped bass feed on blue crabs (*Callinectes sapidus*), which are the single most valuable species in the commercial harvest from the bay. Thus another concern raised by the recovery of striped bass and the low availability of menhaden in Chesapeake Bay is the fear that the recovered striped bass are increasing their consumption of blue crabs and are thereby reducing harvests for crab fishermen. Although striped bass predation on blue crabs is not a new phenomenon, the proportion of blue crabs removed by striped bass may have increased, because the striped bass recovery in the late 1990s has coincided with reduced abundance of blue crabs after years of increased fishing effort.

The complex interactions between striped bass and other predators, and menhaden and other prey, present challenges that will best be met by an explicitly multispecies approach.

Another potential prey group for Chesapeake Bay striped bass is the three alosid species, shad (*Alosa sapidissima*), alewife (*A. pseudoharengus*) and blueback herring (*A. aestivalis*). These three anadromous fish supported substantial commercial fisheries in Chesapeake Bay (removals in the order of 11,000 - 19,800 tons per year) until a precipitous decline in alewives after 1970 added to a century-long decline in the other species and brought landings to less than one tenth of those levels in the 1990s. As a result, alosids do not currently show up as significant components of striped bass diets and are not included in *Figure 1*. The principal causes of the decline of alosids are probably destruction of and loss of access to riverine habitat for spawning; an estimated 84% of the original riverine habitat for alosids has been destroyed or blocked by dams (Busch *et al* 1998). Efforts are currently underway to restore Chesapeake Bay alosids, and if they are successful, these fish may once again present a significant source of food for striped bass.

The complex biological interactions in Chesapeake Bay between striped bass and other predators and menhaden and other prey present challenges for managers that will best be met with an explicitly multispecies approach.

Managing these trophically related species in consort rather than in isolation can have the following benefits: (1) it can foster ecological insights that help elucidate management alternatives and their effects; (2) it can anticipate and thus help resolve conflicting interests and allocation disputes on the part of the harvesters of the various parts of this food web; and, (3) it can help society formulate and meet its goals for the Chesapeake Bay ecosystem.

As an example, it is only in a multispecies context that one of the big questions facing management of living resources in Chesapeake Bay can be addressed; that is, given the success in rebuilding striped bass and the desire to rebuild bluefish, which of the possible prey species should feed these two fish? If blue crabs are considered too valuable to be eaten by these fish, it should be possible to reduce predation on blue crabs in the short term by providing more young of the year menhaden via fisheries adjustments and, in the longer term, by providing more alosids, through habitat restoration.

It is also only in a multispecies context that we can consider the effects of competition between striped bass and other predators, such as bluefish. The increase of striped bass has been coincidental with a decline in numbers of bluefish. Can the two species co-exist in abundance, and at what level, or do environmental conditions now favor one over the other?

We won't know until we ask these questions, and look for answers, in an integrated context. What we do know is that striped bass, bluefish and menhaden are each being managed separately, in isolation from each other and with markedly different management objectives. We know that predators and prey must be treated as integral parts of the ecosystem they share, if we are to achieve and maintain "quality" fisheries for either or both.

EXISTING AUTHORITY FOR PREDATOR-PREY MANAGEMENT

Fishery managers already have the authority, without any changes to current law, to consider predator-prey relationships and interactions in fishery management plans. They are not explicitly required to do so, however, nor are they provided with guidance as to how.

Management authority for the various pieces of the ecological puzzles described in the previous sections resides in several different institutions. Fishing for striped bass, menhaden, bluefish, and the alosids comes under the jurisdiction of the Atlantic States Marine Fisheries Commission (ASMFC). Authority for bluefish is shared with the Mid-Atlantic Fishery Management Council, one of eight quasi-federal bodies created and governed by the Magnuson-Stevens Fishery Conservation and Management Act. Horseshoe crabs are regulated by the ASMFC, but blue crabs are managed by the states individually, with no cooperative management under ASMFC (but with some coordination by the federal Chesapeake Bay Program).

Squid and herring management come under the jurisdiction of two federal bodies, the Mid-Atlantic and New England Councils. The New England Council manages cod and other groundfish, but shares responsibility for dogfish with the Mid-Atlantic Council. To complicate matters further, authority for managing the Atlantic's large pelagics, such as tunas and billfishes, falls to the National Marine Fisheries Service and international agreements, where they exist.

The Magnuson-Stevens Act, as currently written, gives the Regional Councils and NMFS both the mandate and the authority to consider ecological relationships, including predator-prey interactions, in fishery management plans and the setting of optimum catch levels under each FMP.

The principal goal of the Act, the national law governing all fishing in federal waters (3 - 200 miles from shore), is to achieve the optimum yield from each fishery [Sec. 301(a)(1)]. Optimum yield, or OY, is defined as providing "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." [Sec. 3(28)(A)] Moreover, the OY is prescribed as "the maximum sustainable yield from each fishery, as reduced by any relevant economic, social or ecological factor." [Sec. 3(28)(B)]

The Act also requires that fishery management plans identify and describe essential fish habitat (EFH) and minimize the adverse impacts of fishing gear on submerged aquatic vegetation and other live and hard bottom habitats [Sec. 303(a)(7)]. The Act does not, however, require that fishery management plans describe, assess or address indirect impacts of fishing on associated species, except those caught incidentally and discarded as bycatch [Sec. 303(a)].

A number of so-called "multispecies" management plans exist; for example, the Northeast Multispecies Fishery Management Plan, which covers a complex of 13 species of groundfish. But rather than attempting to manage these species based on their ecological inter-relationships, the fisheries are "clustered" into a multi-species FMP which is merely an aggregate of fish caught in the same fishery.

Although the authority for predator-prey management already exists, little has been done because fishery managers are not required by law to take any specific actions.

Finally, the 1996 amendments to the Magnuson-Stevens Act (collectively known as the Sustainable Fisheries Act) underscored the need to look at the larger ecosystem and actually directed fishery managers to move toward ecosystem-based management in a number of ways. Congress charged NMFS with assembling a panel to recommend ways to use ecosystem principles to improve fishery management (NMFS 1999). Through new EFH and bycatch provisions, it also initiated the process of collecting and synthesizing basic information about the ecosystems that managed species inhabit, information that will be vital to a broader management approach.

The ASMFC - made up of 15 states from Maine to Florida - is one of three interstate compacts created by the Interjurisdictional Fisheries Act (the other two being the Gulf States Marine Fisheries Commission and the Pacific States Marine Fisheries Commission). The Act, in the words of ASMFC executive director Jack Dunnigan, is "the foundation for the partnership among state and federal marine fisheries agencies."

But when it comes to predator-prey management, the legal mandate for the Interstate Commissions is even less prescriptive than the federal mandate, though it is equally permissive. Which is to say, despite the absence of explicit requirements to consider predator-prey interactions in single-species management plans, interstate fishery managers also have the discretion to factor them in. They are, in fact, at a point on the learning curve similar to where NMFS and the Councils are; beginning to explore predator-prey issues, gathering baseline information on essential habitats, and performing multispecies assessments. Still, none of the state or federal fishery managers have a road map to show where they are going in terms of predator-prey management, much less how they're going to get there.

In the next section, we try and provide some guidance as to how fishery managers should consider predator-prey relationships under the discretionary authority they currently have. At the same time, we realize that, as with most of the "soft" mandates in the law - that is, those expressed merely as goals ("prevent overfishing," "minimize bycatch," etc.) - little is achieved unless and until fishery managers are actually required to take specific actions. That may be especially true of a new and poorly understood concept like ecosystem-based management of marine fisheries.

Recommendations for Synchronizing Management of Related Predator and Prey Species Within Existing Authority

As previously noted, the principal reason predator-prey relationships are not being properly considered in fisheries management is not a lack of authority. To a certain extent, it is due to a lack of discretion. But there is also a lack of guidance as to what information is needed and, most importantly, how it should be incorporated into management decisions.

In fostering an ecosystem approach to marine fisheries management, an incremental strategy is most practicable. We acknowledge that we have much to learn about how ecosystems work, that there will always be uncertainties, and that our balkanized management system is not now and may never be reconfigured into something resembling a holistic institution. Yet ecosystem-based management does not require that we know everything about all the components of an ecosystem. (NMFS 1999) We do know enough to move towards an integrated, multi-species approach to fisheries management by taking better advantage of the current management system. The first step is to understand and protect the interdependency of key predator and prey species within marine ecosystems.

The recommendations in this section and the next, regarding new, ecosystem-based approaches to management, are made within the context of what the National Marine Fisheries Service and the Regional Fishery Management Councils can accomplish under the existing management structure. (Fishery managers currently have the discretion to adopt these or similar actions. The next section of this report recommends ways to make them mandatory.) We are dealing with changing a way of thinking about management, or an approach to making management decisions that is different from, but nevertheless grows out of, our current approach. We are not proposing a radical restructuring of the management system. We are recommending changes we believe can be implemented now, for benefits to fish conservation in the near future.

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A TEMPLATE

We recommend fishery managers follow a step-by-step process for harmonizing management objectives and synchronizing management regulations for related predator and prey species in each Fishery Management Plan developed by federal and interstate management bodies.

The reader will note that the following template, beginning with step IV, focuses on protecting prey species abundance in order to serve conservation of predator populations. This is not, as it might seem, antithetical to a balanced, holistic approach to maintaining healthy ecosystems. There is good reason why, in most cases, we should favor predators in the management mix. (An exception that immediately comes to mind is introduced or invasive species.)

Overfishing predators - which generally live longer than their prey and thus are slower to respond to opportunities created by a decrease in competition at their trophic level - could have a greater and more enduring impact on the stability of an ecosystem than removing species farther down the food chain. (Larkin 1979) Managing for predator abundance, moreover, is less manipulative of the ecosystem and consequently less risky. It requires a much smaller degree of micro-management to reduce fishing pressure on prey populations in order to achieve an abundance of their predators than it does to somehow constrain the number of predators in order to increase removals of their prey.

I Identify major food sources, life histories, trophic dynamics (including competition), and other factors controlling abundance of each managed species.

Integrated management must begin with an evaluation of the available information relative to predator-prey relationships. Generally, descriptions of predators and prey are treated as "background" information in fishery management plans, often no more than a subjective summary rather than a quantitative and qualitative assessment of inter-relationships. In essence, this exercise should be a "mapping" of the fish's place in the community, with emphasis on interactions with other species at different stages in its life history, as well as noting spatial and temporal changes in species associations and interactions.

II Determine "significant" predators and prey of the managed species.

Because many fish species are omnivorous and/or opportunistic feeders, it is critical to determine "significant" interdependencies. Typically, this is accomplished by measuring the percentage of the major prey consistently consumed by a predator. Scientists have noted that relative frequency of prey in the diet remains fairly stable from year to year. (Sykes and Manooch 1979) The Food Web Dynamics Program of the NMFS Northeast Fisheries Science Center has established the following criterion for significance: a prey species is considered significant to a predator if it constitutes at least 5 percent of the predator's diet, as ascertained by stomach content analyses. (To improve understanding of predator-prey interactions, fishery managers should take greater advantage of the databases of stomach content analyses compiled by the NMFS Fisheries Science Centers. Likewise, NMFS should inform Regional Councils and Interstate Commissions about the existence and content of these databases.) No quantitative criteria have been established to identify significant predators, however, so assessments of significant predators have to be made qualitatively. For both predators and prey, once again, significance is likely to change over time so, in developing models of predator-prey interactions, such determinations should be made for juvenile as well as adult life stages.

III Assess population conditions and trends for the key components of the significant food web.

Each FMP should contain an assessment of the status of the population of each significant predator and prey species. Each FMP should describe the character and the extent of the fisheries in which significant predators and prey are taken, either as targeted catch or as bycatch, including a projection of probable future trends in fishing mortality and population status, (e.g., overfished, approaching an overfished condition, fully exploited or recovering).

IV Evaluate the known and potential impacts of prey species abundance on the managed species.

Each FMP should assess what effect, if any, the current status of prey species may have on the present condition of the managed species, and on the future condition of overfished species under rebuilding programs. It should also consider what the effect would be should current trends in the fisheries continue. This exercise would be enhanced by developing a dynamic model of the functional components of the interactions between species.

V Set optimum population levels and age structures and develop precautionary reference points for related species.

Following a re-evaluation of the respective status and current management objectives for significantly related predator and prey species based on how one effects the other(s), FMPs should state the optimum population size and age structure of each. The optimum yield for each species that is fished, directly or indirectly, should be established with the objective of maintaining the optimum population relative to inter-related species. In all cases, precautionary reference points should be established to create buffers against overfishing and to trigger proactive measures to prevent overfishing of prey species.

VI Make specific recommendations for conservation and management of significantly related predators and prey.

If it is determined that the population level of a prey species is inadequate to support the managed species at levels capable of producing the optimum yield from the fishery (as ecologically redefined in step V), or that it is approaching an inadequate condition, the FMP should recommend the appropriate management regulations, incorporating the precautionary approach where data are incomplete or uncertain, as well as identify short-term and long-term research needs. The recommendations should fall into three categories: 1) biological (optimum population size and structure for meeting the goals of the FMP and related FMPs and associated target fishing mortality rates); 2) regulatory (controls on fishing activities, including catch limits, allowable gears, time-area closures, etc.); and 3) institutional (coordination of management bodies, technical and monitoring committees, with shared jurisdiction over the related species).

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RECOMMENDATIONS SPECIFIC TO MANAGING STRIPED BASS AND MENHADEN

In examining striped bass and menhaden in Chesapeake Bay as a case study, workshop participants developed a number of recommendations specific to improving management of these significantly related species. The detail herein should further elucidate some of the undertakings that will be common to synchronizing the management of all predators and prey.

Research

- **Extend the conceptual model of major predators and their prey from Chesapeake Bay to the whole east coast (Maine to Florida).**

  Build a foundation upon which to move forward on fundamental research on important predator-prey interactions throughout the entire migratory range of each associated species. Identify what organisms are involved and to what degree; e.g., what species of prey, in what numbers, are needed to sustain predators, both temporally and spatially? What are the major species linkages in each major region

(New England, Mid-Atlantic, South Atlantic)?

- **Monitor the stomach contents of the three harvested predator species (striped bass, bluefish and weakfish).**

- **Examine the historical variability of alternate prey for striped bass to look for correlated trends in abundance.**

Are there certain prey strongly associated with downswings and/or upswings in populations of striped bass? Examine and compare the time series of abundance levels of striped bass and significant prey species to identify correlations. Look at weather patterns over time, and how they correlate with abundance of predators and prey. Do they respond in similar or different ways? Expand this exercise to consider historical correlations among a suite of forage species (e.g., anchovy, menhaden and blue crab) and a suite of predators (striped bass, bluefish and weakfish).

- **Conduct bioenergetic modeling to determine the coast-wide demand for menhaden by all major predators.**

How much forage does it take to sustain all these predators? What amount of menhaden is being eaten by what age groups of predators? What is the relationship between demand for menhaden and environmental conditions? These and other questions could be answered, at least in part, by developing bioenergetic models to determine what population level is necessary to sustain or grow the population of striped bass and other predators. After developing the striped bass/menhaden model, it could be "run" for alternative prey.

Management

- **Synchronize the management goals for menhaden and its three major (harvested) predators (striped bass, bluefish and weakfish).**

- **Synchronize the management goals for striped bass and its three major (harvested) prey (menhaden, blue crabs and alosids).**

Menhaden and the fish that prey on them are managed under separate plans, with widely divergent and possibly conflicting management goals. For example, the newly recovered striped bass, which supports highly valuable recreational as well as commercial fisheries, is currently managed for maximum abundance, while menhaden, a fast growing and short lived fish which is harvested commercially for a variety of industrial uses, is managed for maximum annual yields. The latter goal does not consider, much less provide for, ensuring enough forage for the dependent complex of non-human predators. Likewise, the setting of target populations of striped bass, bluefish and weakfish does not consider the consequences of management actions relative to available prey.

- **Add predator demand to the factors considered in setting annual total allowable catches of menhaden.**

Menhaden quotas should be established after factoring in the present and future demand of striped bass and other major predators. To the extent the demand is unknown or uncertain, a suitable buffer should be built in to the quota to guard against negative ecological impacts.

- **Reduce the fishing mortality rate on age 0 menhaden.**

Decreasing fishing pressure on first-year fish and focusing the menhaden catch on higher age classes could have positive effects for both the menhaden and striped bass fisheries, by (1) increasing the yield-per-recruit of menhaden, and (2) increasing the biomass of age 0 fish, the age class that is most valuable as forage for striped bass, as well as bluefish and weakfish. Fishing on first-year menhaden could be reduced either through minimum mesh sizes in the net fisheries or closures in areas and/or at times when there is a high proportion of juveniles in the catch, or both.

GENERAL RECOMMENDATIONS TO EXPAND MANAGEMENT AUTHORITY

During the next reauthorization of the Magnuson-Stevens Act, Congress should explicitly require that all federal Fishery Management Plans be reviewed and revised to consider predator-prey interactions, assess how associated species are affected by fishing allowed under each FMP, and establish conservation and management measures that will protect associated species and their respective roles in the ecosystem as well as the integrity and sustainability of the ecosystem overall. Congress should authorize funds necessary to assist NMFS and the Councils (and the Interstate Commissions) in applying ecosystem principles to fisheries research and management under the Act.

We reiterate here, strongly and unequivocally, that Magnuson-Stevens Act provisions on preventing overfishing, minimizing bycatch and protecting essential fish habitat - as contained in the Sustainable Fisheries Act amendments of 1996 - are critical to improved predator-prey management. These mandates become not less but more important, and our recommended changes are intended to build on this foundation, not replace it.

The following recommendations pertain to changes in the Magnuson-Stevens Act. Recognizing that marine ecosystems, in particular those of migratory fish, transcend a number of political and institutional jurisdictions, we recommend that Congress appoint a Task Force to study ways to standardize the goals and harmonize the mandates of the Magnuson-Stevens Act and the Interstate Fisheries Compacts (and their enabling acts), as well as the Marine Mammal Protection Act and other applicable federal laws.

- **Amend the Magnuson-Stevens Fishery Conservation and Management Act to require consideration of predator-prey interactions:**

  - **Require that all fishery management plans include a description of the "significant" predators, competitors and prey for each species in the fishery with, to the extent practicable, an assessment of how the abundance of one effects the others.**

    Under current law, Fishery Management Plans feature a description of the stock and its environment, including ecological relationships and prey species. In most cases, however, these are usually cursory exercises that produce a list of related species and little more. Section 303(a) of the Act – Required Provisions – should be amended to require that each FMP not only identify related species but include a quantitative and qualitative assessment of their relationship.

- **Require consideration of predator-prey interactions in fishery management decisions.**

Amend section 303(a) of the Act to require that all fishery management plans and/or plan amendments describe and evaluate the anticipated effects of management actions on associated species.

- **Add a new National Standard requiring that all management actions take into account the direct and indirect impacts of fishing on other species and their habitats.**

The National Standards (section 301) are the Ten Commandments of the Act, and every FMP, plan amendment or other regulatory action "shall" be consistent with these standards. For that reason, we recommend adding an 11th standard elevating ecological considerations to the level of preventing overfishing, minimizing bycatch and other fundamental mandates.

- **Redefine Optimum Yield to more explicitly incorporate ecosystem considerations and reconsider the utility of Maximum Sustainable Yield in the ecosystem context.**

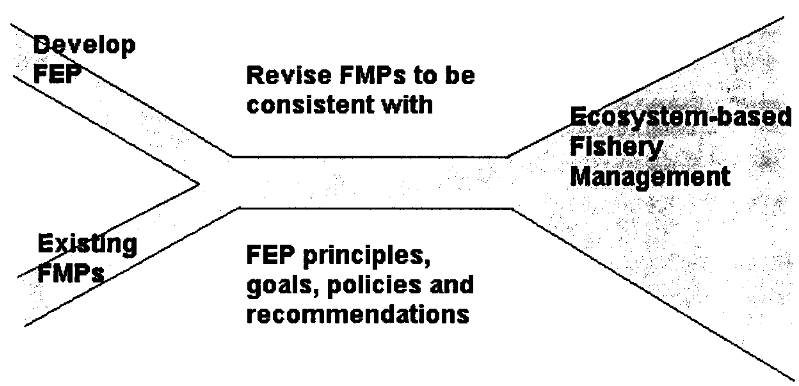
The current definition of optimum yield (OY) in the Magnuson-Stevens Act establishes the population level necessary to produce the maximum sustainable yield (MSY) as the minimum allowable or threshold population. Fishing that reduces a population below this level is prohibited. On the other hand, fishing may be (although it rarely is) constrained in order to maintain the population at a larger size for economic, social or ecological reasons. A more clearly stated obligation to consider ecological factors, including predator-prey relationships, is needed. The present definition does not explicitly require that removals from a fishery minimize fishing induced trophic imbalances, what we call here "ecosystem overfishing."

While OY may account for ecological considerations, the concept of maximum sustainable yield (MSY) is incompatible with an ecosystem-based approach to managing marine fisheries; as either a management goal, or a trigger for defining overfishing (it is both in the current Magnuson-Stevens Act). Under MSY, fishery managers strive to keep a fish population at the level capable of producing the greatest amount of surplus growth available for harvest on an annual basis. Needless to say, that population level may not be what is optimum for preserving the integrity of predator-prey relationships.

Using MSY, FMP definitions of overfishing for individual species are arrived at in isolation from others, even within a management unit of associated species. Instead, overfishing definitions should be expanded to account for the linkage between species. Just as we establish targets and thresholds for individual species (in terms of mortality rates or population sizes) to prevent overfishing, we need to do this for ecosystems, too, by focusing on targets that will preserve the integrity of predator-prey relationships.

Note: Some observers criticize MSY as a management goal, on ecosystem grounds, arguing that it is impossible to maintain all species at a maximum level simultaneously. They seem to be implying that an ecosystem in balance cannot support variety in abundance. It is by no means clear that this is the case. To begin with, the MSY level is not the fish population at its peak size, but rather the size when its reproductive potential is at its peak. These are not the same thing. Moreover, as a population grows beyond the MSY level, natural mortality increases and, in fact, becomes a more important factor in controlling abundance than it is at other levels.

- **Amend the Magnuson-Stevens Act to require each council to develop a Fisheries Ecosystem Plan for each major ecosystem in its area of jurisdiction.**



As the NMFS Ecosystems Principles Advisory Panel recommends, Fisheries Ecosystem Plans (FEPs) would not be intended as a substitute for Fishery Management Plans, but rather a means to augment their effectiveness. The

FEP would be an umbrella document which would include information on the structure and function of the ecosystem each region's managed fishing activities are occurring in, so that fishery managers are aware of the potential impacts of fishing on the various components of the ecosystem, as well as how changes in the ecosystem might affect certain fisheries. The FEP would also establish indices for measuring ecosystem health. Councils would continue to employ FMPs as the primary regulatory vehicle for managing marine fisheries, however, each council FMP should be required to demonstrate that its objectives and conservation and management measures are consistent with the findings and recommendations of the FEP.

- **Encourage fishery management bodies to develop a demonstration Fisheries Ecosystem Plan (FEP) which may serve as a template for subsequent FEPs.**

If FEPs are required of NMFS and the Regional Councils, it will not be before reauthorization of the Magnuson-Stevens Act is concluded, probably no sooner than the end of the 107th Congress in 2002. Proposals already being floated in Congress would charge NMFS with establishing the guidelines for developing FEPs but, once again, this process may not begin until such an amendment is added to the Magnuson-Stevens Act, if it is. In the interim, state and federal fishery management bodies should be encouraged to begin the process of developing the outlines of FEPs for their areas of jurisdiction. Furthermore, those that do undertake FEPs should communicate and coordinate with each other to take advantage of the shared pool of information, innovation and expertise to advance the learning curve as swiftly as possible.

- **Incorporate environmental education into the regular training process for members and staff of the Fishery Management Councils and Interstate Fishery Commissions, as well as the NMFS Office of Sustainable Fisheries and other relevant agency departments. The educational briefings should include a presentation on the Report of the Ecosystems Principles Advisory Panel.**

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ABOUT THE NATIONAL COALITION FOR MARINE CONSERVATION

The **National Coalition for Marine Conservation** (NCMC) is the only national environmental organization dedicated exclusively to conserving ocean fish and their environment. The organization was founded in 1973 by conservation-minded fishermen and today is supported by fishermen, scientists, divers and wildlife enthusiasts - all those who share our goal of making sure there will always be plenty of fish in the sea.

NCMC's conservation programs focus on:

- preventing overfishing and restoring depleted fish populations to healthy levels
- promoting sustainable use policies that balance commercial, recreational and ecological values
- modifying or eliminating wasteful fishing practices
- improving our understanding of fish and their role in the marine environment, and
- preserving coastal habitat and water quality.

For more information on the subject of this report, or other conservation programs, write: NCMC, 3 North King Street, Leesburg, VA 20176 or visit our website at www.savethefish.org.

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