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The Essentials on Estuarine Fish Habitat, its Evaluation and Protection by Federal Fisheries Law

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8. EFH in the Coastal Zone: the Essentials on Estuarine Fish Habitat, its Evaluation and Protection by Federal Fisheries Law

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INTRODUCTION

Robinson Crusoe first learned that he had a human companion on the shores of his island when he found a footprint in the sand. For some of us, the story of Crusoe's stranding and survival provokes a mixture of admiration and envy: admiration at his resourcefulness, envy at his access to a pristine coastline. Imagine finding only scattered footprints, instead of high-rise resorts! The reality is that coastal life is affected in innumerable ways by the concentration of human activity by the sea. Realistically, we may wonder in what condition Crusoe left his island;

did he degrade this habitat? If Crusoe took his family to the island to stay, what could be done to protect important habitat features for the insular plants and animals?

We aim here to take a fisheye perspective on nearshore habitats, and review how federal fisheries law is playing a role in protecting fish habitat. We will consider the ecological concept of habitat, and the degree to which habitat quality is an important issue in the conservation of biological diversity. We then turn to a specific macrohabitat and region, the estuaries of the eastern coast of the U.S., and examine the role that this habitat plays in the region's fish species. Lastly, we will review the features of the Essential Fish Habitat (EFH) provisions of the Sustainable Fisheries Act, which is a federal level effort to protect habitats for fishes, and comment on EFH designations and policy.

HABITAT AND ITS CONSERVATION VALUE

The ecological concept of habitat is quite familiar and is often treated only implicitly. Habitat is defined as the living place of an organism or community, or the type of environment, characterized by its physical or biotic properties (Collin 1998). Habitat clearly is closely related to the notion of ecological niche. Indeed, the conceptual groundwork on the niche concept by early ecologists explicitly included habitat components (Schoener 1988). There have been subsequent efforts to separate the notion of niche as 'ecological role' from habitat as its spatial realization (Whittaker et al. 1967), yet modern ecological theory incorporates habitat features into the niche concept (Schoener 1988).

A difficulty arises in applying the habitat concept. The definition would seem to suggest that habitat is where you find the organism. However, some individuals may be found in suboptimal situations, wherein their appearance or even their survival does not indicate that the location is suitable for long-term persistence of the population. A critical evaluation of habitat is needed, and this need has been recognized in the essential fish habitat components of the Sustainable Fisheries Act (see below). Even so, we are a long way from empirically realizing the critical distinction between the over-generous concept of habitat as “where the organism can be found” and the ideal representation of habitat as “where the population can sustain itself.”

Habitat degradation and loss are commonly cited as factors in reduced biological diversity in a variety of taxa (Cox 1997). Freshwater fishes are notable in this regard. Of North America’s freshwater fishes, which are relatively well studied, about one-third are in need of some protection (i.e., are endangered, threatened, or of special concern: Williams et al. 1989). Habitat loss is a primary cause for extinctions and diminished population size in freshwater fishes (Minckley and Deacon 1991; Moyle and Leidy 1992; Williams and Nowak 1986). That loss is the result of land use practices such as deforestation, water diversion for agriculture, and flood control. Such perturbations have affected fishes in both lentic (lakes and ponds) and lotic (stream) habitats.

Among marine and estuarine fishes, the relative importance of habitat loss versus other threats is less clear-cut, because there is often less information on marine organisms. We consulted a worldwide repository of information on declining and extinct species, the International Union for Conservation of Nature and Natural Resources (IUCN) Redlist (http://www.redlist.org/). The database includes information on the habitats and geographic range of imperiled species, and in some cases designates the causes of decline. The database lists 288 species of threatened marine and diadromous fishes (including bony, jawless, and cartilaginous fishes). The habitat use of 82 of these is presently listed; 72 are listed as marine and 20 are listed as coastal (there are multiple habitats listed for some species). The cause of the threat, or multiple threats, is listed for 70 species. Habitat factors (habitat loss or pollution) are listed in 14 records, whereas direct human impacts (exploitation or accidental mortality such as that from bycatch) are listed in 86 records, and intrinsic population factors, such as poor reproductive rate, are listed in six records. Further investigation on the Redlist species, or at least better documentation in the database, will certainly be helpful; as it stands, habitat factors are a substantial, though not the predominant, threat to the existence of imperiled coastal and marine species. One group on which there should be a focus on threat documentation efforts is the pipefishes and seahorses (Family Syngnathidae). This group has particular habitat needs, often inshore vegetated areas, and comprises 42 of the listed species in the Redlist.

ESTUARY AS HABITAT FOR FISHES

Estuaries provide a multiplicity of ecological services, supporting a concentration of human activity and intense biological production. How can these potentially conflicting services be balanced? Consideration of habitat protection for estuarine fishes should be guided by the following questions, which we use to organize this section:

- What fishes use estuaries? How diverse, and how economically important, are the fishes found in estuaries?
- What are the habitat requirements of fishes during their estuarine residency? What features of estuaries govern the habitat quality for fishes?
- How critical are estuarine habitats for these fishes? How important are individual estuaries for the populations that use them?

A number of excellent reviews of estuarine fish ecology and fisheries science have been published over the past 40 years (Day et al. 1989; Haedrich 1983; Herke and Rogers 1993; McHugh 1967), some with a useful regional focus (Able and Fahay 1998). It is fair to say that estuarine fish assemblages are relatively well known. For most regions, the current literature yields accurate answers to the first of the three questions. In contrast, good information on habitat requirements is available only for some taxa and regions, and answers to the third question are almost entirely speculative.

Estuarine Fish Diversity and Economic Importance

Niche specialists are ubiquitous in the living world; no matter how harsh or stressful the system, organisms have evolved features that permit them to thrive there. Yet among fishes in estuaries, there is little evidence of specialization. Estuarine endemics are few (McLusky 1989). Most fishes using estuaries are present for only a portion of their life cycle. In this respect, estuarine fish assemblages are viewed as possessing low diversity. Two reasons are cited for the limited diversity: high levels of unpredictable variability, and the relative youth of existing estuaries.

Estuaries are dynamic yet relatively resilient. Estuarine physicochemical features (e.g., water temperature, salinity, oxygen) show both seasonal variability, and unpredictable high-frequency variability (Costanza et al. 1995). The estuarine system is also resilient, rapidly recovering from short-term, high-amplitude perturbations; little imprint of stress events remains. Moreover, estuarine organisms are characterized by their high tolerance of change (McLusky 1989).

On longer timescales, it is evident that estuaries have changed despite their resiliency. Over ecological time, i.e., decades to centuries, estuaries have changed in response to intensive human settlement. Changes of this nature include the decline of submerged aquatic vegetation, and increasingly frequent hypoxia events. Over even longer timescales, centuries to millennia, estuaries are affected by sea level rise. Reduced rate of sea level rise and associated stabilization of the coastline permitted estuaries to proliferate. While as a type of natural system, estuaries have as much history as any other marine system, any particular estuary is relatively young (McLusky

1989). This combination of short-term and long-term variability impedes the tracking of resources and limits specialization. Resources are nonetheless abundant in estuaries. Productivity is high due to high nutrient inputs and shallow depths, permitting benthic as well as pelagic primary production. This provides the prospect for rapid growth of individuals and dense populations.

The typical fish species found in an estuary is a marine fish that uses the estuary for a portion of its lifecycle. In most cases, these species use the estuary as a nursery area, where the larvae and juveniles concentrate. Local species in essentially marine families include the winter flounder (*Pseudopleuronectes americanus*), the bluefish (*Pomatomus saltatrix*), bay anchovy (*Anchoa mitchilli*), and weakfish (*Cynoscion regalis*).

Other species are diadromous (anadromous or catadromous), migrating between fresh and salt waters. For example, anadromous striped bass (*Morone saxatilis*), and American shad (*Alosa sapidissima*) spend much of their adult lives in open coastal waters but migrate into fresh waters to spawn. Conversely, the catadromous American eel (*Anguilla rostrata*) spends its juvenile and adult life largely in fresh or brackish waters and migrates to the open sea to reproduce. Some estuarine species are primarily freshwater fishes that possess a degree of salinity tolerance. Fish species that fall into this category include the white perch (*Morone americana*) and the shortnose sturgeon (*Acipenser brevirostrum*).

The estuarine fish assemblage can thus be roughly characterized as comprising a subset of the coastal fish assemblage. Roughly one hundred species can be collected in east coast estuaries of the temperate and subtropical zones, including those species that are only found as occasional or rare records. Typically six to ten species comprise 90%, in numeric terms, of the catch in estuaries of the northeast U.S. (Able and Fahay 1998).

The economic importance of estuaries, in terms of fish production, is disproportionate to the species-level diversity. Many of the fish and shellfish species that are most heavily harvested are dependent on estuaries, usually using estuaries as nursery habitat. Nationally, estuary-dependent species of finfish and shellfish are 75% by mass, and 88% by value (Day et al. 1989). In this light, estuaries can be viewed as natural protein farms; primary production rates are high, and the primary producer energy is efficiently transferred to higher trophic levels.

Estuarine Habitat Features

Space permits only a cursory examination of the habitat variables that can be significant predictors of distribution and abundance of estuarine fishes. Important abiotic factors include salinity, temperature, oxygen, water quality (dissolved and particulate materials in the water), and flow characteristics (turbulence, discharge). Salinity, temperature and oxygen all influence metabolic rate, hence growth and mortality; the interacting effects of these scalars can be complex. The salt distribution within an estuary has an important structuring influence on its biota. Each species has salinity preferences with respect to level of preferred salinity and breadth of salinity tolerance. Short-term (tidal), seasonal, and longer-term (interannual to decadal) changes in fish distribution and abundance can, at least partially, be ascribed to changes in the salt distribution. Vertical distribution is also affected by salinity preference (e.g., Schultz et al. 2003) and vertical distribution in turn affects predator-prey interactions and along-river transport, among other processes.

Small-scale flow features such as turbulence and localized shear can enhance encounter rates with prey items but reduce attack success. At larger spatial scales, the amount of freshwater outflow is known to have a pronounced effect on productivity and the success of fish and shellfish larvae (Sutcliffe 1973). The recruitment of estuarine-dependent species such as winter flounder can be greatly enhanced by circulation gyres that retain larvae in an estuary, rather than ejecting them into coastal water (Crawford and Carey 1985).

Biotic features important to fishes include the abundance and types of submerged aquatic vegetation or algae, the abundance of appropriate food, and predators. Vegetation provides structure and is linked to water quality. The abundance of food is the main determinant of individual growth, and therefore survival; rapid growth through stages that are vulnerable to starvation and size-limited predation is key to survival of the early-stage fish in estuaries (Houde 1987).

Finally, an estuary's overall habitat quality is partly a function of its connections with other marine systems. To serve effectively as a nursery that produces early life-stage fishes, an estuary must have a supply of larvae or spawning adults. Larvae may have to travel some distance across the continental shelf and then penetrate the estuary. Following completion of the estuary-resident life stages, individuals migrate out, often to overwinter on the shelf.

An estuary whose function has not been severely impaired by human disturbance should support a relatively diverse assemblage of fishes. Inverting this conditional is justified; if a relatively diverse assemblage is evident, then ecosystem functions are likely to be intact. This is the reasoning behind development and implementation of indices of biotic integrity that use metrics of faunal assemblages such as fish diversity as indicators of system condition. One such tool for estuarine fish assemblages is the Estuarine Biotic Integrity Index or EBI (Deegan et al. 1997). The developers of this metric compared fish assemblages in medium-quality estuaries relative to degraded sites (based on nitrogen loading, chlorophyll and macroalgae, eelgrass and oxygen levels, and evident physical alteration). They found that degraded sites harbored fewer fish species, at lower abundance, representing a lower diversity of life-history strategies.

Human impacts on estuarine habitats arise from a broad range of activities over a global scale. Direct human use of estuaries has an evident effect; such activities include shoreline development, fishing, dredging, diversion of water for power plant cooling, and point-source pollution. However, some of the threats to coastal waters involve changes in the quality and quantity of freshwater inputs to estuaries, the atmospheric deposition of contaminants, and climate change due to greenhouse gas emissions (National Research Council 1994). Thorough efforts to manage the loss of estuarine habitat by shaping how people act will need to look far inland.

Requirement for Habitats in Estuaries

The characterization of a species as estuarine-dependent implies that there is an absolute requirement for estuarine habitats, during at least a portion of the life cycle. What observations support this characterization? Most commonly, a species is considered estuary-dependent if its early life-stages, i.e., eggs and/or larvae, are found in high concentration in estuarine habitat. It is debatable whether such observations indicate that there is an absolute requirement for estuarine habitat. Consider that the volume of water in estuaries is a small fraction of the water volume in the coastal zone. This means that the concentration of a life stage could be orders of magnitude higher in estuaries, and yet estuaries might still contain only a minority of the population. This is not necessarily inconsistent with the notion of estuarine dependency, but it underscores the need to take the analysis of estuarine importance further than the presence or abundance of the organism. Recent critical analyses of the nursery function of estuarine and coastal areas have emphasized this point (Beck et al. 2001; Heck et al. 2003).

Assessing the requirement for estuarine habitats entails analyzing fitness components for individuals that use the estuary versus those that do not. Even if they are the minority of the population, might the estuarine individuals be in the best environment and have the brightest prospects? Surprisingly, very little is known about the relative success of estuarine vs. coastal individuals; comparisons of growth rate and survival rate are needed.

Assuming that a species is dependent on estuaries, and then extending the notion of estuarine dependence to a smaller scale, the issue arises of whether a particular estuary is critical to the health of the population that inhabits it. If the habitat in this estuary were damaged, would the population persist; what would be the prospects for population recovery if the estuary were rehabilitated? These are questions of population structure, the degree to which there is exchange among different regions in the range of the species. Two ends of a spectrum of possibilities can be outlined. Populations may be closed, in which case each estuary is used exclusively by a population of the species, with no exchange among the populations. Alternatively, populations may be open, in which case there is free exchange among estuaries; an individual that spends its early stages in one estuary is likely to spawn in another estuary. Where estuarine fish species lie along this spectrum is an issue critical to their management. Loss of a particular patch of estuarine habitat will have a relatively small impact over a broad scale if the populations are open, and recovery of local abundance is likely to be rapid should the habitat be restored. Alternatively, if populations are closed then the effects of local habitat loss will be concentrated in local reductions of abundance, and recovery following local habitat restoration will be limited.

Marine populations are expected to be relatively open because of the potential for larval dispersal. Marine organisms, including fishes, have a planktonic larval phase that is at least potentially dispersive, and many migrate as adults as well. The mobility of these organisms means that there is potential for exchange of individuals among patches of habitat over the species range. One way of testing for the degree to which such exchange occurs is to estimate the amount of genetic differentiation among locations over the range of a species. If individuals commonly move, and successfully reproduce in the regions to which they immigrate, the resulting genetic exchange or gene flow will result in relative genetic uniformity among locations. Many such studies have been conducted; the general conclusion is that marine populations are genetically less differentiated than freshwater populations (Gyllensten 1985), as the result of greater gene flow over the species range. In coastal fishes, a longer larval phase increases the amount of gene flow (Waples 1987). But among coral reef fishes, possessing a larval phase that can potentially disperse for weeks to months, genetic differentiation among island populations can be pronounced (Taylor and Hellberg 2003) and is not clearly dependent on larval duration (Shulman and Bermingham 1995). The expectation that marine fish populations are generally open is being reconsidered; sophisticated empirical assessments indicate that return to and use of natal sites are pervasive among demersal fishes (Swearer et al. 2002).

Anadromous fishes have a well-known tendency to return to natal rivers and might be expected to show genetic characteristics of closed populations. This is not always the case. Pacific salmonids (genus *Oncorhynchus*) maintain levels of geographic similarity more like that of marine species than freshwater species (Gyllensten 1985). Analysis of anadromous fishes in eastern estuaries reveals a mixed picture; there is significant geographic differentiation of Atlantic sturgeon and striped bass, but not American shad (Waldman et al. 1996).

Evidence is also accumulating that marine-estuarine fishes are closed to an unanticipated degree. As discussed above, such species tend to migrate out of estuaries for a portion of their life cycle; this creates the potential for wandering. But in winter flounder there are detectable genetic differences among larvae from adjacent estuaries in Long Island Sound (Crivello et al. 2004). Natal site fidelity has also recently been demonstrated for weakfish, using otoliths (earstones) as a recorder of individual environmental history (Thorrold et al. 2001). The chemical signature in the core of otoliths of adults returning to estuaries to spawn indicates that these adults have a strong tendency to return to their natal estuary.

FISHERIES MANAGEMENT AND ESSENTIAL FISH HABITAT

Recent changes in federal fisheries law have brought the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NOAA/Fisheries) directly into the role of protecting certain fish habitats. This is a major expansion in role for the Agency, although habitat protection was an element of NOAA/Fisheries even before its relocation from the U.S. Department of Interior into the Department of Commerce in 1970. There is considerable precedent for federal involvement in protecting fish habitat (Table 1), reflecting a long history of concern for degradation of aquatic (as well as terrestrial) habitat. Several of these laws require environmental review procedures that could involve NOAA/Fisheries consultation.

Before going over details of the legislative action and its implementation, it is worthwhile to briefly examine how fish populations are assessed and managed by NOAA/Fisheries. Information is collected on the abundance of an exploited population (stock) or group of stocks, and characteristics of the stock such as its age structure, based on catches by the fishery and fishery-independent surveys. This information is assimilated to estimate how many new individuals the existing population is likely to produce. Such ‘recruitment’ is expected to be a function of the abundance of the stock and will occur at low rates if the reproducing stock has been fished to low abundances. A basic objective of the traditional population dynamics approach in fishery science has been to advise fishery managers of the long-term effects of catch rates on population replenishment, so that ideally the overexploitation of a stock can be avoided (Cushing 1973; Rothschild 1986).

The tendency of a fishery to overexploit its stock is attributable to many factors, one of which is recognized to be the shortcomings of the population dynamics approach. A key issue is how to deal with variability. One manifestation of the variability in exploited populations is the amount of scatter around a line that purports to fit a stock-recruitment relationship. It has long been recognized that environmental factors such as weather contribute much to this variability. Should this variability be regarded essentially as noise that will be averaged out over time, or as reflecting larger ecosystem processes that have a pronounced effect on the dynamics of the stock? If the former, then the population dynamics approach to fishery management should perform well in the long run. If the latter, then ecosystem processes will at least need to be accommodated in the assessment of the stock, if not become a central focus of fishery science. This latter view is gaining proponents. Accompanying this shift in perspective is the notion that it is better to err on the side of under-exploiting a stock, given the evidence that environmental perturbations can drive population levels. In response to this recognition, there has been a shift in resource management toward a more comprehensive and pessimistic approach. The ‘Ecosystem Approach’ and the ‘Precautionary Principle’ are both making their way into fishery management policy.

A major change in national fishery policy, that among other things incorporated these shifts in perspective, was enacted with the Sustainable Fishery Act of 1996: (SFA; Public Law 104-297; http://www.nmfs.noaa.gov/sfa/magact/). This act reauthorized and amended the Magnuson-Stevens Fishery Conservation and Management Act of 1976 (PL 94-265). The SFA explicitly included an ecosystem approach provision in federal fishery management, by requiring that consideration be given to the protection of essential fish habitat (EFH). In it, EFH is defined as “those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity.” The Final Regulations for EFH (50 CFR Part 600, 2002; http://www.nmfs.noaa.gov/habitat/habitatprotection/efhfinalrule.pdf) clarified this definition on a term-by-term basis: 1) The reference to waters is intended to apply to aquatic areas and their physical, chemical and biological properties, thereby excluding the non-aquatic portions of the watershed. 2) Substrate refers to the physical bottom (sediments and underwater geological features) and its biological associates. 3) Features of the water and bottom are necessary to fish if the features are required to support a managed stock at a desirable level. 4) Fish potentially refers to any marine animal and plant life, excepting mammals and birds. 5) The last phrase of the definition implies that EFH needs to be identified for each stage in the life cycle (egg, larva, juvenile and adult), and reinforces the point that EFH extends to prey requirements.

Implementation of the EFH elements of the SFA involved habitat identification by NOAA/Fisheries and the eight Regional Fishery Management Councils, and designation of EFH by the Secretary of Commerce (NOAA/Fisheries Magnuson-Stevens Act Implementation Activity List; http://www.nmfs.noaa.gov/sfa/activity/). The steps of this process included: 1) synthesis of available habitat use information for each managed stock; 2) application of guidelines for description and identification of EFH habitat, threats to the EFH functions and values, and recommended measures for the conservation and enhancement of EFH; 3) review of federal activities that impact EFH, (including examination of Commerce Department activities that could affect EFH); and 4) development and implementation of policies for consultation with other federal agencies concerning their activities that could be EFH-detrimental. The steps were completed within three years of SFA enactment; EFH designations were announced beginning in March of 1999. More information about each of these steps follows.

NOAA/Fisheries' Fishery Science Centers developed EFH Source Documents on the essential fish habitat for all Federally-managed stocks, by drawing upon autecological information available from prior studies. The information used included estimates of the size and geographic range of stocks, the habitat used by each life stage, and the distribution of these habitats. There is considerable heterogeneity in the quality and detail of existing data on habitat use across different species and life stages. To accommodate this heterogeneity, essential habitat findings are characterized by level of analysis (50 CFR Part 600 and Federal Register, vol 67:12, January 17, 2002). In Level 1, presence/absence distribution data are available for some or all of the geographic range. In Level 2, habitat-related densities of the species are available. EFH is designated as Level 3 when growth, reproduction, or survival rates within habitats are available, whereas designation as Level 4 means that production rates by habitat are available. The lower levels of analysis can be regarded as permissive descriptors of EFH. There is a risk that individuals may have poor prospects in the habitats so identified, or that the production of new fish biomass in these habitats might be relatively minor (see Requirement for habitats in estuaries section above). These permissive descriptors are most useful in situations where the stock is at low abundance; in such cases, it is precautionary to suggest that wherever individuals are or have been found should be treated as essential habitat, at least until the stock has recovered. Hence, the EFH Final Rule (50 CFR Part 600, 2002) states that all habitats in use should be considered essential to depleted stocks, whereas only a subset of those (identified by higher levels of analysis) would be considered “essential” for healthy, fully- or under-exploited stocks. Some habitats of particular ecological value are designated as Habitats of Particular Concern (HAPC). These are EFHs that are especially rare, vulnerable, or uniquely important ecologically. One such HAPC is submerged aquatic vegetation (e.g., eelgrass [*Zostera marina*]) designated for its use by summer flounder (*Paralichthys dentatus*; MAFMC, 1999).

An initial EFH evaluation report has been produced for most of the species managed by the Fishery Management Councils under 43 Fishery Management Plans. These “Essential Fish Habitat Source Documents” describe individual species or guilds of species as well as their habitats and form a library of species-specific knowledge useful for developing EFH Assessments and Conservation Recommendations during the consultation process. The publications are reviewed and will be amended as additional information is obtained. They are published as NOAA Technical Memoranda available online and in hard copy. A portion of the Source Document for winter flounder (Pereira et al. 1999) is reproduced in Table 2(a,b). It describes how various physical and biological components of habitat are used by different life stages of the managed species.

Fishery Management Councils that develop the actual harvesting controls for specific stocks were charged with modification of the Fishery Management Plans (FMPs) to reflect the EFH for each stock. Each plan was required to consider both fishing and non-fishing activities that could adversely affect EFH. The guidance offers that

> Consideration of EFH should be incorporated into amended FMPs such that the FMPs identify and describe the following: (1) activities with known or potential adverse effects on EFH (threats); (2) actions required to counter threats to the existing and historic EFH; and (3) actions to restore or enhance EFH. In this context, "restore" means to reestablish the habitat and associated functions to a desired level that is based on feasibility and historic information; and "enhance" means to improve the

> habitat and associated functions to a desired level that is based on feasibility and historic information. FMP recommendations should assess impacts cumulatively and individually for all activities that adversely affect EFH. With regard to fishing activities, each FMP must include assessments of how fishing equipment used in areas with EFH may potentially cause adverse effects (NOAA Fisheries 1997).

The councils are required to take steps to avoid, reduce or mitigate these effects through restrictions on the gear or the allowable catch. With regard to nonfishing activities, each FMP must identify other activities with potential adverse effects and consider the combined impact of fishing and nonfishing activities on the EFH and the stock. Nonfishing activities in estuaries include dredging, filling, shoreline modification with bulkheads and riprap, vessel-associated disturbances, and discharges of waste materials.

The SFA requires that other federal agencies (e.g., the Army Corps of Engineers) consult with NMFS if they are planning, funding or authorizing activities that may be detrimental to EFH. The agency provides a report to NMFS that describes the proposed activity, assesses the impacts on EFH, and details the measures that will avoid, minimize, or mitigate the impacts. The lead agency is required to respond to the Conservation Recommendations that NOAA/Fisheries may make upon its review of the EFH assessment, although it is not required to follow these recommendations. While State agencies are not similarly required to initiate consultation with NMFS prior to potentially harmful activities, NOAA/Fisheries is required to make recommendations if it learns of such activities (SFA; Public Law 104-297).

The consultation process is modulated in various ways, according to the severity of the threat to EFH and other considerations (50 CFR Part 600, 2002). A General Concurrence is issued to agencies whose responsibilities do not represent a threat to EFH (e.g., the Social Security Administration). Programmatic Consultations cover groups of actions, in cases where the individual and cumulative impacts are expected to be minimal. Abbreviated Consultations deal with activities that have modest individual or cumulative impacts and can be dealt with expeditiously. Expanded Consultations are appropriate for Federal actions that would result in substantial adverse effects to EFH and/or require more detailed analysis to enable NOAA/Fisheries to develop EFH conservation recommendations.

A relevant, instructive and local consultation process took place with the Army Corps of Engineers regarding dredging in New Haven Harbor, CT. The Federal Navigation Channel at New Haven requires periodic dredging to maintain a depth of 35 feet at mean low water. The Harbor contains significant EFH for spawning and early development activity by winter flounder, a SFA managed species. The Corps coordinated both an EFH and Fish and Wildlife Coordination Act (F&WCA) consultation with NMFS. Conservation Recommendations were developed to avoid dredging during the spawning and early life stage development period for winter flounder (February through May) and American lobster and shellfish (May through September). The recommendation was: "… the proposed maintenance dredging effort be designed and implemented in such a fashion as to avoid placing additional stress on the reproductive and early life stage populations of the winter flounder, American lobster, northern quahog (hard clam) and American oyster populations that utilize the habitat provided within New Haven Harbor." (NOAA/Fisheries 2002).

PROSPECTS FOR EFH RESEARCH APPROACHES

The EFH provisions of the SFA will provide meaningful protection for managed stocks only if there is accurate information about habitat use. This is a tall order, requiring considerable additional research. Existing data are primarily in the Level 1 category; they tell us only whether the species was found there, at least once. The limited degree to which this informs us about the true habitat needs of a species has been discussed above. In this section, we provide a brief overview of some research approaches that will yield a more substantive assessment of EFH.

Sampling surveys that are designed to estimate the abundance of organisms associated with habitat features are required for Level 2 assessments of EFH. Such surveys must be carefully designed to yield statistically meaningful estimates of density. In particular, the location of samples should be randomized within precisely drawn and thoroughly characterized strata. Strata can be based on region within the estuary (i.e., upriver/downriver), depth, and/or bottom type. Gear that measures biotic and abiotic features of the habitat should be used in conjunction with the fish collecting gear. A notable example of such a survey in our region is the Hudson River Estuary Monitoring Program, conducted by the Hudson River Utilities (e.g., ASA Analysis and Communication 2003). This long-term survey, conducted with slight modifications since 1974, samples virtually the entire 246 km length of the estuary for most of the year, with multiple gears. The survey is designed appropriately for interannual, along-estuary, and among-habitat comparisons of abundance.

Experiments that measure performance and condition of individuals that live in different habitats are needed for Level 3 information on EFH. Recent growth history can be examined via analysis of the daily age record in otoliths (Jones 2002; Stevenson and Campana 1992). Such analyses have revealed that early life-stage fishes collected in different locations in an estuary can vary significantly in growth rate (e.g., Jordan et al. 2000). Another proxy for recent growth rate is the RNA/DNA ratio, based on the expectation that transcription is relatively rapid in a rapidly growing individual (e.g., Folkvord and Moksness 1998). In addition to RNA/DNA, there are other biochemical techniques, and some morphological indices, for estimating the overall condition of young fish (reviewed in Ferron and Leggett 1994). Development of these condition indices was stimulated by a long-standing interest in the influence of starvation on year-class success, and we expect that they will be used more generally to inform habitat studies.

Tests to demonstrate the influence of habitat on the condition of estuarine fish lack accuracy and power if the fish move readily among habitats. In such cases, the habitat at which an individual is captured is not a reliable indicator of habitat history. To ensure accurate information on habitat history, some researchers have recently conducted experiments in which demersal or benthic fish are confined in cages placed in different habitats (Duffy-Anderson and Able 1999; Phelan et al. 2000).

Level 4 data, providing population-wide estimates of fish production associated with various habitats, will be especially challenging. Accurate estimates of population-wide production will require information on the source of individuals, in particular knowing the juvenile habitat in which rapid first-year growth occurs. A key problem will be, therefore, tracing movement from juvenile habitat to locations where individuals aggregate for winter or subsequent spawning. Tools that are available include analysis of various chemical tracers of habitat history, such as otolith microchemistry or stable isotope analysis, as well as methods of tagging individuals, such as passive integrated transponder (PIT) tags, coded-wire tags, and ultrasonic telemetry.

Common to all levels of EFH determination is the issue of spatial and temporal scale within which habitat use patterns are best determined. A possible beginning for this component of the analysis is to consider the spatial and temporal scale of the threats to habitat; for instance, an exclusive focus on microhabitat use, at the centimeter to meter scale, would be inappropriate if disturbances tend to occur on a kilometer-wide scale. The extent of variability in habitat use also needs to be considered in designing EFH analyses. A study of winter flounder juvenile habitat use, in three estuaries for two subsequent years, found that relative densities of flounder in different habitats varied among estuaries and between years (Goldberg et al. 2002). This indicates that considerable sampling replication over time and space is needed along with assessment of the factors that influence the variability of habitat functions and values.

FINAL THOUGHTS

There is increasing emphasis on protection of habitat and ecosystem processes in marine and estuarine systems. These systems function best, with regards to long-term population viability and biodiversity, when at least some portion of the habitat is left relatively undisturbed. This shift in perception has been articulated within federal fisheries legislation via the EFH provisions of the Sustainable Fisheries Act. Other fisheries agencies have adopted similar approaches (e.g., the Atlantic States Marine Fisheries Commission: Stephan et al. 1999). Within the conservation community, there is a strong parallel movement to protect habitat, which is articulated via the movement to establish marine protected areas (e.g., the Conservation Law Foundation's MPA Initiative, http://www.clf.org/advocacy/MPA_page.htm).

What will habitat protections yield for fisheries? How does a habitat protection policy compare in efficacy to conventional management approaches based on limiting fishing mortality within the stock? Answers to these crucial questions will take time. The short review we offer here suggests the following points:

1. Habitat degradation has been a significant cause of biodiversity loss in many ecosystems, including aquatic and marine systems; conversely, habitat protection is likely to yield benefits to stock management and biodiversity conservation.

2. A number of coastal and diadromous species use estuaries, and may be estuarine dependent. The group represents a substantial portion of the harvested species.

3. Indications that some of these estuarine populations are closed, relying nearly exclusively on one particular estuary, has important implications for how estuarine habitat should be managed; in such cases, harm to an estuary will inflict harm on a single population of a species, and its recovery will be limited by its own regeneration rather than replenishment from other populations.

4. One factor affecting the success of EFH provisions, from a management perspective, is the identification of truly essential habitat meriting vigilant protection measures. Existing EFH determinations are only a first, small step; the remaining steps will require substantial amounts of well-designed research and monitoring, employing research techniques that assess the condition of individuals in different habitats and the production rate of these habitats. Designs will need to include replication over space and time, especially given the variability of estuarine ecosystems.

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Table 1. Some federal legislation relevant to habitat-based protection of fisheries (compiled by Ross 1997).

1928	Act to Provide for the Conservation of Fish, and for other Purposes
1934	Fish and Wildlife Coordination Act
1938	River and Harbors Act (1899) amendments
1965	Water Quality Act
1968	Estuary Protection Act
1969	National Environmental Policy Act
1972	Coastal Zone Management Act
1972	Marine Protection, Research, and Sanctuaries Act
1977	Clean Water Act
1982	Coastal Barriers Resources Act

Table 2. Parameters of essential fish habitat for winter flounder, from the EFH Source Document for this stock (modified from Pereira et al. 1999).
a) Selected abiotic parameters

Life Stage	*Temperature*	*Salinity*	*Dissolved Oxygen*	*Depth*
Eggs	*highest hatch at 3-5º C; 18º lethal*	*10-32 ppt; little effect on survival or hatch*	*11.1-14.2 mg/l*	*0.3-4.5 m; $\leq$ 90 m on Georges Bank*
Larvae	*hatch 1-12º C; most abundant 2-15º C*	*3.2-30 ppt; higher on Georges Bank*	*10.0-16.1 mg/l*	*1-4.5 m*
Young of Year	*2-29.4º C; preferred temperature 19.5º C*	*23-33 ppt; 5 ppt lower avoidance level*	*constant 2.2 mg/l or diurnal 2.6 to 6.4 mg/l variation adversely affects growth*	*0.5-12 m*
Juveniles	*common 10-25º C*	*19-21 ppt; 10 ppt lower avoidance level*		*peak abundance in spring 18-27 m in Long Island Sound; 11-18 m in Canada*
Adults	*0.6-23º C; 12-15º C preferred; upper incipient lethal level 27º C*	*15-33 ppt*	*Lower dO_2 avoided by larger fish and/or reduces growth*	*mostly 1-30 m inshore, shallowest while spawning*

Table 2 (cont.)
b) Selected biotic parameters

Life Stage	*Vegetation*	*Predators*	*Prey*	*Migration*
Eggs	*Diatom mats, drifting macroalgae*			
Larvae		*Mackerel, Sarsia tubulosa*	*nauplii, invertebrate eggs, protozoans, polychaetes*	
Young of Year	*Ulva, eelgrass and unvegetated adjacent areas*	*Crangon sp., summer flounder, striped searobin (Prionotus evolans)*	*amphipods, copepods, polychaetes, bivalve siphons*	*limited; deeper for first winter*
Juveniles		*Cormorants, snapper bluefish, gulls*	*sand dollars, bivalve siphons, polychaetes, amphipods, Crangon sp.*	*movement to deeper waters as size increases*
Adults		*Goosefish, spiny dogfish, sea ravens, striped bass, seals, sculpins*	*amphipods, polychaetes, bivalves or siphons, capelin eggs, crustaceans*	*inshore in fall; offshore in spring; long post-spawn migrations in some fish*