7.0 RESEARCH AND INFORMATION NEEDS

The regulatory text of the Interim Final Rule directs the Council to include in the EFH amendment recommendations, preferably in priority order, for research efforts that the Council and NMFS view as necessary for carrying out their EFH management mandate. The need for additional research is to make available sufficient information to support a higher level of description and identification of EFH. Additional research may also be necessary to identify and evaluate actual and potential adverse effects on EFH including, but not limited to, direct physical alteration, impaired habitat quality / functions, cumulative impacts from fishing, or indirect adverse effects such as sea level rise, global warming and climate shifts, and non-equipment related fishery impacts. The need for additional research on the effects of fishing equipment on EFH is also included. The research needed to quantify and mitigate adverse effects on EFH identified in this amendment and determined to be an impediment to maintaining a sustainable fishery and the contribution of the managed species to a healthy ecosystem is identified.

The research recommendations include expanded life history information that will result in the comprehensive identification of the habitat requirements of the species or species assemblages, including all life history stages, as well as habitat-related information that defines the interrelationship between the species, the environment and the food web. The identified research needs also include information on adverse impacts from both non-fishing and fishing activities. Fishing activities include both recreational and commercial fishing equipment or practices.

The Council has conducted an initial inventory of available environmental and fisheries data sources relevant to the managed species (Table 5). This inventory should illuminate major species-specific habitat data gaps. Only juvenile Atlantic cod has a level of information higher than Level 2. For example, the highest level of information available for some life history stages of many species managed by the Council is Level 0. Although not defined in the Interim Final Rule, Level "0" has been used to identify those areas where very little information exists, if any at all. Gaps in data availability (i.e., existence, accessibility, use and application of the data) and in data quality (including considerations of scale and resolution; relevance; and potential biases in collection and interpretation) are identified. The recommendations for basic life history information are intended to provide the Council comprehensive identification of the habitat requirements of the species, including all life stages, as well as habitat-related information that defines the interrelationship between the species, the environment, and the food web.

Implementation of the Magnuson-Stevens Act requires a program of research that provides information to support higher levels of description and identification of EFH. Research on the ecology of fish and their linkages with habitat is the foundation for such description and identification of EFH. The diversity, quality, and extent of habitats are among the most significant environmental determinants of distribution, abundance, and diversity of fishery resources. At present, the contribution of many of these habitats to the productivity of managed fishery species is unknown. Scientific information is required on

the structure and function of fishery habitats to judge the impacts of threats and provide recommendations to protect and restore habitats.

In considering research and information needs, the Council hopes to integrate and coordinate as closely as possible with the NMFS Habitat Research Plan (HRP) (Thayer, G.W., J.P. Thomas, and K.V. Koski. 1996. The habitat research plan of the National Marine Fisheries Service. *Fisheries* 21(5) pp.6-10). The HRP provides a framework to conduct coastal and estuarine research and transfer results to those management components involved in permit reviews, development of habitat sections of FMPs and Protected Species Recovery Plans, and development of restoration options and plans as part of the Natural Resources Damage Claims. While not so stated, EFH is implicit in this plan. Under provisions of the Magnuson-Stevens Fishery Conservation and Management Act, the three tasks given to the Councils (identify and describe EFH; identify threats to EFH; and make recommendations for the conservation and enhancement of EFH) readily translate into four of the five research areas contained in the HRP:

- Research to identify EFH relates to HRP research area 1, "Ecosystem Structure and Function." Elements of the four-level process to describe EFH have been identified in the HRP.
- Fishing and non-fishing related threats to EFH relate to HRP area 2, "Effects of Habitat Alterations on Living Marine Resources."
- Conservation and enhancement measures, including restoration, relate to HRP area 3, "Habitat Restoration Methods."
- Research that is required to identify responses to degradation as well as ecosystem responses to conservation and enhancement measures relates to HRP area 4, "Indicators of Habitat and Living Marine Resources Degradation and Recovery."

The need for such a research program of coastal and estuarine research is not only mandated by the Magnuson-Stevens Act, but also was recognized by the National Academy of Sciences in their 1994 National Research Council Report on Priorities for Coastal Ecosystem Science which states that among the research areas requiring scientific information to eliminate shortcomings in our understanding of coastal habitat needs, functions, and processes are: relationships between habitat structure and function; recruitment and population and community development in both natural and restored ecosystems; processes that regulate and control interannual variability in populations; techniques, including the use of dredged material, for coastal habitat restoration; and, improved physical and biological models to help advance the design of ecosystem restorations.

The Council hopes to help direct NMFS habitat research priorities by identifying EFH research according to the five categories NMFS uses to structure its annual habitat research. Within these categories, the Council has identified a range of research and information needs from the short-term to the long-term.

- Short-term needs are defined as those which the Council believes will be required

to meet the objectives of the EFH strategic plan within the five-year timeframe described in the plan.

- Long-term needs are defined as those the Council believes would be useful for improved habitat management, but probably will not be accomplished in the next few years and are not necessary for the Council to meet the immediate objectives of the EFH strategic plan.

The short-term and long-term designations reflect the Council's expectation that some types of needs can be met with information that already exists but that was not available to the Council for the current EFH process or information that could be obtained in the next few years. Although the Council has also attempted to provide the relative priorities of the needs, the designation of a need as either short-term or long-term is an implicit prioritization. Obtaining the information needed to meet the objectives of the Council's five-year plan is more important that obtaining the long-term type information.

7.1 ECOSYSTEM STRUCTURE AND FUNCTION

7.1.1 Oceanographic Information

Water mass characteristics limit the distribution of fish and invertebrates on a regional scale, but fish react to their surroundings on a very fine scale. To assist fishery management, oceanographic work must help make the distinction between large scale features that determine the distribution of fish populations and the finer features that determine the movement of fish over fishing grounds.

Long-term

1. Model water masses and develop predictive capabilities for the movement of water masses.
2. Provide information on the effects of water mass movements on biological communities.

7.1.2 Sediment Mapping Information

The general sedimentary structure of the New England shelf is known but the detailed distribution and extent of sediment types is only known in a few, relatively small areas.

Short-term

1. Undertake high resolution mapping of the most important sediments and topographic bedforms in areas of the Gulf of Maine, Georges Bank, southern New England, the mid-Atlantic, and their estuaries and bays.
2. The Department of Defense should make available to the Council and NMFS information it has collected on the sediment and biogenic structures and topographic bedforms of the Gulf of Maine, Georges Bank, southern New England, and the mid-

Atlantic and their estuaries and bays.

7.1.3 Species Life History, Distribution, and Abundance Information

Life history information and data on abundance and distribution of fishes are basic to natural resource management. Although basic characteristics are known for many managed species, they are not known for all life history stages of all species.

Short-term

Existing Data and Information

1. NMFS should provide the Council with information on the landings of each Council-managed species, identified to the ten minute square from which they were harvested.
2. NMFS should homogenize / standardize the landings data (e.g., interview trips vs. non-interview trips).
3. Review and monitor federal and state historical databases for trends in abundance and distribution with an emphasis on unassessed species.
4. Investigate egg and larval data from power plant surveys to verify and possibly identify inshore distribution and abundance of these life stages.

Additional Biological Sampling -- This information is needed for all Council-managed species.

5. Enhance biological sampling to complete life history distributions and abundances of managed species in the New England region. Investigate habitats of the Gulf of Maine and Middle Atlantic Bight that currently are not sampled, but are likely habitat for important commercial species managed by the Council. Conduct biological surveys of continental slope habitats not adequately sampled for abundance and distribution of species occupying deepwater offshore habitats.
6. Provide information on species' distributions, relative abundance, habitat associations and habitat-related production rates. Develop consistent, high resolution, and standard survey techniques, such as used by Massachusetts in the Massachusetts inshore trawl survey, for all inshore areas not currently part of a sampling program.
7. Complement current surveys (i.e., bottom trawl, scallop dredge, MARMAP) with fixed, less intrusive gears (i.e., gill nets, fish pots) that may sample particular bottom types efficiently (i.e., ledges, deep crevices).

Species-Specific Needs -- Although general information is needed for all species (see above), NMFS identified the following specific needs for certain species.

Atlantic halibut

8. Information on the egg and larval stages of Atlantic halibut is very scarce. They have proven to be very difficult to catch in large enough numbers to be useful. More directed sampling effort, better sampling techniques, and better information about the location of spawning events are required. Data on these highly dispersive, pelagic stages are important to understanding recruitment and stock structure. Information on the migratory patterns of juvenile Atlantic halibut is lacking. It is believed that larger

juveniles / sub-adults are highly dispersive, but no migration patterns have been shown. Mapping of size groups relative to habitat types (e.g., bottom type) based on groundfish survey catches would be of great benefit to describing EFH for Atlantic halibut.

Haddock

9. A better understanding of the factors affecting haddock recruitment and year-class strength is needed. Research into obvious factors such as the effects of water temperatures, food levels, and predation on the survival of the early life history stages is needed. Also, the role of other factors such as hydrographic effects (e.g., tidal and non-tidal currents) which affect the retention and transport of eggs and larvae should be investigated more thoroughly. Interactions with other closely related species (e.g., cod) are most likely important, and could be better understood. Detailed information on spawning is needed, the NMFS literature search uncovered very few spawning details, other than the fact that spawning occurs at the bottom over gravel substrate.

Pollock

10. Many details of the biology of northwest Atlantic pollock are not well known. No information is available on the locations of spawning event. This is important information for understanding or modeling EFH.

Red hake

11. Red hake spawning grounds and their habitat characteristics should be more precisely defined. A cost-effective way to separate and identify the eggs of various *Urophycis* spp. found in the northeast is needed to better define what habitats support the eggs of each species. The occurrence and habitat use of red hake larvae in shallow coastal areas of the Gulf of Maine needs to be further assessed.

White hake

12. Need details on the spawning of white hake, especially where and when, and their habitat requirements. Need information on the distribution of white hake eggs and larvae. Need better identification of white hake eggs and larvae. Need information on the habitat requirements for white hake eggs, larvae, and juveniles. Need to understand the movement of white hake juveniles in pelagic stage to estuaries. Need information on locations and requirements for residency of white hake juveniles in demersal stage in colder months.

Windowpane flounder

13. Better information on windowpane flounder spawning times and locations (e.g., spring adult aggregation in Nantucket Sound and other major estuaries) and spawner habitat requirements (e.g., high salinity) is needed. Studies (e.g., tagging) to determine seasonal usage of estuaries and nearshore coastal waters are needed.

Winter flounder

14. The different components of the winter flounder stock complexes need to be better described and their habitat preferences need to be documented.

Witch flounder

15. There are no details in the existing literature on the specific nature of witch flounder spawning.

Atlantic sea herring

16. Need better information on distribution and abundance of herring larvae. Need more complete assessments of areas important for herring spawning which consistently support herring egg beds.

Atlantic sea scallops

17. Existing information on recruitment processes (i.e., which beds are self-sustaining and which are not) for Atlantic sea scallops is rather vague. Relatively little information exists since the identification of planktonic sea scallop larvae in the wild was not possible until quite recently. New genetic techniques make it possible to track the movement of larvae, providing very detailed information about recruitment processes. Better information on the effect of environmental variables on growth, survival, and production is needed. There is close to no information on the scallop egg stage in the wild; what is known is restricted to morphometrics and fecundity. More data on the duration of the egg stage, mortality rates, predation and substrate effects are needed. Within scallop beds, examine density dependent effects on growth, maturation, fecundity, and survival.

Long-term

18. Develop models based on small-scale studies to extrapolate to population level interactions.
19. Explore new technologies, e.g., acoustics or laser illumination, for improving surveys of all life stages.

7.1.4 Species Habitat Relationships

The relationship between habitat and fishery production is inferred as part of the designation of EFH. Identifying the critical factors and quantifying this relationship is in the very beginning stages of research. Although there are specific information needs identified for certain species, the following information is needed for all species.

Short-term

1. Life history-stage specific information on growth and survival rates by habitat type (i.e., Level 4 information) is needed to accurately designate EFH for all species.
2. Develop and test laboratory and field techniques to measure habitat-specific survival, growth, reproduction, and production rates. Conduct habitat related growth and maturity investigations and food habitat studies using new technologies such as stable

isotope and insulin-like growth factor analysis. Examine genetic parameters such as presence of rare alleles to determine the reproductive value of different habitats for major managed fish species. Examine the utility of using molecular genetics, biochemical and tissue indices of energy status of selected species as indicators of habitat quality. Conduct research on the growth and metabolic rates of larval and juvenile fishes as a function of salinity, temperature and habitat type.

3. Identify primary cues (e.g., temperature, salinity, turbidity, habitat structure, habitat location or quality and prey abundance) used by larvae and juvenile of commercially important fishery species for recruitment from oceanic spawning areas to coastal and estuarine habitats using remote sensing and field surveys. Identify factors regulating utilization of emergent and submergent habitats using field surveys, remote sensing, and such approaches as stable isotope analysis. Determine the importance of hydrographic, biotic, and structural components of the environment to the growth and survival of young of the year managed species that recruit to offshore banks. Identify sources and sinks of managed species' production throughout the region, including identification of the origins of spawning adults and the fate of offspring spawned in various aquatic habitats within a region.
4. Identify and describe the biogenic structure associated with physical habitats.
5. Growth and survival rates by habitat (Level 3) and production rates by habitat (Level 4) are necessary to better identify EFH for all species.
6. The role of seafloor habitats on the population dynamics of fishes. While there are often good time series data on late-juvenile and adult populations and larval abundance, there is a general lack of empirical information on linkages between habitat and survival, which would allow modeling and experimentation to predict outcomes of various levels of disturbance.
7. Focus research on quantifying the mortality of species associated with habitat loss and alteration, contamination by toxics and power plant entrainment and impingement, as is being done for winter flounder. Determine if results of winter flounder studies are indicative of effects on other species and can be extrapolated to understand the effects on other species.

Atlantic cod

8. How many weeks do juvenile Atlantic cod reside on gravel during the eastward drift to sand habitats on the southeastern part of Georges Bank?

Ocean pout

9. The potential role that ocean pout may have in creating or expanding sheltering habitat, by burrowing or evacuating crevices and holes, for other species needs more research. The effect of intensive trawling on the persistence and use of these ocean pout created habitat modifications is also worth study. The means to assess ocean pout's use of reef-like habitats, where the species can readily avoid trawls, are needed to better characterize the relative value of all habitats used by the species at post-larvae life stages.

Pollock

10. The importance of inshore areas, specifically rocky subtidal and intertidal zones and salt marshes, as nursery areas of juvenile pollock requires more study. A better understanding of the role of these areas to recruitment and year class strength is needed to determine if these habitats are critical bottleneck areas.

Red hake

11. The use and relative importance to juvenile red hake of other sheltering habitats besides scallop and clam shells needs to be better defined. Do scallop and ocean clam dredging affect the habitat value of shellfish beds for juvenile red hake (and juveniles of other species)? The construction of sediment depressions by adult red hake for shelter or ambush-feeding (and the reuse of these depressions by other species) and the effects of intensive trawling / scallop dredging on the use of these shelters needs study.

Winter flounder

12. Conduct studies of winter flounder populations in impacted areas to fully quantify physiological adaptation to habitat alteration, and interactive effects, on an individual and population level.

Witch flounder

13. Information on growth and survival rates by habitat type is lacking, as are data to support theories of habitat use by the different life stages of witch flounder.

Atlantic sea scallop

14. Do young sea scallops survive best on gravel substrate and on non-mobile sand? Are young sea scallops (attached to the bottom) buried by sand moved by tidal and storm currents? Are sea scallops more abundance on disturbed gravel than on undisturbed gravel? If so, why? Does limited dredging benefit sea scallops by: (1) removing sea scallop predators; (2) removing competitors for food; (3) recycling buried food particles; or, (4) other factors?

<u>Long-term</u>

15. Determine the appropriate scale for resolving features of habitat and communities suitable for management for each habitat type. This work requires determining the appropriate physical parameters needed for characterization of each habitat type.
16. There is anecdotal evidence that clay pipes are rich groundfish habitat, and that historical clay pipe habitats have been destroyed by trawling and dredging. Determine actual utility of clay pipe habitat and effects of mobile fishing gear. Clay pipe habitat will not recover naturally; is it possible and advisable to restore and expand this habitat by emplacing artificial clay pipes made of other materials in areas where this habitat traditionally occurred?
17. Fresh blasted rock from the Ted Williams Tunnel excavation in Boston Harbor, Massachusetts, was disposed in the Massachusetts Bay Disposal Site region in 1992 - 1993. Rocks were disposed on sandy gravel habitat and on mud habitat. Rock piles are now utilized by lobsters and redfish. How do the rock piles compare in

productivity with the natural sea bed in this region? How do the rock piles on mud bottom compare in productivity with the rock piles on sandy gravel bottom in this region? If more rock needs to be disposed in this region, where should it go and how should it be deposited?

7.1.5 Predator-Prey Relationship Information

Stomach contents data exist for many of the fish occurring along the New England shelf. Incorporating this into more than descriptive accounts of who eats whom has not yet been done.

Short-term

Ocean pout

1. The diets of larval and early juvenile ocean pout needs to be better known to more fully understand the function of the habitats they use. The interactions between ocean pout and other species that use or compete for the seasonal shelter used by ocean pout needs study, especially the interactions that influence the survival of some species.

Pollock

2. Information on predation of the various life history stages of pollock is lacking, and data on species interactions in general are needed.

Red hake

3. Is the degree of cannibalism associated in any way with larval / juvenile red hake habitat quality or quantity (i.e., shelter availability)?

Witch flounder

4. Little is known about the effects of predation on witch flounder, as well as interactions with other species in general.

7.2 EFFECTS OF HABITAT ALTERATIONS ON LIVING MARINE RESOURCES

7.2.1 Fishing Related Impacts

The ultimate goal of research on fishing impacts is not to retrospectively evaluate what fishing does to the environment but to predict cause and effect given a particular management protocol.

Short-term

1. Information on the recovery rates of the various habitat types following fishing activity in inshore and offshore waters.
2. Need information on the spatial extent of fishing-induced disturbance. While many

observer programs collect data at the scale of single tows or sets, fisheries reporting systems often lack this level of spatial resolution. The available data make it difficult to make observations, along a gradient of fishing effort, in order to assess the effects of fishing effort on habitat, community, and ecosystem level processes.

3. Need to assess the effects of specific gear types, along a gradient of effort, on specific habitat types. These data are the first order needs to allow an assessment of how much effort produces a measurable level of change in structural habitat components and associated communities.
4. NMFS should add entry lines to the NMFS Vessel Trip Reports to expand description of gear size and type used to harvest catch (i.e. chains, cookies, rock-hopper, etc.).
5. NMFS should provide the Council with effort data on the use of the various fishing gear types, tagged to the ten minute square in which it was used.
6. The appropriate entities (i.e., fishing industry, academia, NMFS, states, etc.) should conduct comparative studies of roller, rockhopper, chain, brush sweep, and other bottom-tending trawl gear (not including scallop dredges) to assess habitat impacts as well as bycatch, efficiency, and other impacts. As part of this work, examine any available existing information (e.g., Massachusetts DMF films) on the effects of various gear types.
7. What kinds of habitats are most vulnerable to bottom-tending mobile fishing gear? What kinds of habitats experience repeated natural change? Are they less vulnerable to gear effects than other kinds of habitats? What is the relationship between vulnerability to natural events (e.g., storms) and vulnerability to fishing gear?
8. NMFS should provide the Council with high resolution data on fishing effort throughout New England and the Mid-Atlantic.
9. Determine the effects of harvesting on the stability of eelgrass habitat.

Long-term

10. How much time is required for hard bottom habitats to "recover" from disturbances from fishing gear and from storms, and how do these relate? Determine how to distinguish between the effects of human and natural habitat disturbance on the fishery and the effects of overfishing.
11. NMFS, state fisheries agencies and private, non-profit organizations (e.g., Center for Marine Conservation) should sponsor continued research into fishing gear and practices that reduce marine debris, including the use of biodegradable materials.
12. Determine / monitor cumulative nature of fishing-related impacts.
13. Investigate other fish collection processes (i.e., fish wheels). New England fisheries are dominated by only three gears.

Aquaculture

Research on cultivating marine organisms in the wild (i.e. Seastead Site) and inland is an important aspect of managing the culture fishery. The following topics are areas of research to consider during the development of the culture fishery to lessen possible habitat impacts:

14. Direct impacts of particular aquaculture protocols on specific habitat qualities, particularly the impact of water-based culture facilities on natural habitat processes and functions, should be investigated to ease habitat impacts.
15. Filtration of land-based culture systems can be developed further to lessen potentially harmful discharge. Efficient filtration techniques to remove by-products (i.e. nutrients, feed additives, contaminants, etc.) from effluent can reduce potential impacts associated with aquaculture. Development of filtration techniques that require less water or reuse more water will assist in reducing pressure on a clean water supply and lessen the amount of discharge. Techniques to use aquaculture filtration to cultivate seaweed or to use effluent as fertilizer may lessen the amount of discharge.
16. The life history requirements of marine and aquatic organisms are broadly known for an array of species. Further research is needed to improve the quality and quantity of information on life history requirement to increase aquaculture production through efficient rearing techniques. Nutritional requirements of reared organisms is an important aspect to investigate to develop efficient feeds to reduce uneaten and unassimilated feed entering the environment.
17. Aquaculture facilities continuously deal with disease outbreaks. Research on how to control or reduce the risk associated with disease episodes can potentially lessen the threat of reared organism disease outbreaks spreading to the wild.
18. Environmentally safe aquaculture may occur with continuing research on the development of alternate methods and practices of culturing organisms. Determining the carrying capacity of particular locations may provide aquaculture with higher production and more effective management decisions. Improvements in biological management strategies and engineering technologies may reduce environmental risk and increase productivity (USDA 1998). Facility design and technology needs to be researched to lessen potential environmental impacts, such as escapees, disease transmission, and harmful discharge.
19. Technological developments in aquaculture should be monitored to track the advancement of the industry and address potential environmental problems and solutions.
20. The different permitting and monitoring requirements provides some difficulty for aquaculturists. Addressing the differences in permitting and monitoring requirements for the variety of species cultured and location of cultivation, may assist in effective management measures.

7.2.2 Non-Fishing Related Impacts

Fishing is the most obvious impact on our fishery resources but there are many non-fishing related factors that can influence the sustainability of these resources. Identification and quantification of these factors is an essential part of developing an ecosystem based approach to management. The Council provides the following as general guidance on the types of information that would be valuable to our EFH process and habitat management program.

Long-term

General

1. Identify the effects of watershed management practices (such as regional comparisons of system responses to silviculture, agriculture, and urbanization) on maintaining the quality and quantity of essential fish habitat.
2. Develop better methods to use coastal change analyses to document and track changes in habitat types, structure, and quantity. Use this information to determine any trends directed at particular EFH.
3. Improve our knowledge of the nature and degree of pollutant effects upon marine organisms, particularly how they affect the capacity to survive and reproduce (growth rates).
4. Determine and monitor the synergistic or cumulative nature of non-fishing related (anthropogenic) impacts on habitat health.
5. Determine the relative impacts of different land use practices on coastal essential fish habitat functions and values.
6. Determine the extent of degradation of salt marsh habitat from tidal restriction and the rate of habitat loss from dredge and fill activities.
7. Determine the response of mud flat habitats to discharge and dumping.
8. Conduct studies of fish populations in impacted areas to fully quantify physiological adaptation to habitat alteration, and interactive effects, on an individual and population level.

Heavy metals, etc.

9. Some research questions include the impact of chronic levels of toxics at the population level, the spatial distribution of toxics outside of a few intensively monitored urban harbors, the persistence and turnover of different toxics within the sediments, and the exchange of toxics between the sediments and water column.
10. There also needs to be experimental studies to develop innovative methods of disposing contaminated dredge spoils and recovering toxics from dredge spoils to avoid degrading essential fish habitat.
11. Investigate decontamination techniques for dredged material / sediment / sewage sludge.

Chlorine

12. Research needs to be carried out on the impact of chlorine, dechlorinating agents, and chlorine derivatives on important marine organisms, such as eelgrass, kelps, lobsters, etc.

Nutrients

13. Identify sources of nutrients (e.g. septic systems) likely to impact EFH.
14. Verify models used to predict nitrogen sensitivity with some actual field studies of particular embayments.
15. Determine the transformations, if any, of nitrate and other forms of nitrogen in groundwater.
16. Examine the impact of different landscapes as source of nutrients to coastal waters

within a watershed context.
17. Determine the role of coastal wetlands as sources and sinks for nitrogen.
18. Examine the impact of nutrients on algal community structure, including its potential role as a stimulator of red tide blooms.

Exotic Species

19. Targeted studies are needed to determine the ecological impacts of nonindigenous species that are most successful and threaten marine ecosystems and investigate whether there are any reasonable methods of controlling their introduction and spread.
20. There needs to be innovative techniques to eliminate the transport of nonindigenous organisms in the ballast water of ships.

Harmful Algal Blooms

21. Research is needed to enable better predictions to be made about the spread of toxic algal blooms from Maine throughout the rest of the Gulf of Maine. We also need to understand whether the severity of an algal bloom can be enhanced by passage through a relatively small area of elevated nutrients.

Pathogens

22. Research is needed on the links between pathogens of marine organisms and natural and human-induced environmental conditions.
23. Identify the long-term implications of pathogens entering the environment.

Dredging and dredged material disposal

24. Research should be carried out on the efficacy of capping as a technique for disposal of contaminated dredge spoils. Review capping protocols and operational constraints for effectiveness.
25. Investigate potential for toxicity and/or bioaccumulation of contaminants from in-situ and relocated marine sediments (before dredging and after disposal).
26. Determine the appropriate trigger levels for specific contaminants to predict bioeffects on Council-managed species.
27. Investigate the potential for bioremediation of contaminated sediments.
28. Critically evaluate temporal dredging windows to minimize adverse effects to Council-managed species during critical life stages and/or migratory patterns.
29. Review documented effects of disposed dredged material on essential fish habitats and associated benthic organisms and secondary productivity.
30. Develop a predictive model for evaluating the effects of volume and sediment quality.
31. Define salient geotechnical parameters for high capping efficiency and grain size.

Artificial reefs

32. NMFS and state fisheries agencies should sponsor research to investigate the impacts of artificial reefs on living resources, and determine if artificial reefs have beneficial effects on fish populations and therefore may enhance EFH.
33. The role that the expanding use of artificial reefs in the northeast plays in the relative abundance, distribution, and productivity of this seasonal, shelter-using, or possibly shelter-dependent needs to be evaluated.

7.3 HABITAT RESTORATION METHODS

Long-term

1. Develop habitat restoration design, monitoring and success criteria. Simulation modeling could be useful to vary design aspects for evaluation of temporal and spatial success rates.
2. Need to reach better understanding of the processes of natural recovery and restoration.
3. Develop hydrologic models to guide restoration of tidal flow.
4. Determine the conditions needed for successful habitat restoration and develop the best assessment methodology.

7.4 INDICATORS OF HABITAT AND LIVING MARINE RESOURCES DEGRADATION AND RECOVERY

7.4.1 Techniques to Mitigate Adverse Impacts

The challenge is not to eliminate fishing but to develop techniques and philosophies that are more compatible with habitat protection.

Short-term

1. Research into alternative fishing gear types that may have less adverse impact on some types of essential fish habitat.
2. Determine the influence of existing buffer zones on habitat functions and values. Determine the changes in buffer requirements needed to improve buffer zone effectiveness.

7.4.2 Habitat Conservation

Improving our ability to conserve existing habitat from further degradation is a critical part of the Council's habitat management program.

Long-term

1. Evaluate new and innovative techniques directed at assessing functional value and restoration success of anadromous fish habitat, restored saltmarsh, seagrass, and shellfish reef habitats throughout the region. Conduct comparative research on the impacts of urban development, agriculture, and silviculture on fishery habitats and evaluate restoration approaches that will include assessment of the role of buffer zones to ameliorate land use effects. Determine the importance of patch size and proximity to adjacent habitats in the development of restored habitats. Develop simulation

models based on field evaluations of the functional development of restored habitats to provide management recommendations on the most cost effective design, approaches, and specifications for habitat restoration.
2. Evaluate the function and value of refugia relative to stock enhancement efforts and other management techniques for habitat conservation and protection.

7.4.3 Habitat Enhancement

There are natural limits to productivity but understanding what controls productivity may allow us to maximize fishery yield through habitat enhancement.

Short-term

1. Need to better understand "productivity" in the habitat sense and how overall productivity can be increased by habitat enhancement.