5.0 ANTHROPOGENIC NON-FISHING RELATED THREATS AND IMPACTS

5.1 INTRODUCTION

The Essential Fish Habitat (EFH) amendment fulfills the Magnuson-Stevens Act requirement to identify and characterize activities other than fishing that potentially reduce the quantity and/or quality of essential fish habitat. This section of the amendment will serve as a reference of non-fishing related threats and activities for the New England Fishery Management Council (Council), the National Marine Fisheries Service (NMFS), habitat management action agencies, and other interested parties. Once EFH is designated, federal agencies must consult with NMFS regarding any proposed activities that may adversely affect EFH. NMFS must provide federal and state agencies with conservation recommendations regarding any agency action that would adversely affect EFH. The Council is also empowered to comment on any federal or state agency action that would affect the habitat, including EFH, of a species under the Council's authority. To assist with these consultation and commenting activities, this section of the EFH amendment addresses those activities most likely to reduce the quantity and/or quality of essential fish habitat. This document is not meant to provide an exhaustive review and analysis of the impacts of all potentially detrimental activities; yet, it should highlight notable threats and provide enough information to determine if further examination of a proposed activity is necessary.

The northwest Atlantic, including the Gulf of Maine, Georges Bank, and portions of the continental shelf south of New England (e.g. Nantucket Shoals), supports a number of commercial, recreational and non-commercial fish and invertebrates and provides essential habitat for the reproduction, development, growth, feeding, and sustainability of these fishery resources. Management plans regulate fishery harvest in the northwest Atlantic; however, continual adverse human impacts, including non-fishing and fishing activities, and natural disturbances have contributed to the depletion of fishery resources and associated biological, chemical and physical environmental conditions. Adverse effects of non-fishing activities are of particular concern for the maintenance of a healthy ecosystem in riverine, coastal, and offshore habitats of the New England region.

The three subregions of the New England marine habitat differ in topography and oceanography and are a heterogeneous and dynamic environment with notable spatial and temporal variations (Buchholtz ten Brink *et al.* 1996). The offshore bottom type within the Gulf of Maine is quite patchy and generally related to topography (Schlee 1973) and is characterized by deep basins containing silty clay or clay sediments with topographic peaks covered with sand and gravel (NEFMC 1993). Coastal benthic habitat south of Casco Bay, ME is largely sand, and to the north and east is generally a finer proportion of silt and clay (Schlee 1973). Georges Bank is a shallow elongate extension of the northeastern U.S. Atlantic continental shelf which is covered by glacial debris that ranges from very coarse gravel to sand (Valentine *et al.* 1993) with scattered boulders (Collie *et al.* 1997). The southern New England region is broad and flat and is characteristically sand with patches of gravel (NEFMC 1993). Riparian habitats located along the coast of

New England provide essential habitat to anadromous fishes and are critical to chemical conditions (e.g. salinity) of coastal environments.

The biological, chemical and physical requirements of specific aquatic and marine organisms throughout their life history demonstrate the evolutionary adaptation to particular habitats for successful, healthy and sustainable populations. Sediment type has been directly associated with biological characteristics in the New England marine environment (Langton *et al.* 1995). In particular, fish species (e.g. Gadidae) and bottom topography have been positively related on Georges Bank (Valentine and Lough 1991). Tidal current velocity and substrate type have been associated with the spawning and settling behavior of marine organisms (e.g. Clupeidae and *Placopecten magellanicus*) (Sinclair and Iles 1985; Collie *et al.* 1997).

Coastal nursery habitat, including surf zones, estuaries, tidal creeks and channels, is essential for the development of many anadromous, estuarine, and marine fish and invertebrates. For instance, aquatic vegetation is very productive and performs a number of critical ecological functions, which include providing food and shelter for commercial, recreational and non-target organisms (Thayer *et al.* 1997) (Section 2.6.5). Other complex habitats within aquatic and marine regions (e.g. oyster and mussel beds) may offer important features for survivorship and development of fish and shellfish. Marine and aquatic organisms require specific nursery habitats for development.

Habitat alteration and disturbance occurs from natural processes and human activities. Natural disturbances to habitat can result from summer droughts, winter freezes, and heavy precipitation, and strong winds, waves, currents and tides associated with major storms (i.e. hurricanes and northeasters), along with world-wide climatic changes. Biotic factors, including bioturbation and predation, may also disturb habitat (Auster and Langton 1998). These natural events may have detrimental effects on habitat, including disrupting and altering biological, chemical and physical processes, and may impact fish and invertebrate populations. Potential adverse effects to habitat from fishing and non-fishing activities may include direct (e.g. contamination or physical disruption), indirect (e.g. loss of prey or reduction of species diversity), site-specific or habitat-wide impacts, including individual, cumulative or synergistic consequences of the actions. Non-fishing threats to habitat may include the intentional or accidental discharge of contaminants (i.e. heavy metals, oil, nutrients, pesticides, etc.) from non-point and point sources, and direct habitat degradation from human activities (i.e. channel dredging, marina / dock construction, etc.).

For the purposes of this document, the following definitions and descriptions apply throughout the text.

- *Riverine regions* are freshwater streams, rivers, and streamside wetlands including banks and associated vegetation that may be bordered by other freshwater habitats (e.g. palustrine emergent, scrub-shrub, or forested vegetation) (Pedevillano 1995).

- *Inshore regions* are coastal marine and estuarine environments, including rocky intertidal areas, exposed beaches, mudflats, salt marshes, seagrass flats, kelp beds, near-shore rocky bottoms, near-shore soft bottoms, tidal inlets, and other coastal habitats (Moyle and Cech 1988). The neritic waters (i.e. pelagic zone of the continental shelf and inshore waters) are important to a variety of estuarine and marine fishes and invertebrates. Inshore habitats are dynamic and heterogeneous environments which support the majority of marine and anadromous fishes at some stage of ontogeny.
- *Offshore regions* are open-waters, including habitat seaward of the inshore designation. Offshore benthic habitat features include sand waves, shell aggregates, gravel beds, boulder reefs, and submerged canyons which provide nursery requirements for demersal fishes (Auster 1997). The pelagic zone (e.g. epipelagic, mesopelagic, and bathypelagic) presents notable environmental features in offshore waters. Many marine organisms inhabit the stable offshore environment for substantial stages of their life history.
- A *threat* is defined as any chemical, biological or physical stress that may diminish, disrupt, degrade or eliminate essential fish habitat.

Healthy riverine, inshore and offshore ecosystems are crucial for the sustainability of ecological productive capacity, diversity of flora and fauna, and the ability of the environment to regulate itself. A healthy ecosystem should be similar to comparable, undisturbed ecosystems with regard to standing crop, productivity, nutrient dynamics, trophic structure, species richness, stability, resilience, contamination levels, and frequency of diseased organisms. The main goal for the identification of non-fishing adverse effects is to promote an awareness of the number of non-fishing threats that potentially impact EFH. To achieve this goal, this section of the EFH amendment addresses the following specific objectives:

(1) Identify the non-fishing threats, sources, and activities that have the potential to adversely affect EFH quantity, quality, or both.

The source and impacts (short- and long-term) of the chemical, biological or physical threats and activities are addressed. These threats are identified in order to lessen actions potentially contributing to non-point and point source discharge and physical habitat alteration, that may eliminate, diminish or disrupt the function of EFH. The identification of chemical, biological and physical threats will assist in developing conservation and enhancement recommendations to avoid, minimize or compensate for these adverse impacts to EFH (see Section 6.0).

(2) Discuss particular areas in New England that documented non-fishing threats occur.

Past, current, and potential areas that may be impacted by stresses and human activities are noted to assist in the mitigation of these sources of habitat

degradation. Vulnerable habitats may include but are not limited to past sites of sludge disposal, known discharge sites, and potential mining areas. Nursery areas of notable resource value (e.g. submerged aquatic vegetation, cobbles, gravel, etc.) are also addressed.

5.2 IDENTIFICATION OF NON-FISHING THREATS OF THE NEW ENGLAND REGION

Riverine, inshore and offshore habitats are subject to numerous chemical, biological and physical threats (Table 10). Inshore and riverine habitat is being degraded and altered by many human activities and sources of degradation. Deep-sea habitats (e.g. offshore region) are relatively stable and contain less resilient communities than habitats found within inshore waters (Radosh *et al.* 1978). Offshore environmental conditions are often altered by unnatural stress. The pelagic environment within coastal and offshore potentially presents essential habitat conditions for many marine organisms throughout substantial stages of ontogenetic development. These areas can also be disrupted. Chemical, biological, and physical threats potentially limit survivorship, growth, and reproduction rates of finfish and shellfish species and populations in New England.

Table 10: Potential non-fishing threats to fish habitat in the New England region prioritized within regions (" = high; ³ = moderate; ! = low)[1].

THREATS	RIVERINE	INSHORE	OFFSHORE
Chemical			
oil	³	³	³
heavy metals	³	³	³
nutrients	"	"	!
pesticides	³	³	!
herbicides / fungicide	³	³	!
acid	"	³	
chlorine	³	³	
thermal	³	³	
metabolic & food wastes	³	³	
suspended particles	³	³	!
radioactive wastes	!	³	³
greenhouse gases	³	³	³
Biological			
nonindigenous / reared species	³	³	³
nuisance / toxic algae	³	"	³
pathogens	³	³	³

THREATS	RIVERINE	INSHORE	OFFSHORE
Physical			
channel dredge	3	"	
dredge and fill	"	"	
marina / dock construction	3	"	
vessel activity	3	"	!
erosion control			
bulkheads	3	3	
seawalls		3	
jetties		3	
groins		3	
tidal restriction	3	"	
dam construction / operation	"	3	
water diversion			
water withdrawal	"	3	
irrigation	3	3	
deforestation	"	3	
mining			
gravel/mineral mining	3	3	3
oil/gas mining	!	3	3
peat mining	!		
debris	3	3	3
dredged material disposal	!	3	3
artificial reefs	!	3	3

[1] prioritization developed by compilation of *EFH Technical Team* survey

The major threats to marine and aquatic habitats are a result of increasing human population and coastal development which is contributing to an increase of human generated pollutant loadings. These pollutants are being discharged directly into riverine and inshore habitats by way of point and non-point sources of pollution. The development of coastal regions to accommodate more people leads to an increase in impervious surfaces, including but not limited to roads and parking lots. Impervious surfaces cause greater volumes of run-off and associated contaminants into aquatic and marine waters. Golf courses are one of several examples of alteration of hydrology that contribute a substantial source of contaminated run-off that potentially impact fishery resources. Humans attempt to control and alter natural processes of aquatic and marine environments for an array of reasons, including industrial uses, coastal development, port and harbor development, erosion control, water diversion, agriculture, and silviculture. Environmental conditions of fish and shellfish habitat are altered by human activities (see Wilk and Barr 1994 for review) and threatened by non-point and point sources of pollution (Table 11).

Table 11: Activities and sources of threats to EFH in the New England region (2° ≡ secondary sources of contamination).

NON-POINT SOURCES	ACTIVITIES & POINT SOURCES
run-off (municipal[1] / agricultural)	industrial discharge[4]
atmospheric deposition	power plants[5]
wildlife feces[2]	sewage treatment plants
industrial shipping	ocean disposal of dredged material
recreational boating[3]	aquariums
septic systems	biotechnology labs
contaminated groundwater (2°)	silviculture (forestry)
contaminated sediments (2°)	water diversion
nuisance / toxic algae (2°)	decaying shoreline structures
	energy and mineral exploration/transportation[6]
	marine transportation
	coastal development
	port / harbor development
	erosion control

[1] municipal run-off includes, but not limited to, sewer overflows
[2] wildlife is defined as animals other than domesticated livestock and pets
[3] includes fishing boats, pleasure cruisers, jet skis, etc.
[4] may include pulp and paper mills, tanneries, textile mills, metal fabricating and finishing operations, chemical, plastic, rubber, electronic, equipment manufacturing plants, etc.
[5] includes nuclear, hydropower, and fossil fuel burning plants
[6] includes mining, pipeline transport, and other byproducts from the particular industry
- aquaculture impacts are discussed in section 4.7

5.3 THREATS TO RIVERINE EFH

New England rivers historically supported large runs of native Atlantic salmon (*Salmo salar*). Freshwater habitat is necessary for the growth, survivorship, and reproduction of salmon and represent an important historic commercial and recreational fishery. Atlantic salmon abundance, distribution and ontogenetic development has been studied extensively because of poor population levels (see FWS 1995 for review). Among the major identified causative factors of the population demise of Atlantic salmon, non-fishing related activities may be the most dramatic. Chemical, biological and physical threats to fish habitat in riverine environments, including both terrestrial and aquatic sources, have led to habitat disruption and degradation. Also, rivers may assist in the transport of non-point and point sources of contamination to nearshore environments implicating marine organisms.

5.3.1 Chemical Threats

Oil (defined as any hydrocarbon or petroleum substance) can degrade riverine habitat, consequently interfering with biotic communities. Oil may be discharged into rivers from both non-point and point sources, including municipal and agricultural run-off, industrial shipping, recreational boating, contaminated sediments, power plant discharge, marine transportation, energy and mineral exploration and transportation, and disposal of dredged

material. Oil potentially interferes with reproduction, development, growth, and behavior of aquatic organisms (see Gould *et al.* 1994 for review). Benthic habitat and the shoreline can be covered and destroyed by oil. Oil has been demonstrated to disrupt the growth of freshwater vegetation (Lin and Mendelssohn 1996). Long-term exposure to oil may lead to the disruption of population dynamics of aquatic communities. Rivers may also transport oil to adjacent estuaries and inshore habitats that are important areas for marine and aquatic organisms.

Heavy metals entering riverine habitats from municipal and agricultural run-off, contaminated groundwater and sediments, industrial shipping, recreational boating, atmospheric deposition (non-point sources), industrial discharge, power plants, disposal of dredged material, and marine transportation (point sources) can negatively impact fish habitat. New England rivers were heavily loaded with metals during the nineteenth century from industries dependent on hydropower (Larsen 1992). Metal contaminants are found in the water column and persist in sediments (Buchholtz ten Brink 1996) and may inhibit reproduction and development of aquatic organisms. Fish and invertebrates may be directly killed by lethal concentrations of heavy metals, especially early life history stages (Gould *et al.* 1994). Heavy metals have also been implicated in disrupting endocrine secretions of aquatic organisms, potentially disrupting natural biotic properties (Brodeur *et al.* 1997). Long-term impacts may not be noticeable in riverine fish; however, heavy metals may cascade through trophic levels, accumulate in fish, and eventually cause health problems in humans.

Aquatic environments depend on nutrients to control the productivity of fishery resources; however, an excess of nutrients discharged into the environment can degrade habitat (ASMFC 1992; NOS 1997). Nutrient over-enrichment can cause eutrophication that has disrupted many aquatic systems (see O'Reilly 1994; Wilk and Barr 1994). Excess nutrients entering riverine habitat originate from non-point sources, including municipal and agricultural run-off, contaminated groundwater and sediments, atmospheric deposition, septic systems, industrial shipping, recreational boating, wildlife feces, and nuisance / toxic algae, and point sources, including industrial discharge, sewage treatment plants, water diversion, disposal of dredged material, silviculture, energy and mineral exploration, and aquariums. Eutrophic habitats are characterized by low dissolved oxygen (anoxia is possible), high turbidity, phytoplankton and filamentous algal blooms, and inhibited denitrification. Severe eutrophic conditions can reduce the amount of aquatic vegetation (Goldsborough 1997), cause mass mortality of aquatic organisms, and alter long-term community dynamics. Harmful algal blooms (HABs) associated with unnatural aquatic nutrient levels have been associated with fish disease and kills (see Section 5.3.2 for further discussion) (NSF and NOAA 1998).

Pesticides and herbicides from agricultural and municipal run-off, atmospheric deposition, contaminated groundwater (non-point sources), water diversion, and disposal of contaminated dredged material (point sources) have killed aquatic organisms and accumulated in the benthos. Herbicides are also frequently used to inhibit colonization of boat hulls and pipes by micro-algae and subsequent growth of seaweeds (Readman *et al.*

1993). Pesticides may be re-released to the environment during substrate disturbance causing habitat disruption and degradation. Aquatic organisms may accumulate pesticides within tissues which potentially cause health problems in humans. Pesticides also have gained recent attention as being endocrine disrupters of aquatic organisms. The chemicals may also cause mortalities of aquatic insects which contribute to the food base of salmonids (USFWS 1995). Herbicides may alter long-term natural community structure by hindering plant growth or directly destroying vegetation. The combination of pesticides and herbicides contribute to the degradation of aquatic habitat (see Meyers and Hendricks 1982 for review).

The influx of acid to riverine environments can cause severe habitat degradation and disruption. The freshwater environment does not have the buffering capacity of marine ecosystems, so acidification has serious implications on riverine habitat. Acidification potentially disrupts or prevents reproduction, development, and growth of aquatic fish and invertebrates (USFWS 1995). Low pH (< 5.0) has been implicated with osmoregulation problems (Staurnes *et al.* 1996), pathological changes in eggs (Peterson *et al.* 1980; Haines 1981), and reproduction prevention (Watt *et al.* 1983) of Atlantic salmon. Periodic and long-term discharge of acid into aquatic environment can disrupt and destroy important fish and shellfish habitat. Major non-point sources of acid include agricultural and municipal run-off, contaminated groundwater, and atmospheric deposition, and point sources include industrial and sewage plant treatment discharge.

Substances containing chlorine compounds [e.g. organochlorides – polychlorinated biphenyls (PCBs)] can disrupt and degrade aquatic habitats. Chlorine can exert acute and sublethal effects on aquatic organisms (Sasikumar *et al.* 1993; Manning *et al.* 1996), especially early life history stages (Hose *et al.* 1989). The USEPA water quality criteria state that chlorine discharge should not exceed 11 μg/L as a four-day average and 19 μg/L as a one-hour average more than once every three years (USEPA 1986). Septic systems, contaminated groundwater, industrial and sewage treatment plant discharge, and power plants are potential sources of chlorine that can lower habitat quality or directly kill aquatic organisms. Also, chlorinated compounds are used to inhibit the settlement of biofouling organisms. Long-term chlorine effluent can change habitat quantity and quality and disrupt population dynamics.

Dams, power plants, and industrial facilities produce thermal effluents in aquatic habitats which potentially cause thermal shock to organisms. The benthic community may be changed by the unnatural water temperature discharged. Aquatic organisms, especially early life history stages, can be directly killed by thermal plumes. Water temperature influences biochemical processes of the environment, behavior of aquatic organisms, and community assemblages. Altering the natural temperature regime, potentially changes indigenous habitat characteristics and associated biotic communities. Forestry activities, including clear-cutting or loss of riparian habitat, also contributes to higher water temperatures that may disrupt and degrade habitat conditions.

Agricultural facilities, septic systems, wildlife feces, nuisance / toxic algae (non-point source), livestock waste, and sewage treatment plants (point sources) are sources of organic wastes potentially impacting habitat. Metabolic wastes, excess food, and organic fertilizers entering riverine environments can increase levels of nutrients and pathogens, lead to eutrophication, and alteration of local benthic dynamics. Long-term influx of organic wastes may degrade the quantity and quality of habitat.

Fish and invertebrate habitat may be negatively impacted by an unnatural influx of suspended particles (Arruda *et al.* 1983). Lethal and sublethal impacts to riverine organisms may occur with various concentrations of suspended sediments (Barr 1993). Erosion and watershed development can contribute suspended sediments entering riverine environments thus embedding particulate in benthic habitat and making it unsuitable habitat (USFWS 1995). Particulate matter also enters riverine habitats from non-point source municipal and agricultural run-off, industrial shipping, and recreational boating, and point source industrial discharge (e.g. pulp mills), dredging, ocean disposal of dredged material, water diversion, energy and mineral exploration and transportation, erosion control, silviculture, and marine transportation. Short-term impacts of an increase in suspended particles include high turbidity, reduced light, and sedimentation which may lead to the loss of benthic structure and disrupt the overall productivity streams (USFWS 1995). Other problems associated with suspended solids include disruption of respiration, water transport rates, filtering efficiency of fishes and invertebrates, sorption of metals and organic materials, reduction of growth and survival of filter feeders, and decreased foraging efficiency of sight feeders. Fry and parr find refuge within interstitial spaces provided by gravel and cobble that are potentially clogged by sediments and subsequently decrease survivorship (USFWS 1995). Toxic metals and organics absorbed by suspended solids may recur and become more available to aquatic organisms in the habitat when disturbed (e.g. dredging). Resuspension of sediments may supply nutrients to the water column that are needed for primary production. However, increased flux of nutrients into the water column may stimulate phytoplankton production and contribute to increased turbidity and alteration of nutrient cycles. Frequent high levels of suspended particles can lead to the loss of habitat for aquatic creatures.

Radioactive wastes may be a potential threat degrading aquatic habitat used by fish and shellfish species. Fishery resources may accumulate radioactive isotopes in tissues posing problems for the resource and consumers (ICES 1991). Long-term exposure to radioactive wastes may alter the natural dynamics of the habitat. Potential sources of radioactive wastes are municipal run-off, atmospheric deposition, contaminated groundwater and sediments (e.g. past dumping locations) (non-point sources), and industrial and power plant discharge (point sources).

Global warming presents an array of potential impacts on riverine habitats (Lehtonen 1996). Global warming may be accelerated by the continued release of greenhouse gases from the burning of fossil fuels and forests and using aerosol-producing substances (i.e. the greenhouse effect). Greenhouse gases, including carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons, are discharged into the atmosphere from respiration of all

living organisms, burning fossil fuels and forests, and using aerosols. Possible impacts on riverine habitats from global warming and subsequent sea level rise are the loss of wetlands, salinization of freshwater environments (eliminating freshwater supplies), and change in natural biotic characteristics [e.g. shift in fish composition to cyprinid and percid dominance with the decline of salmonid populations (Lehtonen 1996)] and abiotic properties (e.g. currents and nutrient availability). Sea levels have fluctuated through the history of earth and have been rising since the end of the Pleistocene. Tectonic and postglacial isostatic adjustments and effects of atmospheric temperature contribute to changes in the rate of sea level rise (Valiela 1995). The change in the rate of sea level rise may alter freshwater riverine habitats. Freshwater wetlands, which have an array of important functions, may be unable to accrete fast enough to keep pace with sea level rise, or unable to accrete because of the development of land.

5.3.2 Biological Threats

The introduction of nonindigenous species or the escapement of farmed organisms entering the environment has been documented (Rosecchi 1993; USFWS 1995) and can threaten habitat. Human activities are closely tied to exotic introductions. Non-native plants (e.g. *Phragmites*) potentially degrade riverine habitat by changing natural qualities. New diseases may be introduced and spread throughout the habitat with the release of exotic organisms. Exotic and reared fish, shellfish, plants, and pathogens enter riverine habitats from industrial shipping (e.g. ballast water), recreational boating (non-point sources), biotechnology, aquariums, and aquaculture (addressed in Section 4.7) (point sources). Native populations and habitat are threatened by escapement and release of nonindigenous organisms. Introduced fish, shellfish, and plants compete with or forage on wild organisms which can change habitat characteristics and hinder the success of fisheries dependent on rivers. Long-term natural community structure and dynamics may be changed with the introduction of organisms through altering the genetic diversity of wild stocks, transmitting diseases, and changing biotic assemblages.

Harmful algal blooms (HABs) have been associated with unnatural levels of nutrients in riverine habitats. HABs have detrimental impacts to habitat and toxic effects on organisms and humans (see O'Reilly 1994; Boesch *et al.* 1997). Organisms responsible for HABs have naturally occurred in the environment for a long time, so the apparent increase of bloom events may simply reflect better detection of natural phenomena (NSF and NOAA 1998). However, the current intensity and frequency of HABs compared to the past appears to indicate more toxic algal species, more algal toxins, more areas affected, more fishery resources affected, and higher economic losses (Boesch *et al.* 1997; NSF and NOAA 1998). Nonindigenous algal species may be introduced to the environment from ballast water of commercial vessels, recreational boating, shellfish transfer (e.g. seeding), dredging, and disposal of sediments (Boesch *et al.* 1997) adding to the potential problem of blooms. HABs can indicate eutrophic conditions, alter, impair, or kill plankton and fish communities, smother indigenous vegetation, and lower dissolved oxygen (NOAA 1997). Certain toxic organisms (e.g. *Pfiesteria* spp.) are associated with HABs and have caused major outbreaks of disease and fish kills (NCSU 1998). These

short-term impacts can eventually change the natural processes of habitat, reducing viable fish and shellfish populations.

The spread of disease among aquatic organisms may adversely impact riverine habitat. Pathogens introduced inadvertently or purposely may spread diseases which can be lethal or sublethal to fish and shellfish. Diseases and parasites enter the environment through agricultural and municipal run-off, septic systems, wildlife feces, industrial shipping, recreational boating (non-point sources), disposal dredged material, biotechnology, aquariums, and sewage treatment plants (point sources). Human influences, including nutrient over-enrichment, have been shown to stimulate outbreaks of pathogens (NCSU 1998). The toxic dinoflagellate, *Pfiesteria piscicida*, has been implicated as the primary causative agent of may fish kills and disease episodes (Burkholder *et al.* 1992; NCSU 1998). Atlantic salmon are susceptible to a number of diseases and parasites, including the gill maggot (*Salmincola salmonea*), freshwater louse (*Argulus foliaceus*), leech (*Piscicola geometra*), trematodes, cestodes, acanthocephalans, nematodes, sea louse (*Lepeophtheirus salmonis*), sea lamprey (*Petromyzon marinus*), and numerous bacterial, viral, and fungal diseases (see USFWS 1995). Disease outbreaks and fish kills may have cascade effects through the environment by altering community structure and transferring toxins through the trophic web. Continual disease outbreaks may have long-term implications on the success of fish and shellfish populations in riverine habitat.

5.3.3 Physical Threats

Channel dredging is a frequent long-term maintenance activity associated with shoreline development, port and harbor development, and vessel activity (see Barr 1987). The increased need for channel dredging has resulted from increased marine transportation, increased vessel size, expansion of commercial fleets, and alterations in sedimentation patterns of rivers due to increased settlement and urbanization (Messieh *et al.* 1991). The short-term impacts to habitat can be substantial. Dredging resuspends sediments (see Section 5.3.1) and associated contaminants and potentially degrades habitat quality and fish populations. Changes in water quality, depth, water temperature, current velocity, bottom topography, and sediment type are associated with dredging of channels. The changes can decrease dissolved oxygen and SAV distribution and density while smothering the surrounding benthic community. The channel can increase the transport of sediment and siltation of riparian habitat resulting in alteration of feeding, spawning, and refuge habitat. For example, cobble or gravel streambed may be covered, consequently decreasing the amount of refuge habitat available for early life history stages of fish (USFWS 1995). Fragmentation of habitat can hinder the movements (i.e. dispersal, recruitment, migrations, etc.) of organisms. The continual maintenance involved with channel dredging can eventually change the indigenous habitat and population dynamics of the region.

The dredging and filling of wetlands for shoreline, coastal, port, and harbor development directly removes potentially important habitat and alters the habitat surrounding the developed area. The direct removal of riverine habitat from dredge and fill activities may be one of the biggest threats to riverine habitats and the success of freshwater and

anadromous organisms. Dredge and fill activities reduce the wetland functions (i.e. retain floodwater and uptake nutrients) and decrease the amount of detrital food source available to biotic communities. Hydrological modifications from dredge and fill activities and general coastal development (e.g. golf courses) may increase the amount of run-off entering the aquatic environment that may contribute to the degradation of fishery resources. Along with these specific impacts of wetland dredge and fill activities, the short- and long-term impacts are similar to channel dredging.

Marina and dock construction is an inevitable result of shoreline development. Port development has been implicated in disrupting important riverine habitat for salmonids and clupeids (Levings 1985). The construction of marinas and docks aggregates contaminants associated with the vessels that use the facilities. Along with contamination of the habitat, the construction of marinas changes habitat parameters such as water quality, depth, water temperature, current velocity, and SAV and benthic composition, distribution, and abundance. SAV is removed during construction and shaded by the physical structures after construction eventually destroying the vegetation. Sedimentation patterns are changed because of the change of current velocity and pattern. Sedimentation may occur at greater rates which may depleted the amount of habitat available for spawning, foraging, and development. Mooring chains located in riverine environments may degrade habitat conditions by disrupting benthic features. Repeated small-scale habitat loss can have cumulative effects and can fragment habitat which can have a detrimental impact on fish and shellfish stocks. The long-term presence of marinas can contaminate the localized area and change natural habitat qualities and population dynamics in the region.

Vessel activity, including industrial shipping, recreational boating, and marine transportation (e.g. ferry transportation), may contribute to the physical degradation of aquatic habitats and related organisms. Increased vessel activity within riverine waters is directly related to the increase in shoreline, port and harbor development. The benthos, shoreline and pelagic habitat may be disturbed or altered from vessel use in riverine regions. The severity of disruption on riverine processes may depend on the size of the river (i.e. depth, width, and length), vegetation type on river bank, current speed, composition of sediments in the river bed, and type of boat traffic (Yousef 1974; Karaki and vanHoften 1975; Barr 1993).

- The direct disturbance of bottom topography (e.g. prop scarring) results in increased turbidity (see Section 5.3.1 for further details) which can lead to the loss of SAV, nursery and forage habitat adversely affecting benthic communities (Yousef 1974; Hilton and Phillips 1982; Barr 1993). Vessel-induced disturbance of surficial sediments rich in nutrients may indirectly contribute to nutrient over-enrichment of riverine habitats (Barr 1993). Vessels coming in direct contact with surficial sediments may contribute to siltation of riverine habitats. The destruction of SAV, either by direct prop disturbance or increased turbidity, and the disturbance or siltation of riparian habitat (i.e. gravel) may consequently fragment, decrease quality, and/or destroy large areas of habitat.

- Elevated wakes caused by industrial and recreational shipping and transportation can have substantial impacts on aquatic shoreline and backwater areas. Wave activity intensifies with increase of riverine boat traffic (Karaki and vanHoften 1975). The continual disturbance of water along frequently traveled routes can lead to shore erosion, substrate disturbance, increase turbidity, pelagic disturbance, and spillage to backwater areas which can eventually cause the loss of habitat (Karaki and vanHoften 1975; Barr 1993).

Watershed development can contribute to erosion and sedimentation of aquatic habitats. Bulkheads are rigid structures built parallel to the shoreline for erosion control (Leatherman 1988) that can alter habitat by eliminating the land-water interface and changing run-off patterns. Changing the land-water interface may actually increase erosion along the shoreline. Sedimentation of benthic habitat may occur with erosion, degrading important fish habitat. Benthic community structure can be degraded or removed adding to the disruption of fish habitat. The long-term presence of bulkheads can lead to severe erosion and sedimentation and change natural habitats and associated biotic dynamics of the region.

Development of the shoreline may include structures which restrict water movements (i.e. roads, bridges, dikes, etc.). Natural drainage, current, and sedimentation patterns can be hindered by the construction of tidal restricting structures. Physicochemical properties (i.e. water temperature, dissolved oxygen, flow, etc.) are altered changing the habitat characteristics that may hinder migratory, spawning, feeding and dispersal movements of aquatic organisms resulting in depleted stocks of fish and invertebrate species. Sedimentation of riparian habitat may increase because of increased erosion and changed current patterns. Confined aquatic habitats with restricted water exchange may allow HABs to persist (Boesch *et al.* 1997). The hindrance or blockage of tidal flushing and associated biotic movements can degrade associated habitat by altering the natural dynamics.

Dam construction and operation occurs within New England riverine habitat for flood control, power generation, navigation, and reservoir formation. The construction of dams with either inefficient or non-existent fish ways was the primary agent of the population decline of U.S. Atlantic salmon (USFWS 1995). Historical records link the decline of Atlantic salmon with construction of dams (USFWS 1995 for review). Dams alter water flow and sedimentation patterns, depth, water temperature, water quality, and stream bed properties. Salmonids are threatened by unnatural condition created by dams, including passage over spillways, passage through turbines, passage through impoundments (Ruggles 1980), and entrainment and impingement. Migration of fishes is hindered or blocked. Fishes are impinged and entrained, and exposed to dissolved gas supersaturation, aggregated contaminants, and high concentrations of predators and disease in the habitat surrounding dams. The disruption of fish development can change the natural habitat and fishery dynamics of aquatic habitat. The loss of wetlands by the reduction of freshwater input and sediments can have potentially serious impacts on both fish and invertebrate populations.

Natural freshwater flows are subject to human alteration through water diversion and use and modifications to the watershed (i.e. deforestation, tidal restrictions, and stream channelization) (Boesch *et al.* 1997). Water withdrawal for freshwater drinking supply, power plant coolant systems, and irrigation occurs along urban and agricultural coasts causing potential detrimental effects on aquatic habitats and is associated with coastal development. The mass flow of water into a power plant and other reservoirs results in entrainment and impingement of fishes (especially early life-history stages of fish). Larval and juvenile demersal fishes along with invertebrates are susceptible to entrainment and impingement around intake pipes (ASMFC 1992). Important habitat is lost for aquatic organisms that are not capable of recruiting and settling around the intake and may adversely affect fish and shellfish populations by adding another source of mortality to the early life stage which often determines recruitment and strength of the year-class (Travnichek *et al.* 1993). Water withdrawal and diversion along with anthropogenic watershed changes have been related to the increase in some HABs (Boesch *et al.* 1997) impacting aquatic and marine habitat. The continued diversion and use of water from coastal waters can lead to degradation of fish and shellfish habitats.

- Freshwater is becoming limited because of natural events (e.g. droughts), increasing demand of potable water, and inefficient use. Freshwater is withdrawn for human use from riverine environments. The withdrawal of water can alter natural current and sedimentation patterns, water quality, water temperature, and associated biotic communities.

- Irrigation for agriculture alters currents, water quality, water temperature, depth, and drainage and sedimentation patterns of aquatic habitat. Sedimentation within rivers can hinder benthic processes and communities. Irrigation can also increase run-off containing materials (i.e. heavy metals, nutrients, etc.) which stress the habitat. The changes to the natural habitat caused by irrigation can potentially lead to changes in the dynamics of aquatic organisms.

The growth and harvest of forestry products is a major land use of much of watershed in New England that can have short- and long-term impacts that may adversely affect riverine habitat (USFWS 1995). Silviculture practices and shoreline development lead to the removal of vegetation, an increase of impervious surfaces, and decrease of the water retention of watersheds. These watershed changes may result in inadequate river flows, increase of stream bank and stream bed erosion, sedimentation of riparian habitat, and an increase of run-off and associated contaminants (e.g. herbicides). Hydrologic characteristics (e.g. water temperature) are changed and greater variation in stream discharge is associated with the forestry industry (USFWS 1995). Debris (i.e. wood and silt) are released into the water as a result of the harvest of the forest which can smother benthic habitat. Deforestation can alter or impair natural habitat structures and dynamics.

Mining is a potential problem within riverine habitats. Mining can have direct and indirect chemical, biological, and physical impacts to the habitat of the mining site and surrounding regions. Structures are built within habitats to assist in mining and transporting materials.

In a review by Pearce (1994), the effects of mining have been listed as: (1) destruction of existing benthic biotic community; (2) resuspension of sediments with negative impacts on fishery resources (see Section 5.3.1); (3) changes in bottom topography and sediment composition; and (4) consequences related to the sediment transport from the site by currents. Gravel, mineral, and oil mining occur in inshore environments which are essential for fisheries.

- Gravel / mineral mining is associated with an increase in stress to the surrounding habitat and the removal and disturbance of substrate. The alteration of the mining site can fragment habitat, negatively impacting fish and shellfish populations. Long-term mine sites can potentially change natural habitats and associated fish and shellfish populations (Wilk and Barr 1994).

- Oil mining has similar impacts as gravel / mineral mining but more risk is associated with spills and leakage from pipelines (i.e. blow-outs) which can disrupt habitat (Wilk and Barr 1994). Drilling muds and well cuttings are potential environmental concerns associated with operation of oil wells. Drilling muds (either water-based or oil-based muds) are complex and variable mixture of fluids, suspended solids, and chemical additives (Messieh *et al.* 1991).

- Deposits of peat are common in the watersheds of eastern Maine (USFWS 1995). Peat mining has the potential to remove riverine habitat and vegetation resulting in accelerated run-off, alteration of flow patterns, and the release of contaminants (i.e. peat fiber, arsenic residues, and other toxic chemicals).

Debris, either floating on the surface, suspended in the water column, covering the benthos, or along the shoreline, can have deleterious impacts on fish and shellfish within riverine habitat (see Coe and Rogers 1997). Debris is usually defined as man-made solid objects introduced into the environment (Hoagland and Kite-Powell 1997). Substrate and associated communities can be smothered or shaded by debris which results in alteration of the benthic community. Aquatic organisms may ingest pellets or plastic fragments or become entangled in rope or plastic strings which eventually kill the organisms. The natural processes of the environment are potentially disrupted by debris discharged into rivers and streams. Plastics account for nearly half of the marine debris found in Maine, New Hampshire, and Massachusetts. Metals, glass, and paper also constitute a proportion of debris in the three states. Cigarette butts are a potential problem in marine environments (Hoagland and Kite-Powell 1997). Major non-point sources of non-fishing related debris entering the marine environment include industrial shipping, recreational boating, municipal run-off, and decaying shoreline structures. Solid waste disposal, landfills, offshore mineral exploration, and industrial discharge are potential point sources of debris (USEPA 1994) (see Section 4.6 for fishing related debris).

Disposal of dredged material can disrupt and degrade natural habitat and biotic communities. The stresses associated with dredged material (i.e. oil, heavy metals, nutrients, suspended particles, etc.) potentially threaten the dump site and adjacent

habitats. Along with contaminating the habitat, direct disturbance of the benthic and pelagic communities occurs with disposal. Benthic communities are smothered, associated physicochemical conditions are altered, and increased turbidity may hinder pelagic processes (e.g. photosynthesis of algae) by material settling to the bottom (see Section 5.3.1). The potential deleterious impacts of dredged material disposal can alter local and surrounding community structure.

Restoring or creating riverine habitat may include revegetation of banks and adding or cleaning gravel in streambeds. Considering these measures as 'artificial reefs' may be inappropriate, but for the purposes of this section artificial reefs will encompass these approaches. Artificial reefs can be an effective tool in fishery development with proper management (ASMFC 1993). Properly constructed artificial reefs potentially enhance rough bottom habitat and provide quality fishing grounds to the benefit of anglers and fishing communities (Stone 1982). The location and composition of artificial reefs in aquatic habitats should be assessed properly for the most effective methods to enhance fish and shellfish populations. Artificial reefs placed improperly may change natural habitat conditions, including sedimentation patterns and stream wandering. Also, community structure may be changed by attracting unnatural species assemblages.

5.4 THREATS TO INSHORE EFH

Inshore habitats have been impacted by decades of habitat destruction and degradation throughout the United States (NOAA 1994). Development of coastal lands for a suite of reasons has reduced habitat important to the spawning, breeding, feeding, and growth of finfish, shellfish, and aquatic vegetation. NOAA (1994) estimates that half of the original 11.7 million acres of coastal wetlands have been lost since 1780 and continue to be removed at a rate of 20,000 acres per year. The dynamic and productive nature of inshore habitats are threaten by point sources and non-point sources of contamination, and physical destruction. The flux of chemical, biological, and physical threats into inshore habitats impact fishery resources.

5.4.1 Chemical Threats

Oil (characterized as petroleum and any derivatives) may be a major stress on inshore fish habitats (see Wilk and Barr 1994 for review). Short-term impacts include interference with the reproduction, development, growth and behavior (e.g. spawning, feeding, etc.) of fishes, especially early life-history stages (see Gould *et al.* 1994 for review). Carcinogenic and mutagenic properties of oil compounds are receiving increasing attention around the world (Larsen 1992). Oil spills may cover and degrade coastal habitats and associated benthic communities, or may produce a slick on the surface waters which disrupts the pelagic community. Oil has been demonstrated to disrupt the growth of vegetation in estuarine habitats (Lin and Mendelssohn 1996). These impacts may eventually lead to disruption of community organization and dynamics in affected regions. Oil can persist in sediments for years after the initial contamination. This may cause problems to physiological and metabolic processes of demersal fishes (Vandermeulen and Mossman

1996). Non-point sources of oil are municipal and agricultural run-off, industrial shipping, recreational boating, and contaminated sediments. Point sources include power plant discharge, marine transportation (i.e. ferries, freighters, and tankers), energy and mineral exploration and transportation, and ocean disposal of contaminated dredged material.

Metal contaminants are found in the water column and persist in the sediments of coastal habitats, including urban centers and fairly uninhabited regions, and are a potential environmental threats (Larsen 1992; Readman *et al.* 1993 Buchholtz ten Brink 1996). High levels of metals are found in the sediments of New England estuaries due to past industrial activity (Larsen 1992). Heavy metals may initially inhibit reproduction and development of marine organisms, but at high concentrations, they can directly or indirectly contaminate or kill fish and invertebrates. The early life-history stages of fish are the most susceptible to the toxic impacts associated with heavy metals (Gould *et al.* 1994). Shifts in phytoplankton species composition can occur. This shift in the plankton composition may lead to an alteration of community structure by replacing indigenous producers with species of little worth as a food source to the trophic structure. Heavy metals have also been implicated in disrupting endocrine secretions of marine organisms, potentially disrupting natural biotic properties (Brodeur *et al.* 1997). While long-term impacts do not appear notable in marine organisms, heavy metals may move upward through trophic levels and accumulate in fish at toxic levels (bioaccumulation), which can eventually cause health problems in human consumers. Municipal and agricultural run-off, contaminated groundwater and sediments, industrial shipping, recreational boating, and atmospheric deposition are non-point sources of heavy metals. Point sources include industrial discharge, power plants, ocean disposal of dredged material, and marine transportation [e.g. hull paint containing lead to hinder biofouling – tributyltin (the use of tributylin has been banned in many regions but persists in the environment)].

Nutrients are essential for healthy ecosystems and control the productivity of the environment. However, nutrient over-enrichment can cause habitat degradation (ASMFC 1992; NOAA 1997). Eutrophication is a well documented impact involving nutrient over-enrichment occurring in coastal habitats (see O'Reilly 1994; Wilk and Barr 1994 for review). Habitats that become eutrophic are characterized by low dissolved oxygen (anoxia is possible), high turbidity, phytoplankton and filamentous algal blooms, and inhibited denitrification. Severely eutrophic conditions may reduce submerged aquatic vegetation (SAV) (Short and Burdick 1996; Goldsborough 1997), cause mass mortality of fish and invertebrates, and alter long-term natural community dynamics. Harmful algal blooms (HABs), commonly known as "red tides," associated with unnatural nutrient levels have been known to stimulate fish disease and kills (see Section 5.4.2 for further discussion) (NSF and NOAA 1998). Excess nutrients within coastal waters originate from non-point sources such as municipal and agricultural run-off, contaminated groundwater and sediments, atmospheric deposition, septic systems, industrial shipping, recreational boating, wildlife feces, and nuisance and toxic algae (see Section 5.4.2). Point sources include industrial discharge, aquariums, sewage treatment plants, water diversion, ocean disposal of contaminated dredged material, silviculture, and energy and mineral exploration and transportation.

Pesticides found in coastal habitats have killed marine organisms, and they accumulate in sediments and can be re-released into the water column during substrate disturbance (e.g. channel dredging). Pesticides may bioaccumulate by being absorbed by sediments and detritus then ingested by zooplankton, plankters, which in turn are eaten by fish (e.g. Pleuronectiformes) (ASMFC 1992). Winter flounder (*Pseudopleuronectes americanus*) livers from Boston and Salem Harbors contain the highest concentrations of dichlorodiphenyl trichloroethane (DDT) found on the east coast of the US and are ranked first and third, respectively, in the country in terms of total pesticides (Larsen 1992). This accumulation may cause health problems in humans consumers. Several pesticides are know to be endocrine disrupter of marine organisms. Agricultural run-off is a major non-point source, but pesticides can also occur at notable levels in residential areas. Other sources of pesticide discharge into coastal waters include atmospheric deposition and contaminated groundwater and sediments (non-point sources) and ocean disposal of dredged material and water diversion (point source) (see Meyers and Hendricks 1982 for review).

Herbicides may alter long-term natural community structure by hindering aquatic plant growth or destroying aquatic plants. Hindering plant growth can have notable effects on fish and invertebrate populations by limiting nursery and forage habitat. Chemicals used in herbicides may be endocrine disrupters. Coastal development and water diversion contribute substantial levels of herbicides entering fish and shellfish habitat. The major non-point sources are agricultural and municipal run-off, contaminated groundwater, and atmospheric deposition (Goldsborough 1997). Herbicides are also frequently used to inhibit colonization of boat hulls and pipes by micro-algae and subsequent growth of seaweeds (Readman *et al.* 1993).

Inshore regions can be impacted by the influx of acid. The brackish waters of estuaries are especially sensitive to acid effluents due to the lower buffering capacity of the higher salinity, oceanic waters. Acidification potentially disrupts or prevents reproduction, development and growth of fish (USFWS 1995). For example, osmoregulatory problems in Atlantic salmon smolts have been demonstrated to be related to habitats with low pH (Staurnes *et al.* 1996). Continual influx of acid to marine habitats can hinder the survival and sustainability of fisheries. Municipal and agricultural run-off, contaminated groundwater, and atmospheric deposition are potential non-point sources of acid influx to marine habitats. Industrial discharge and sewage treatment plant discharge are point sources of acid entering fish and shellfish habitat.

Chlorine can exert acute and sublethal effects on marine organisms (Sasikumar *et al.* 1993; Manning *et al.* 1996), especially early life history stages (Hose *et al.* 1989). The USEPA water quality criterion for chlorine discharge in marine and estuarine systems may not exceed 7.5 μg/L as a four day average and 13 μg/L as one-hour average more than once every three years (USEPA 1986). Chlorine effluent can decrease habitat quality and quantity leading to reduction of fishery resources. Chlorinated compounds [e.g. organochlorides – polychlorinated biphenyls (PCBs)], which can harm humans, have been

found to accumulate in the tissue of fish (e.g. Pomatomidae) (Eldridge and Meaburn 1992). Long-term stress from chlorine on the habitat can alter natural community structure and dynamics. Compounds containing chlorine are often used to inhibit settlement of biofouling organisms (Sasikumar *et al.* 1993). Chlorine non-point sources include septic systems and contaminated groundwater, and point sources include discharge from sewage treatment plants, industrial facilities, and power plants.

Thermal effluents in inshore habitat can be a severe problem by directly altering the benthic community or killing marine organisms, especially larval fish. Temperature influences biochemical processes of the environment and the behavior (e.g. migration) and physiology (e.g. metabolism) of marine organisms (Blaxter 1969). Long-term thermal discharge may change natural community dynamics. Sources of thermal pollution include industrial and power plant discharge. Forestry activities such as clear-cutting and the alteration or removal of riparian habitat can also lead to above normal water temperatures contributing to the degradation of habitat conditions.

Metabolic and/or excess food entering the marine environment can increase levels of nutrients and pathogens and lead to eutrophication and alteration of local benthic dynamics. A major source of metabolic and food wastes is agricultural facilities. Run-off from farmlands, including animal wastes and organic fertilizers, may contribute to the degradation of habitat. Septic systems, wildlife feces, and nuisance / toxic algae (non-point source), livestock waste and sewage treatment plants (point sources) are other sources of organic wastes potentially impacting habitat.

Fish and invertebrate habitat may be negatively impacted by an unnatural influx of suspended particles (Arruda *et al.* 1983). Lethal and sub-lethal impacts to marine organisms may occur with various concentrations of suspended sediments (Barr 1993). Short-term impacts of an increase in suspended particles include high turbidity, reduced light, and sedimentation which may lead to the loss of SAV and other benthic structure. Other problems associated with suspended solids include respiration disruption of fishes and invertebrates, disruption of water transport rates in marine organisms, reduction of filtering efficiency of invertebrates, sorption of metals and organic materials, reduction of egg buoyancy, disruption of ichthyoplankton development, reduction of growth and survival of filter feeders, and decreased foraging efficiency of sight-feeders (Messieh *et al.* 1991; Barr 1993). Toxic metals and organics absorbed by suspended solids may recur and become more available to marine organisms in the habitat when disturbed (e.g. dredging). Resuspension of sediments may supply nutrients to the water column that are needed for primary production. However, increased flux of nutrients into the water column may stimulate phytoplankton production and contribute to increased turbidity and alteration of nutrient cycles. Frequent high levels of suspended particles can lead to the loss of habitat for particular creatures. Suspended particles enter coastal areas from non-point source municipal and agricultural run-off, industrial shipping and recreational boating, and point source industrial discharge (e.g. pulp mills), dredging, ocean disposal of dredged material, water diversion, energy and mineral exploration and transportation, erosion control, silviculture, and marine transportation.

Radioactive wastes may be a potential threat degrading inshore habitat used by finfish and shellfish species. Fishery resources may accumulate radioactive isotopes in tissues posing problems for the resource and consumers (ICES 1991). Long-term exposure to radioactive wastes may alter the natural dynamics of the populations of fisheries and habitat. Potential sources of radioactive wastes are sunken vessels and submarines, municipal run-off, atmospheric deposition, contaminated groundwater and sediments (e.g. past dumping locations), and industrial and power plant discharge (e.g. nuclear power plants).

Sea levels have fluctuated through the history of earth and have been rising since the end of the Pleistocene. Changes in the rate of sea level rise result from tectonic and postglacial isostatic adjustments and effects of atmospheric temperature (Valiela 1995). Concern has been voiced that global warming and subsequent sea level rise may be accelerated by the continued release of greenhouse gases from the burning of fossil fuels and forests and using aerosol-producing substances (i.e. the greenhouse effect). Greenhouse gases, including carbon dioxide, methane, and chlorofluorocarbons, are discharged into the atmosphere from respiration of all living organisms, burning fossil fuels and forests, and using aerosols. Possible impacts on inshore habitats from sea level rise are the loss of wetlands, salinization of freshwater environments (eliminating freshwater supplies), and change in natural marine biotic (e.g. species composition) and abiotic (e.g. currents) properties (see Kelley 1992 for review). Salt marshes may be unable to accrete fast enough to keep pace with sea level rise; however, salt marshes can easily keep pace with the sea level rise found on the northeast coast of the United States (Valiela 1995) provided uplands are undeveloped adjacent to the salt marsh. Conflicting studies indicate that salt marshes of Maine are not keeping pace with sea level rise (Wood *et al.* 1989). According to Bigford (1991), the severity of the impacts of sea level rise on natural resources (e.g. marine organisms) depends on physical obstruction to inland habitat shifts from natural and human barriers, resilience of species to withstand new environmental conditions during periods of erosion-induced transition and the rate of environmental change.

5.4.2 Biological Threats

The introduction of nonindigenous species and/or reared species to the environment has been documented (Rosecchi *et al.* 1993; USFWS 1995; Witman 1996) and have been tied closely to human activities (Pearce 1998). Exotic introductions have apparently increased with the development of large, powerful vessels and aquaculture. The transportation of nonindigenous organisms to new environments can have many severe impacts on habitat (Omori *et al.* 1994). New pathogens or higher concentrations of disease can be spread throughout the environment resulting in deleterious habitat conditions. Non-native plants (e.g. *Phragmites*) potentially degrade coastal habitat by changing natural habitat qualities. Introduced organisms increase competition with indigenous species or forage on indigenous species which can reduce fish and shellfish populations. For example, the introduction of bryozoan (*Membranipora membranacea*) has reduced kelp populations,

ascidian (*Botrylloides diegensis*) has competitively displaced native hydroids, nudibranch (*Tritonia plebia*) has reduced invertebrate prey populations, and macroalgae (*Codium fragile*) has changed benthic structure (see Witman 1996). Long-term impacts of the introduction of nonindigenous and reared species can change the natural community structure and dynamics, lower the overall fitness and genetic diversity of natural stocks, and pass and/or introduce exotic lethal disease. Exotic fish, shellfish, pathogens, and plants enter the environment from industrial shipping (e.g. ballast), recreational boating, aquaculture (addressed in Section 4.7), biotechnology, and aquariums. Nonindigenous species of algae accidentally introduced to the environment is another potential problem for habitat (*expanded below*).

An increase in natural levels of nutrients induced by human activities can stimulate population explosions of nuisance and toxic algae [harmful algal blooms (HABs)] which have detrimental impacts to habitat and toxic effects on organisms and humans (see Milligan and Cosper 1994; O'Reilly 1994; Boesch *et al.* 1997; Burkholder and Glasgow 1997). Organisms responsible for HABs have naturally occurred in the environment for a long time, so the apparent increase bloom events may simply reflect better detection of natural phenomena (NSF and NOAA 1998). However, the current increased intensity and frequency of HABs compared to the past appears to indicate more toxic algal species, more algal toxins, more areas affected, more fishery resources affected, and higher economic losses (Boesch *et al.* 1997; NSF and NOAA 1998). Blooms of HABs have been nearly an annual event in coastal waters of New England for several years (White *et al.* 1993). Nonindigenous algal species may be introduced to the environment from ballast water of commercial vessels, recreational boating, shellfish transfer (e.g. seeding), dredging, and disposal of sediments (Boesch *et al.* 1997), adding to the potential problem of blooms. HAB-related events have occurred around the entire coast of the United States. HABs can indicate eutrophic conditions, alter, impair, or kill plankton and fish communities, smother indigenous vegetation, and lower dissolved oxygen (NOAA 1997). Certain toxic organisms (e.g. *Pfiesteria* spp.) are associated with HABs and have caused major outbreaks of disease and fish kills (Burkholder *et al.* 1992; NCSU 1998). These short-term impacts can eventually change the natural processes of habitat, reducing viable fish and shellfish populations.

The spread of disease among marine organisms is a potential adverse impact to fish habitat in coastal regions. Pathogens introduced inadvertently (e.g. via run-off) or advertently (e.g. from restocking programs) may spread infections which can be sublethal or lethal and possibly decrease the health and fitness of fish stocks (Kent *et al.* 1995). Human influences (e.g. nutrient over-enrichment) also have been illustrated to stimulate blooms of naturally occurring pathogens (NCSU 1998). The toxic dinoflagellate, *Pfiesteria piscicida* and other species, has been implicated as the primary causative agent of many fish kills and disease episodes in estuaries and inshore areas (Burkholder *et al.* 1992; NCSU 1998). Mortality and gill lesions in Atlantic salmon ware associated with a bloom of *Skeletonema costatum* and *T. rotula* (Kent *et al.* 1995). Shellfish area closures have resulted from the infestation of diseases (i.e. paralytic, amnesic, and neurotoxic shellfish poisoning) caused by pathogens (i.e. *Alexandrium, Pseudo-nitzchia, Gymnodinium breve*

respectively), but the toxins also move up through the trophic web, affecting zooplankton, fish eggs and larvae, juvenile and adult fish, birds, and marine mammals (Boesch *et al.* 1997). Direct sources of pathogens entering the environment include non-point sources such as municipal and agricultural run-off, septic systems, wildlife feces, industrial shipping, and recreational boating, and point sources such as disposal of dredged material, biotechnology labs, aquariums, and sewage treatment (ASMFC 1992).

5.4.3 Physical Threats

Channel dredging is a frequent long-term maintenance activity associated with coastal development, port and harbor development, and vessel activity (see Barr 1987 for review). The increased need for channel dredging has resulted from increased marine transportation, increased vessel size, expansion of commercial fleets, and alterations in sedimentation patterns of estuaries due to increased coastal settlement and urbanization (Messieh *et al.* 1991). The short-term impacts to habitat can be substantial. Dredging resuspends sediments (see Section 5.4.1) and associated contaminants and potentially degrades habitat quality and fish populations. Changes in tidal prism, depth, water temperature, salinity, water velocity, bottom topography, and sediment type are associated with dredging of channels. The changes can decrease dissolved oxygen and SAV distribution and density while smothering the surrounding benthic community. The reconfiguration of sediment type and the removal of biogenic structure may decrease the stability of the bottom and increase the ambient turbidity levels (Messieh *et al.* 1991). The dredged channel can increase the transport of sediment and siltation rates in the embayment resulting in alteration of local habitats. Increased siltation can effect spawning, feeding, and recruitment habitat (Messieh *et al.* 1991). Fragmentation of habitat can hinder the movements (i.e. dispersal, recruitment, migrations, etc.) of organisms. The continual maintenance involved with channel dredging can eventually change the indigenous habitat and population dynamics of the region.

The dredging and filling of wetlands for shoreline, coastal, port, and harbor development removes and alters habitat surrounding the developed area. Dredge and fill reduces the wetland function (i.e. retain floodwater and uptake nutrients) and decreases the amount of detrital food source available to biotic communities. Hydrological modifications from dredge and fill activities and general coastal development (e.g. golf courses) may increase the amount of run-off entering the coastal environments that may contribute to the degradation of fishery resources. Along with these specific impacts of wetland dredge and fill activities, the short- and long-term impacts are similar to channel dredging.

Marina and dock construction is an inevitable result of shoreline and port development. Regions that ports are constructed usually contain important estuarine habitats such as salt marshes and grass flats. The development of ports and harbors usually removes or alters these important habitat features (Vandermeulen 1996). The construction of marinas and docks also aggregates contaminants associated with the vessels that use the facilities. Along with contamination of the habitat, the construction of marinas changes habitat parameters such as tidal prism, depth, water temperature, salinity, current velocity and

SAV composition, distribution, and abundance. SAV is removed during construction and shaded by the physical structures after construction eventually destroying the vegetation. Mooring chains are frequently used in embayments surrounding marinas and docks. Mooring chains potentially degrade habitat conditions through physical disturbance of benthic features (e.g. SAV). Repeated small-scale habitat loss can have cumulative effects and can fragment habitat which can have a detrimental impact on fish and shellfish stocks. The long-term presence of marinas can contaminate the localized area and change natural habitat qualities and population dynamics in the region. Channel dredging and its associated threats (see Section 5.3.3) is directly related to the development of ports and harbors.

Vessel activity, including industrial shipping, recreational boating, and marine transportation (e.g. ferry transportation), may contribute to the physical degradation of marine habitats and related marine organisms. Increased vessel activity within coastal waters is directly related to increase in coastal urbanization and port and harbor development. There is generally a paucity of information of boating use levels, but there has been increasingly more boats using coastal waters for the last two decades (Stolpe 1996). For example, the Gulf of Maine is one of the busiest fishing ports on the east coast and is the third largest oil port in the east (Larsen 1992). Recreational boating may also be a particular concern since most boating activity occurs in warmer months – the time of greatest biological activities in east coast estuaries (Stolpe 1996). The severity of boating-induced disruption on coastal habitats may depend on the geomorphology of the impacted area (i.e. water depth, width of channel or tidal creek, etc.), current speed, composition of sediments, vegetation type and extent of cover, and classification of boat traffic (Yousef 1974; Karaki and vanHoften 1975; Barr 1993). The benthos, shoreline, and pelagic habitat may be disturbed or altered from vessel use in inshore regions, and may result in a cascade of cumulative impacts from hundreds of trips per day in heavily used areas (Barr 1993).

- The direct disturbance of bottom topography (e.g. prop scarring) results in increased turbidity (see Section 5.4.1 for further details) which can lead to the direct loss of SAV, nursery and forage habitat that may adversely affect benthic recruitment, or re-release nutrients into the water column and increase primary productivity that may indirectly reduce SAV through decreasing the depth of light penetration (Yousef 1974; Hilton and Phillips 1982; Barr 1993; Stolpe 1996). Disturbance of nutrient-rich surficial sediments by vessels may indirectly contribute to nutrient over-enrichment of inshore habitats (Barr 1993). Other environmental conditions (i.e. water temperature, dissolved oxygen, pH, etc.) may also change with the resuspension of bottom sediments (Barr 1993). The destruction of SAV and other benthic habitat (i.e. sponge colonies) may consequently fragment, decrease quality, and/or destroy large areas of habitat.

- Elevated wakes caused by industrial and recreational shipping and transportation can have substantial impacts on coastal habitat. The continual disturbance of water along frequently traveled routes can lead to shore erosion, substrate

disturbance, increase turbidity, and pelagic disturbance (Barr 1993; Stolpe 1992) which can eventually cause the loss of habitat.

- The water column, especially the pelagic and neritic communities, is critical for the survival and health of fish and shellfish stocks. The propeller or impeller of vessels may directly damage or kill ichthyoplankton or other creatures in the upper water column (Stolpe 1992; Stolpe 1996), or indirectly damage important creatures (i.e. diatoms and other microflora) by increasing turbidity in the water column (Barr 1993). It was also suggested that the noise and direct disturbance to the neritic zone may be notable factors in disturbing the migration or recruitment of coastal organisms (Barr 1993; Stolpe 1996). Continued disturbance of these particular pelagic habitats that fishes aggregate can result in decreases of numbers of marine organisms.

As more people move to the coast, development pressure increases and structures are often constructed along the coastline to prevent erosion and stabilize shorelines. Attempts to protect beaches and reduce shoreline erosion are associated with the development of the coast. Bulkheads, seawalls, jetties, and groins are structures designed to slow or stop the shoreline from eroding. In many cases the opposite occurs with erosion rates increasing along the regulated area. Adjacent coastal habitat is altered and potential short- and long-term impacts to fish and shellfish stocks are associated with the presence of the erosion control structures.

- Bulkheads are rigid structures built parallel to the shoreline (Leatherman 1988) of bays and can alter habitat by changing the wave energy dynamics along the coast which can increase erosion and eliminate the land-water interface. The change in wave energy dynamics alters sedimentation patterns which can disrupt benthic structure (e.g. SAV). The long-term presence of bulkheads can lead to severe erosion along the shoreline and change the natural habitat and associated biotic dynamics of the region.

- Seawalls are very similar to bulkheads, but are built along the coast of the open ocean for erosion protection. Seawalls change the wave energy dynamics along the shore which prevents natural sediment exchange. They can quickly erode the shore, eliminate the land-water interface, and potentially remove the benthic community. Disruption of littoral drift and the associated patterns of egg and larval dispersal occurs with the construction of seawalls along the coast. Potential long-term impacts to habitat are erosion of the shore and subsequent changes to natural habitat and dynamics.

- Jetties are paired structures constructed perpendicular to the shore at the mouth of a channel, often used to reduce the filling of channels with sediments to protect and maintain navigable inlets (Leatherman 1988). The construction of jetties can have deleterious impacts on coastal habitats. Longshore transport of sediment is trapped on the updrift side of the jetty, and the beaches downdrift erode with no

accretion to replace sediments. The change in sedimentation, tidal, and current patterns can alter the movement of eggs and larvae which depend on natural patterns of dispersal for survival. The natural habitat and population dynamics are potentially changed with the presence of jetties.

- Groins are a series of small jetties constructed perpendicular to the shore which extend from the beach into the surf zone (Leatherman 1988) and are a potential source of erosion control. The impacts to habitat are less severe than jetties and equilibrium of sediment transport may occur along the coast. The long-term impacts of groins appear to be low, but potential problems should not be ignored.

Development of the shoreline may include structures which restrict tidal movements (i.e. roads, bridges, dikes, etc.). The natural flushing of estuarine habitats (e.g. salt marshes) can be hindered by the construction of tidal restricting structures. Confined inshore waters with restricted water exchange may allow HABs to persist (Boesch *et al.* 1997). Physicochemical properties (i.e. salinity, dissolved oxygen, flow, etc.) are altered changing the habitat characteristics that may hinder migratory, spawning, feeding and dispersal movements of marine organisms resulting in depleted stocks of fish and invertebrate species. The hindrance or blockage of tidal flushing and associated biotic movements can degrade associated habitat by altering the natural dynamics.

Dam construction and operation occurs along the New England coast for flood control, power generation, and reservoir formation. The construction of dams with either inefficient or non-existent fish ways was a major cause of the population decline of U.S. Atlantic salmon, *Salmo salar* (USFWS 1995). Dams alter water flow and sedimentation patterns, depth, water temperature, salinity and stream bed properties. Estuaries directly lose freshwater input with the construction of dams. Migration of fishes is hindered or blocked. Fishes are impinged and entrained, and exposed to dissolved gas supersaturation, aggregated contaminants, and high concentrations of predators and disease in the habitat surrounding dams. The disruption of fish development because of riverine dam construction can directly change the natural habitat and fishery dynamics of inshore regions. The loss of wetlands by the reduction of freshwater input and sediments can have potentially serious impacts on both fish and invertebrate populations.

Freshwater flows into inshore environments are subject to human alteration through water diversion and use and modifications to the watershed (i.e. deforestation, tidal restrictions, and stream channelization) (Boesch *et al.* 1997). Water withdrawal for freshwater drinking supply, power plant coolant systems, and irrigation occurs along urban and agricultural coasts causing potential detrimental effects on marine habitats and is associated with coastal development. The mass flow of water into a power plant and other reservoirs results in entrainment and impingement of fishes (especially early life-history stages of fish). Larval and juvenile demersal fishes along with invertebrates are susceptible to entrainment and impingement around intake pipes (ASMFC 1992). Critical habitat is lost for marine organisms that are not capable of settling around the intake and may adversely affect fish and shellfish populations by adding another source of mortality

to the early life stage which often determines recruitment and strength of the year-class (Travnichek *et al.* 1993). Water withdrawal and diversion along with anthropogenic watershed changes have been related to the increase in some HABs (Boesch *et al.* 1997) impacting aquatic and marine habitat. The continued diversion and use of water from coastal waters can lead to degradation of fish and shellfish habitats.

- Freshwater is becoming limited because of natural events (e.g. droughts), increasing demand of potable water, and inefficient use. Fresh and saline water is withdrawn for human use from the estuarine and coastal environments. The withdrawal of water can alter natural current patterns, water temperature, salinity, tidal prisms, and associated biotic communities.

- Irrigation for agriculture alters currents, salinity, water temperature, depth and drainage and sedimentation patterns of estuarine and marine habitat along the coast. Sedimentation within estuaries can hinder benthic processes and communities. Irrigation can also increase run-off containing materials (i.e. heavy metals, nutrients, etc.) which stress the habitat. The changes to the natural habitat caused by irrigation can potentially lead to changes in the dynamics of marine organisms.

Inshore habitats are impacted by deforestation. Silviculture practices and coastal development contribute to the removal of vegetation and subsequently an increase of impervious surfaces along a river which increases stream bank and stream bed erosion and sedimentation of riparian and estuarine habitat. Hydrologic characteristics (e.g. water temperature) are changed and greater variation in stream discharge is associated with the forestry industry (USFWS 1995). Debris (i.e. wood and silt) are released into the water as a result of the harvest of the forest which can smother benthic habitat. Deforestation can alter or impair natural habitat structures and dynamics.

There is an increasing demand for good-quality sand and gravel aggregate and an increasing exploration for oil, and offshore habitats are being seen as a possible source (Messieh *et al.* 1991). Mining presents potential direct and indirect problems within inshore habitats such as issues related to toxicity of operational chemicals, accidental discharge of wastes, removal of benthic flora and fauna, changes in substrate character, and the suspension of sediments (ICES 1991). Mining can have direct and indirect impacts to the habitat of the mining site and surrounding regions. Structures are built within habitats to assist in mining and transporting materials. In a review by Pearce (1994), the effects of mining have been listed as: (1) “destruction” of existing benthic biotic community; (2) resuspension of sediments with negative impacts on fishes (see Section 5.4.1); (3) changes in bottom topography and sediment composition; and (4) consequences related to the sediment transport from the site by currents. Gravel, mineral, and oil mining occur in inshore environments which are essential for fisheries, and operational and accidental discharges are an environmental concern (Messieh *et al.* 1991).

- Gravel aggregates are abundant throughout the Gulf of Maine and are a potential source for miners (Messieh *et al.* 1991). Removal of sand from inshore habitats may increase coastal wave action and erosion as a result of the removal of source material for the maintenance of barrier islands and beaches (Messieh *et al.* 1991). Gravel / mineral mining is associated with an increase in stress to the surrounding habitat and removal and disturbance of substrate (Scarrat 1987). The alteration of the mining site can fragment habitat, negatively impacting fish and shellfish populations. Long-term mine sites potentially can change natural habitats and associated fish and shellfish populations (Wilk and Barr 1994).

- Oil mining has similar impacts as gravel / mineral mining but more risk is associated with spills and blow-outs (i.e. ruptured pipelines) which can disrupt habitat (Wilk and Barr 1994). Oil wells are in the initial stage of exploration, and drilling muds and well cuttings are potential environmental concerns. Drilling muds (either water-based or oil-based muds) are complex and variable mixture of fluids, suspended solids, and chemical additives (Messieh *et al.* 1991).

Debris, either floating on the surface, suspended in the water column, covering the benthos, or along the shoreline within inshore habitat can have deleterious impacts on fish and shellfish habitat (see Coe and Rogers 1997). Debris is usually defined as man-made solid objects introduced into the environment (Hoagland and Kite-Powell 1997). Benthic communities can be smothered or shaded by debris which results in alteration of the benthic community. Marine organisms may ingest pellets or plastic fragments or become entangled in rope or plastic strings which eventually kill the organisms. The natural processes of the environment are potentially disrupted by debris discharged into inshore habitats. Hoagland and Kite-Powell (1997) review the type, sources, and fates of marine debris in the Gulf of Maine. Plastics account for nearly half of the marine debris found in Maine, New Hampshire, and Massachusetts. Metals, glass, and paper also constitute a proportion of debris in the three states. Cigarette butts are a potential problem in marine environments. Major non-point sources of non-fishing related debris entering the marine environment include industrial shipping, recreational boating, municipal run-off, and decaying shoreline structures. Solid waste disposal, landfills, offshore mineral exploration, and industrial discharge are potential point sources of debris (USEPA 1994) (see Section 4.6 for fishing related marine debris).

Disposal of dredged material can disrupt and degrade natural habitat and biotic communities. The stresses associated with dredged material (i.e. oil, heavy metals, nutrients, suspended particles etc.) can threaten the habitat of the dump site and adjacent areas. Along with contaminating the habitat, direct disturbance of the benthic and pelagic communities occurs with disposal. Benthic communities are smothered, associated physicochemical conditions are altered, and increased turbidity may hinder pelagic processes (e.g. photosynthesis of algae) by material settling to the bottom (see Section 5.4.1). The potential deleterious impacts of dredged material disposal can alter local and surrounding community structure.

Artificial reefs can be an effective tool in fishery development with proper management (McGurrin *et al.* 1989; ASMFC 1993). Properly constructed artificial reefs can enhance rough bottom habitat and provide quality fishing grounds to the benefit of anglers and coastal communities (Stone 1982). The location and composition of artificial reefs in inshore waters should be assessed properly for the most effective methods to enhance fish and shellfish populations. Artificial reefs placed improperly may change natural habitat conditions and community structure by attracting unnatural species assemblages. Inappropriate reef material (i.e. combustion/incineration ash and tires) may decompose and release toxic substances to the surrounding area, and reefs may become dislodged from the bottom and disrupt benthic structure.

5.5 THREATS TO OFFSHORE EFH

Habitats within the offshore region of New England are found, generally, in deep waters with stable biological communities. There are also many high energy offshore habitats in which environmental conditions are continuously changing. Benthic and pelagic marine life are disrupted by a growing number of threats within offshore waters. As threats are continually added to inshore waters, contamination migrates away from the coast and potentially endangers the health of offshore habitats. Offshore waters are being looked to more frequently to supply new resources or resources that have been eliminated from coastal environments. Deep, stable waters and high energy offshore habitats may be disturbed by the increasingly amount of non-fishing threats and may disrupt environmental conditions. Low levels of disturbance in deep, stable habitats may present serious implications on finfish and shellfish populations. Disruptions in more stable environments also presents concern for marine ecosystems. Chemical, biological, and physical threats continue to grow in areas important for fishery resources in the offshore region.

5.5.1 Chemical Threats

Oil can have severe detrimental impacts on offshore habitat. Spills or blowouts can produce an oil slick on surface waters which can disrupt the entire pelagic community (i.e. phytoplankton, zooplankton, ichthyoplankton). The contaminant can interfere with reproduction, development, growth and behavior (e.g. feeding) of fishes, especially in early ontogenetic stages. Carcinogenic and mutagenic properties of oil compounds are receiving increasing attention around the world (Larsen 1992). Oil slicks may not persist in surface waters of the offshore for a long period; however, if repeated spills or blowouts associated with wells or transport persist, the community organization and dynamics may be disrupted. Oil will accumulate and persist in sediments. Contaminated sediments may degrade benthic communities. Non-point and point sources of oil in offshore habitats originate from industrial shipping, recreational boating, marine transportation, energy and mineral exploration and transportation, and ocean disposal of contaminated dredged material.

Marine organisms can be contaminated or killed directly and indirectly from the stress of heavy metals discharged into offshore waters. Sediment accumulates the toxic metals, and

fishes bioaccumulate contaminants which can cause health problems in human consumers of fish. Industrial and recreational shipping and atmospheric deposition are non-point sources of heavy metals. Ocean disposal of contaminated dredged material, energy and mineral exploration (e.g. drilling muds), and marine transportation (e.g. hull paint containing lead) introduce heavy metals into the environment (Larsen 1992; Buchholtz ten Brink 1996).

Localized eutrophic conditions, characterized by phytoplankton and filamentous algal blooms (HABs), high turbidity, low dissolved oxygen, and low denitrification rates, can occur in offshore habitats with unnaturally high concentrations of nutrients. Any increase in the nutrient levels of the open ocean will markedly effect the productivity of phytoplankton communities (Omori *et al.* 1994). Increasing the surface productivity may increase the flux of material from the sea surface to the deep sea benthos (Omori *et al.* 1994). The stable, deep sea environment is trophically linked to the surface waters and an increase flux of organic matter may have notable impacts on bottom habitats (Omori *et al.* 1994). Other toxic organisms may be implicated with the blooms of noxious algae causing outbreaks of disease or fish kills (see Section 5.5.2). Long-term impact of persistent eutrophication in offshore habitats can cause mass mortality of marine organisms and alter natural community dynamics. Nutrients enter offshore waters from non-point sources such as industrial shipping, recreational boating, and atmospheric deposition, and point sources, including ocean disposal of contaminated dredged material, and energy and mineral exploration and transportation.

Fish and invertebrate populations may be impacted by the input of pesticides into offshore habitats. Marine organisms may be directly killed by pesticides or bioaccumulation may occur with long-term exposure. Contaminated sediments can accumulate in the benthos providing a potential source of stress through trophic levels. Pesticides enter offshore habitats through atmospheric deposition illustrating a potential non-point source, and ocean disposal of dredged material illustrating a point source.

Herbicides and fungicides can alter marine habitats by hindering phytoplankton growth and possibly leading to lasting community structure change. Alteration of the photosynthetic plankton community can alter fishery dynamics by replacing natural plankton species composition with new species. The change in the planktonic community may change the lower trophic structure so cascade effects may hinder fish populations (e.g. bottom-up process). Herbicides can be released into offshore habitats from atmospheric deposition and disposal of dredged material.

Unnatural levels of suspended particles in offshore habitats can increase turbidity, smother benthic habitat, hinder respiration, disrupt water transport rates, and reduce filtering efficiency of organisms. Other problems associated with suspended solids include sorption of toxic metals and organic materials, reduction of egg buoyancy, disruption of ichthyoplankton development, reduction of growth and survival of filter feeders, and decreased foraging efficiency of sight-feeders (Barr 1993). The functions (e.g. photosynthesis) and properties (e.g. dissolved oxygen) of the entire water column may be

frequently disrupted. Long-term flux of suspended sediments to offshore waters may provide a source of nutrients that stimulate primary production and contribute to increased turbidity and altered nutrient cycles. Continued high levels of suspended material within offshore waters can lead to fragmentation and alteration of localized community of benthic and pelagic organisms. Suspended particles enter the offshore environment from ocean disposal of dredged material and mining practices.

Radioactive wastes (see Section 5.4.1).

Greenhouse gases (see Section 5.4.1).

5.5.2 Biological Threats

Nonindigenous species and reared species potentially impact natural populations by transmitting diseases (exotic or natural), increasing competition with indigenous species, increasing predation on natural organisms, and altering the natural genetic pool (e.g. less genetic heterogeneity). These deleterious impacts can potentially lead to lower fitness of stocks and change the natural community structure and dynamics. Human activities are closely associated with exotic introductions. Shipping (e.g. ballast water), aquariums, and biotechnology are potential sources of nonindigenous species in offshore waters. Dredged material disposal may introduce algal species that degrade habitat conditions.

An increase in natural levels of nutrients induced by human activities can stimulate population explosions of nuisance and toxic algae [harmful algal blooms (HABs)] which have detrimental impacts to habitat and toxic effects on organisms and humans (see O'Reilly 1994; Boesch *et al.* 1997). Organisms responsible for HABs have naturally occurred in the environment for a long time, so an apparent increase in bloom events may simply reflect better detection of natural phenomena (NSF and NOAA 1998). However, the current increased intensity and frequency of HABs compared to the past appears to indicate more toxic algal species, more algal toxins, more areas affected, more fishery resources affected, and higher economic losses (Boesch *et al.* 1997; NSF and NOAA 1998). Nonindigenous algal species may be introduced to the environment from ballast water of commercial vessels, recreational boating, shellfish transfer (e.g. seeding), dredging, and disposal of sediments (Boesch *et al.* 1997), adding to the potential problem of blooms. HABs can indicate eutrophic conditions, alter, impair, or kill plankton and fish communities, and lower dissolved oxygen (NOAA 1997). Certain toxic organisms (e.g. *Pfiesteria* spp.) are associated with HABs and have caused major outbreaks of disease and fish kills within inshore waters (NCSU 1998); however, these outbreaks may spread to offshore habitats. These short-term impacts can eventually cause a change in the natural processes of habitat reducing viable fish and shellfish populations.
Pathogens can be a serious problem in offshore waters by spreading disease and possibly impacting the long-term success, health, and fitness of fish and invertebrate populations. Shellfish area closures may be required as a result of the spread of diseases (i.e. paralytic, amnesic, and neurotoxic shellfish poisoning) which have impacts on human health. For example, paralytic shellfish toxins have been detected in Atlantic surfclams (*Spisula*

solidissima), Atlantic sea scallops (*Placopecten magellanicus*), northern horse mussels (*Modilus modiolus*), and ocean quahogs (*Arctica islandica*) within areas of Georges Bank at levels exceeding the public health safety threshold (White *et al.* 1993). Potential origins for pathogens in the environment include non-point sources of discharge such as industrial shipping, recreational boating, and point sources of discharges such as aquariums and biotechnology (NOAA 1992). Localized regions of high nutrients may trigger outbreaks in harmful organisms that may hinder the health and success of fish and shellfish populations.

5.5.3 Physical Threats

Vessel activity, including industrial and recreational shipping and ferry transportation, may contribute to the physical degradation of marine environments and associated organisms. Marine organisms may be directly injured or killed by the propeller or impeller of vessels (Stolpe 1996). Frequently traveled ferry routes within offshore waters may slightly disturb pelagic habitat which can potentially disrupt spawning behavior, recruitment patterns, and egg and larval transport (Barr 1993). The continual disturbance of the pelagic habitat may potentially hinder long-term productivity of offshore waters.

There is an increasing demand for good-quality sand and gravel aggregate and an increasing exploration for oil, and offshore habitats are being seen as a possible source (Messieh *et al.* 1991). For example, Georges Bank is being proposed for several exploratory drillings because of its hydrocarbon potential (Messieh *et al.* 1991). Mining presents potential direct and indirect problems to habitat of the mining site and surrounding regions such as issues related to toxicity of operational chemicals, accidental discharge of wastes, removal of benthic flora and fauna, changes in substrate character, and the suspension of sediments (ICES 1991). Structures are also built within habitats to assist in mining and transporting materials. In a review by Pearce (1994), the effects of mining have been listed as: (1) "destruction" of existing benthic biotic community; (2) resuspension of sediments with negative impacts on fishes (see Section 5.5.1); (3) changes in bottom topography and sediment composition; and (4) consequences related to the sediment transport from the site by currents. Gravel, mineral, and oil mining occur in marine environments which are essential for fisheries, and operational and accidental discharges are an environmental concern (Messieh *et al.* 1991).

- Gravel aggregates are abundant throughout the Gulf of Maine and are a potential source for miners (Messieh *et al.* 1991). Gravel / mineral mining is associated with an increase in stress to the surrounding habitat and removal and disturbance of substrate (Scarrat 1987). The alteration to the mining site can fragment habitat, negatively impacting fish and shellfish populations. Long-term mining sites potentially can change natural habitats and associated fish and shellfish populations (Wilk and Barr 1994).

- Oil mining has similar impacts as gravel / mineral mining with more risk associated with accidental spills and blow-outs which can disrupt habitat (Wilk and Barr

1994). Oil wells are in the initial stage of exploration in offshore New England waters. Drilling muds and well cuttings are potential drilling wastes of oil exploration. Drilling muds (either water-based or oil-based muds) are complex and variable mixture of fluids, suspended solids, and chemical additives (Messieh *et al.* 1991). If exploration results in notable amounts of resources, industrial development may occur in offshore waters; consequently, leading to larger amounts of drilling wastes and discharge (Messieh *et al.* 1991)

Debris discharged or transported offshore may degrade and disrupt benthic and pelagic habitats (see Coe and Rogers 1997). Debris within offshore habitat can smother benthic communities or be ingested by fish (Hoagland and Kite-Powell 1997). Reduction of habitat by destroying the benthos can alter community structure and hinder the sustainability of fisheries. Debris non-point sources include industrial shipping and recreational boating, and a point source includes ocean disposal of garbage and mineral exploration (USEPA 1994) (see section 4.6 for fishing related marine debris).

Disposal of dredged material can disrupt and degrade natural habitat and biotic communities. The associated stresses of dredged material (i.e. oil, heavy metals, nutrients, suspended particles etc.) potentially threaten the habitat of the dump site and adjacent areas. Providing a flux of nutrients to offshore habitats from dredged material may be a notable source contributing to algal blooms. Along with contaminating the habitat, direct disturbance of the benthic and pelagic communities occurs with disposal. Benthic communities are smothered, associated physicochemical conditions are altered, and increased turbidity may hinder pelagic processes (e.g. photosynthesis of algae) by material settling to the bottom (see Section 5.5.1). The potential deleterious impacts of dredged material disposal can alter local and surrounding community structure.

Artificial reefs can be an effective tool in fishery development with proper management (McGurrin *et al.* 1989; ASMFC 1993). Properly constructed artificial reefs can enhance rough bottom habitat and provide quality fishing grounds to the benefit of anglers and offshore fisheries (Stone 1982). The location and composition of artificial reefs should be assessed properly for the most effective methods to enhance fish and shellfish populations. Artificial reefs placed improperly may change natural habitat conditions and community structure by attracting unnatural species assemblages. Inappropriate reef material (i.e. combustion/incineration ash and tires) may decompose and release toxic substances to the surrounding area, and reefs may become dislodged from the bottom and disrupt benthic structure.

5.6 SPECIFIC EXAMPLES OF POTENTIAL NON-FISHING THREATS

Coastal development has been previously noted as a major contributor to the alteration and degradation of aquatic and marine habitats. The New England coast is lined with numerous urban centers and associated harbors and ports (Table 12). Potential habitat loss or change is greater in areas of high population density.

Table 12: The major ports and harbors within the New England region. List compiled from NOAA 1996.

PRIMARY PORTS
Portland, ME
Boston, MA
Gloucester, MA
New Bedford, MA
Providence, RI
Point Judith, RI

SECONDARY PORTS
Boothbay, ME
Bucksport, ME
Eastport, ME
Ellsworth-Bar Harbor, ME
Jonesport, ME
Searsport, ME
Southwest Harbor, ME
Stonington, ME
Ogunquit, ME
Kennebunkport, ME
Portsmouth, NH
Provincetown, MA
Chatham, MA
Wellfleet, MA
Newport, RI
Montauk, NY

Past, present and potential sites of offshore disposal of domestic (e.g. sewage) and industrial (e.g. wastewater) wastes are potential areas of concern to fish and shellfish habitat. Barr and Wilk (1994) summarized dumpsites in New England waters (Table 13). Two industrial waste dumpsites in the Mid-Atlantic Bight are described which may influence fish and shellfish populations in the New England region. There are no sewage sludge dumpsites in the Gulf of Maine; however, sewage sludge was discharged into Boston Harbor from the Deer Island and Nut Island Waste Water Treatment Plants for decades which ended in December 1991. The discharged material contained toxic heavy metals, oil, and pesticides which has been incorporated in sediments.

Table 13: Past industrial and sewage sludge dumpsites, materials discharged, duration of dumping, and year dumping was ended.

SITE	MATERIALS	DURATION	ENDED
Massachusetts Bay Industrial Waste Site (42° 27.7'N, 70° 35.0'W) located 19 miles off Boston	radioactive wastes toxic/hazardous chemicals heavy metals	100 years	1976
Acid Waste Site, New York Bight (40° 16' to 40° 20'N, 73° 36' to 73° 40'W) located off New York City	acid and alkaline wastes		1988
Deepwater Dumpsite 106 (38° 45'N, 72° 20'W) located 106 miles from New York Harbor	industrial waste sewage sludge		1991
12-Mile Dumpsite (12 miles off Sandy Hook, NJ)	sewage sludge heavy metals	63 years	1987

Dredging occurs in coastal waters and lands for the maintenance of navigable channels and development. Disposal of dredged material may have serious detrimental impacts to habitat. Historical sites of ocean disposal of dredged material are potential locations of important fish and shellfish habitat (Table 14).

Table 14: Major and minor locations of dredged material disposal, noting several locations off the New York and New Jersey coast that can indirectly impact New England fishery resources (Table partially reproduced from Kurland *et al.* 1994).

MAJOR SITES	DESCRIPTION
Rockland, ME	3.3 miles northeast of Rockland Harbor. Has been used since 1973.
Portland, ME	3.5 miles from Portland Harbor. Has been used since 1973.
Cape Arundal, ME	2.75 mile southeast of Cape Arundal. Has been used since 1985
Massachusetts Bay, MA	"Foul Area" west of Stellwagen Basin
Buzzards Bay, MA	1.4 miles from Chappaquoit Point, West Falmouth
New London, CT	2 miles south of harbor. Has been used since 1972.
Cornfield Shoals, CT	6.5 miles southwest of the Connecticut River delta.
Central Long Island Sound	5 miles south of New Haven Harbor. Has been used since 1955.
Western Long Island Sound	2.7 miles south of Noroton, CT. Has been used since early 1980's
MINOR SITES	
St. Helena, ME	Outside St. Helena Harbor entrance. Last used in 1988.
Frenchman's Bay, ME	Used infrequently.
Saco Bay, ME	Used once in 1989.
Sandy Bay, ME	Used once in 1987.
Sheep Island, ME	Used twice in 1987 and 1988.
Cape Cod Bay, MA	Used since 1995
Wellfleet, MA	Adjacent to Wellfleet Harbor entrance. Last used in 1983.

All types of power plants potentially degrade and alter surrounding habitat through water withdrawal and effluent discharges containing contaminants. Several nuclear power plants threaten aquatic and marine environments in New England (Table 15).

Table 15: Nuclear power plants along coastal and riverine habitat in New England.

Connecticut	Rhode Island	Massachusetts	New Hampshire	Maine
Millstone - Waterford	none	Pilgrim - Plymouth	Seabrook - Seabrook	Maine Yankee[1] - Wiscassett

[1] *no longer operating, ceased in 1997*

Navigation of inshore waters requires maintenance that includes channel dredging. Channel dredging potentially adversely effects a suite of biological, chemical, and physical aspects of the environment. Rivers, channels, shoals, ponds, canals, harbors, and bays are potentially dredged to maintain navigable waterways (Table 16).

Table 16: Federal navigation projects in Massachusetts (from north to south).

RIVERS	HARBORS / BAYS		OTHER*
Merrimack River	Newburyport Harbor	Provincetown Harbor	Pollock Rip Shoals

Ipswich River
Essex River
Annisquam River
Island End River
Malden River
Mystic River
Neponset River
Weymouth fore
Town River
Weymouth Back
Westport River
Taunton River
Menemsha Creek

Sandy Bay
Rockport Harbor
Pigeon Cove
Gloucester Harbor
Beverly Harbor
Salem Harbor
Lynn Harbor
Winthrop Harbor
Boston Harbor
Dorchester Bay
Cohasset Harbor
Ningham Harbor
Scituate Harbor
Green Harbor
Duxbury Harbor
Kingston Harbor
Plymouth Harbor

Wellfleet Harbor
Pleasant Bay
Stage Harbor
Buttermilk Bay
Hyannis Harbor
Falmouth Harbor
Little Harbor
Woods Hole Harbor
Wareham Harbor
New Bedford Harbor
Fairhaven Harbor
Fall River Harbor
Cuttyhunk Harbor
Vineyard Haven Harbor
Edgartown Harbor
Nantucket Harbor

Cross Rip Shoals
Lagoon Pond
Cape Cod Canal
Canapitsit Channel

Table 17: Non-Fishing Related Threats to EFH and Activities and Sources Contributing the Threats

ACTIVITIES & SOURCES ("2°" ≡ secondary source)	THREATS: Chemical												Biological			Physical																		
																				erosion control						water diversion			mining					
	oil	heavy metals	nutrients	pesticides	herbicides / fungicide	acid	chlorine	thermal	metabolic / food wastes	suspended particles	radioactive wastes	greenhouse gases	exotic / reared organisms	nuisance / toxic algae	pathogens	channel dredge	dredge and fill	marina/dock construction	vessel activity	bulkheads	seawalls	jetties	groins	tidal restriction	dam construction/operation	water withdrawal	irrigation	deforestation	gravel / mineral mining	oil / gas mining	peat mining	debris	artificial reefs	dredged material disposal
non-point sources																																		
municipal run-off	X	X	X	X	X	X			X	X	X			X	X																	X		
agricultural run-off	X	X	X	X	X	X			X	X				X	X																			
atmospheric deposition		X	X	X	X	X				X	X	X																						
wildlife feces			X						X					X	X																			
septic systems			X				X		X					X	X																			
industrial shipping	X	X	X							X			X	X	X	X		X	X									X	X	X	X		X
recreational boating	X	X	X							X			X	X		X		X	X												X		X
contaminated groundwater (2°)		X	X	X	X	X	X				X			X																				
contaminated sediments (2°)	X	X	X	X							X			X																				X
nuisance / toxic algae (2°)			X						X						X																			
point sources																																		
industrial discharge		X	X			X	X	X	X	X	X			X																				
power plants	X	X					X	X			X														X									
sewage treatment plants			X			X	X		X					X	X																			
ocean disposal of dredged material	X	X	X	X						X				X																				
aquariums			X										X		X																			
biotechnology labs													X		X																			
silviculture			X						X	X				X													X							
water diversion			X	X	X					X				X	X									X	X	X	X							
decaying shoreline structures																		X	X													X		
energy and mineral exploration/transportation	X		X							X				X															X	X	X			X
marine transportation	X	X								X						X		X	X															X
coastal development			X	X	X											X	X	X	X	X	X	X	X	X	X	X	X	X						X
port / harbor development																X	X	X	X	X	X	X	X	X	X			X				X		X
erosion control										X										X	X	X	X	X	X									

5.7 CUMULATIVE AND SYNERGISTIC IMPACTS

Natural, uncontrolled environments are rarely impacted by isolated threats. A number of threats combine or simultaneously act to change or degrade habitat. Cumulative impacts are the combined outcome of numerous actions and stresses which alone may have relatively minor impacts, yet add up to severe habitat degradation or loss (Vestal *et al.* 1995). For example, the alteration of habitat through loss of wetlands, degradation of water quality from non-point and point sources of pollution, and changes in water chemistry (e.g. salinity) from water diversion operations can lead to notable losses of habitat both spatially and temporally on a broad scale. Synergistic impacts are a more complex magnification to produce a greater impact than additive effects.

Fishing and non-fishing activities influence habitat function. Depending on the characteristics of habitat, including spatial and temporal variations, physical, biological, and chemical properties, a suite of potential deleterious actions and threats, both human and natural threats, can impact habitat differently. Current programs to assess and mitigate cumulative impacts in coastal regions are reviewed in Vestal *et al.* (1995) and include:

- The U.S. Fish and Wildlife Service Cause / Effect Process
- EPA's Synoptic Approach
- Alaska's Assessment of Cumulative Impacts on Fish Habitat in the Kenai River
- Regional Ecological Risk Assessment
- A Landscape Conservation Approach