FISHERY ECOSYSTEM PLAN
OF THE SOUTH ATLANTIC REGION

VOLUME IV: THREATS TO THE SOUTH ATLANTIC ECOSYSTEM AND RECOMMENDATIONS

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ABBREVIATIONS AND ACRONYMS

ABC	Acceptable Biological Catch
ACCSP	Atlantic Coastal Cooperative Statistics Program
ACE	Ashepoo-Combahee-Edisto Basin National Estuarine Research Reserve
APA	Administrative Procedures Act
AUV	Autonomous Underwater Vehicle
B	A measure of stock biomass either in weight or other appropriate unit
B_{MSY}	The stock biomass expected to exist under equilibrium conditions when fishing at F_{MSY}
B_{OY}	The stock biomass expected to exist under equilibrium conditions when fishing at F_{OY}
B_{CURR}	The current stock biomass
CEA	Cumulative Effects Analysis
CEQ	Council on Environmental Quality
CFMC	Caribbean Fishery Management Council
CPUE	Catch per unit effort
CRP	Cooperative Research Program
CZMA	Coastal Zone Management Act
DEIS	Draft Environmental Impact Statement
EA	Environmental Assessment
EBM	Ecosystem-Based Management
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EFH-HAPC	Essential Fish Habitat - Habitat Area of Particular Concern
EIS	Environmental Impact Statement
EPAP	Ecosystem Principles Advisory Panel
ESA	Endangered Species Act of 1973
F	A measure of the instantaneous rate of fishing mortality
$F_{30\%SPR}$	Fishing mortality that will produce a static SPR = 30%.
$F_{45\%SPR}$	Fishing mortality that will produce a static SPR = 45%.
F_{CURR}	The current instantaneous rate of fishing mortality
FMP	Fishery Management Plan
F_{MSY}	The rate of fishing mortality expected to achieve MSY under equilibrium conditions and a corresponding biomass of B_{MSY}
F_{OY}	The rate of fishing mortality expected to achieve OY under equilibrium conditions and a corresponding biomass of B_{OY}
FEIS	Final Environmental Impact Statement
FMU	Fishery Management Unit
FONSI	Finding Of No Significant Impact
GOOS	Global Ocean Observing System
GFMC	Gulf of Mexico Fishery Management Council
IFQ	Individual fishing quota
IMS	Internet Mapping Server
IOOS	Integrated Ocean Observing System
M	Natural mortality rate

MARMAP	Marine Resources Monitoring Assessment and Prediction Program
MARFIN	Marine Fisheries Initiative
MBTA	Migratory Bird Treaty Act
MFMT	Maximum Fishing Mortality Threshold
MMPA	Marine Mammal Protection Act of 1973
MRFSS	Marine Recreational Fisheries Statistics Survey
MSA	Magnuson-Stevens Act
MSST	Minimum Stock Size Threshold
MSY	Maximum Sustainable Yield
NEPA	National Environmental Policy Act of 1969
NMFS	National Marine Fisheries Service
NMSA	National Marine Sanctuary Act
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
OY	Optimum Yield
POC	Pew Oceans Commission
R	Recruitment
RFA	Regulatory Flexibility Act
RIR	Regulatory Impact Review
SAFE	Stock Assessment and Fishery Evaluation Report
SAFMC	South Atlantic Fishery Management Council
SEDAR	Southeast Data, Assessment, and Review
SEFSC	Southeast Fisheries Science Center
SERO	Southeast Regional Office
SDDP	Supplementary Discard Data Program
SFA	Sustainable Fisheries Act
SIA	Social Impact Assessment
SSC	Scientific and Statistical Committee
TAC	Total allowable catch
T_{MIN}	The length of time in which a stock could rebuild to B_{MSY} in the absence of fishing mortality
USCG	U.S. Coast Guard
USCOP	U.S. Commission on Ocean Policy
VMS	Vessel Monitoring System

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6.1 Adverse impacts of non-fishing activities

The waters and substrate that comprise essential fish habitat (EFH) as defined by the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act), and under jurisdiction of the South Atlantic Fishery Management Council (SAFMC), are diverse, widely distributed, and closely affiliated with other aquatic and terrestrial environments. These characteristics make them readily susceptible to a large number of human activities.

The Essential Fish Habitat (EFH) Interim Final Rule (Federal Register 62 FR 244) defines EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." The following definitions apply for interpreting the definition of the EFH rule:

- Waters include aquatic areas and their physical, chemical, and biological properties that are used by fish and invertebrates, and where appropriate may include areas historically used by fish and invertebrates;
- Substrate includes sediment, hard bottom, structures underlying the waters, and biological communities;
- Necessary means the habitat required to support a sustainable fishery and a healthy ecosystem; and
- Spawning, breeding, feeding, or growth to maturity covers species' full life cycle.

Fish habitat is the geographic area where the species occurs at any time during its life. This area can be described by ecological characteristics, location, and time. EFH includes waters and substrate that focus distribution; (e.g., coral reefs, marshes, or submerged aquatic vegetation), and other characteristics that are less distinct such as turbidity zones, water quality, and salinity gradients. Habitat use may change or shift over time due to climatic change, human activities and impacts, and/or other factors such as change with life history stage, species abundance, competition with other species, and environmental variability in time and space. The type of habitat available, its attributes, and its functions are important to species productivity, diversity, health, and survival.

Convention for Threats Identification

The ecological requirements for managed species and biotic communities, including identification of EFH, are addressed in this document. Threats to those habitats are described in terms of those that generally occur landward of the shoreline (Threats to Estuarine Processes) and those that occur oceanward of the shoreline (Threats to Offshore Processes). Threats to Estuarine Processes include but are not limited to agriculture; aquaculture; silviculture; urban/suburban development; commercial and industrial activities; navigation; recreational boating; mining; hydrologic modifications; transportation projects; and natural events and global change. Threats to Offshore Processes include navigation; dumping; offshore sand and mineral mining; oil and gas exploration, development, and transportation; commercial and industrial activities; and natural events and global change. A more comprehensive list of individual activities that may be considered as threats is provided in Section 6.3.17.

Every reasonable effort was made to identify the principal non-fishing and fishing-related threats to EFH and to provide examples and information concerning the relationship between threat-related activities and EFH. Other information sources and examples undoubtedly exist and related studies are underway or are in various stages of publication. Accordingly, the following discussion is a starting point for the identification of threats to EFH. While it meets the strict time limitations imposed by the Magnuson-Stevens Act, regular updating is required to ensure comprehensive and current coverage of the topic addressed.

6.1.1 Freshwater/estuarine/inshore processes

Many species of the South Atlantic region are dependent during at least some life history stages on near-shore waters vulnerable to impacts from land-based sources. Especially vulnerable are species or species groups that require estuaries or freshwater tributaries as primary larval or post-larval habitat. In the southeast, these species include anadromous fish such as striped bass, blueback herring, alewife, American shad, hickory shad, and sturgeons; and brackish species including Atlantic menhaden, summer and southern flounder, red drum, spot, croaker, weakfish, penaeid shrimp, blue crab, and others (Epperly and Ross 1986).

Nearshore EFHs at risk from land-based impacts include submerged shellfish beds; subtidal and intertidal mudflats and shell hash; SAV beds, including eelgrass (*Zostera marina*), Cuban shoal grass (*Halodule wrightii*), and widgeon grass (*Ruppia maritima*); tidal freshwater forested wetlands dominated by tupelo-cypress communities (*Taxodium distichum*, *Nyssa aquatica*), and emergent tidal marshes including both saltmarshes dominated by smooth cordgrass (*Spartina alterniflora*) and brackish marshes dominated by black needlerush (*Juncus roemerianus*). These habitats may be affected both by direct destruction and by degradation of water quality or other factors such as hydrologic modification. Elimination or degradation of wetlands not immediately adjacent to EFH also may diminish the quality and productiveness of downstream estuaries.

The precise relationship between fishery production and habitats is undetermined. Accordingly, the exact degree to which habitat alteration has affected fishery production is also unknown, but is thought to be substantial. Turner and Boesch (1987) assembled and examined evidence of the relationship between the extent of wetland habitats and the yield of fishery species that depend on coastal bays and estuaries. The evidence examined show that fishery stock losses follow wetland losses and fishery stock gains follow wetland gains. While most of the studies were related to shrimp production, other fisheries are likely follow this trend.

In the southeastern U.S., the dominant sources of land-based impacts include major land-disturbing activities such as agriculture, silviculture, and residential and commercial development. The following discussions characterize major threats in the coastal zone of the southeast, summarize ways that EFH is impacted, and characterize the current extent of such impacts. Impacts can occur at three scales: immediate watersheds of EFH; broader watersheds of important estuarine nurseries; and distant or indirect impacts mediated through more widespread movement of water and its chemical and physical make-up.

6.1.1.1 Agriculture

Agriculture in the southeast has undergone dramatic changes over time. Most operations were at one time individual and small-scale enterprises, but in recent years have transformed into highly integrated, large-scale industries. Besides the extensive conversion of wetlands to crop and animal production, the most dramatic change in southern agriculture is the large scale expansion in animal production that has occurred during the last decade. The most dramatic increases have occurred in corporate hog operations in North Carolina. According to North Carolina Agricultural Statistics, the 1996/1997 hog numbers (8,969,200) for the 44 coastal counties are more than quadruple the 1986 numbers (2,117,800) for the same area. At the same time, the number of hog farms has declined precipitously, by a factor of three.

Other southeastern states have not yet experienced the same increase in swine herds. South Carolina's coastal counties, in fact, experienced a net reduction in swine herds from 374,000 head in 1986 to 194,900 head in 1996 (South Carolina Agricultural Statistics). Georgia had a similar decrease in the coastal plain counties, decreasing from 400,911 head in 1987 to 317,795 head in 1992 (Georgia Agricultural Statistics). Florida numbers experienced a decline in Atlantic watersheds from about 23,541 head in 1987 to 12,482 head in 1992 (Florida Agricultural Statistics). Part of the reason for the differences in hog production among the states is the development of industrial hog-growing technologies in North Carolina, plus differences in state regulatory programs. South Carolina, for instance, recently adopted very stringent and restrictive new laws governing hog-growing operations.

Poultry production, a second major agricultural animal product, has also increased substantially in the southeast. Again, North Carolina leads the nation in several poultry categories. In 1996, 313,735,000 birds were produced in coastal North Carolina; up from 45,588,966 birds in 1986. South Carolina coastal counties also showed a significant increase in production over this decade: 57,834,000 birds were produced in 1986 and 140,038,000 in 1996. The increases in the Georgia and Florida Atlantic coastal counties were much more moderate from 1987 to 1992, with production rates of 12,907,265 to 15,438,031 birds, and 2,780,706 to 2,886,335 birds, respectively (all data from state agricultural statistics).

Patterns in cropland use also have been in flux. In the North Carolina coastal plain, harvested cropland has remained almost static during the past decade, at about three million acres. However, fertilizer use has increased from 848,927 tons in 1986 to 2,006,251 tons in 1996 (not including swine and other animal waste land application). During the same period, South Carolina has experienced a net decrease in harvested acreage in the coastal plain, from 1,759,162 acres to 1,589,420 acres, but a net increase in fertilizer usage of about 38% to 331,597 tons. Harvested cropland along the Georgia coast is up slightly, to about 900,000 acres in 1992. Comparable data on fertilizer usage are not yet available. Harvested cropland in the Florida Atlantic coastal plain is down from about 1.1 million acres in 1992 to 675,081 acres in 1996. (All data from state agricultural statistics).

The overall pattern in crop production is one of great intensification of use on a fairly stable land base. Large increases in fertilizer usage and manure-based nitrogen fluxes (from surface and groundwater and from airborne sources) have occurred during the last decade in at least some southeastern states, including watersheds that were already artificially enriched.

Nutrient pollution can result in cascading ecological and economic impacts, including fish kills due to oxygen depletion, seagrass die-offs, excessive and sometimes toxic algal blooms, changes in marine biodiversity, increases in human illnesses, and loss of tourism (NRC 2000). For example, in southeast Florida nutrient inputs to Lake Okeechobee from central Florida agriculture activities (primarily sugar) are then discharged to important estuaries including the St. Lucie estuary. Timed releases associated with flood control activities result in large quantities of nutrient-laden water inputs to the St. Lucie estuary. Between 2004 and 2005, it is estimated that approximately 320 billion gallons of this water was diverted to the St. Lucie estuary. Many researchers have suspected that algal blooms and resulting fish kills in 2005-2006 were a result of this activity.

Potential Threats to EFH from Agriculture

Potential threats include: conversion of wetlands to agricultural lands, or for farm related purposes such as roads and irrigation ponds; direct and non-point source discharge of fill, nutrients, chemicals, and surface and ground waters into streams, rivers, and estuaries; hydrologic modification of ditches, dikes, farm ponds and other similar structures and water control devices; damage to wetlands and submerged bottoms by livestock grazing and/or movement; and cumulative and synergistic effects caused by association of these and other related activities.

Certain agricultural activities present a threat to EFH in the southeast. The major components of this threat include wetland conversion, nutrient over enrichment with subsequent deoxygenation of surface waters, shading by excessive algae and plant growth, and stimulation of toxic dinoflagellates; sedimentation; and delivery of toxicants into sensitive waters. Agriculture (including silviculture) accounted for 87% of all wetland losses observed nationally between the mid 1950's and mid 1970's (Tiner 1984). This loss has been estimated at more than 458,000 acres per year between the mid 1950's and mid 1970's in the coterminous U.S. (Tiner 1984). The most extensive losses observed in the southeast were in Florida and North Carolina where agricultural drainage continues to destroy large tracts of wetlands (Tiner 1984). Current agriculture conversion statistics for the southeast show that:

- During the mid-1970s to the mid-1980s “Florida showed a net wetland loss of 260,000 acres, mainly from the destruction of palustrine wetlands. Two-thirds of the loss of palustrine wetlands was attributable to agricultural development...” (Hefner et al. 1994).
- “Between the mid-1970s and mid 1980s, more than 100,000 acres of freshwater forested wetlands in Georgia were destroyed, mostly because of conversion to land uses such as agriculture” (Dahl et al. 1991).
- Between 1982 and 1989, South Carolina lost 155,500 acres, of this amount agriculture was responsible for 28% (Dahl 1997).

- In North Carolina about one-third of the wetland alteration in the coastal plain has occurred since the 1950s. Of this amount, agriculture was responsible for about 42% (Cashin et al. 1992).

Excessively enriched waters often do not support desirable species or populations of fish and invertebrates. They also may not support food chain and other ecological assemblages needed to sustain desirable species and populations. When overly abundant, nutrients such as nitrogen (ammonia) and phosphorus may degrade or eliminate EFH and its flora and fauna through several processes. Most problematic of these is the process whereby dissolved oxygen in the water is reduced by decaying plant life that prospered under nutrient rich conditions. In severe oxygen depletion situations fish and invertebrates may suffocate from oxygen deprivation.

Nutrient enrichment may also lead to direct toxicity when toxic organism populations "bloom" or become excessively large -- situations that are becoming more prevalent and which are discussed in detail in subsequent sections. Although affected by acidity, water temperature, and other factors, total ammonia concentrations in excess of about 2 mg/L normally exceed the chronic exposure level for fish (Mueller and Helsel 1996). In alkaline water at high temperature, the criteria may be exceeded by total ammonia concentrations of less than 0.1 mg/L. The natural conversion of ammonia to nitrate in streams removes oxygen from water and, therefore, may also harm fish (Mueller and Helsel 1996). While less problematic in estuarine and marine environments, phosphorus is a major factor in nutrient enrichment and eutrophication of freshwater systems. There are no minimum discharge standards for phosphorus; however, the U.S. EPA recommends that phosphates should not exceed 0.05 mg/L when discharged into streams entering lakes and reservoirs (Muller and Helsel 1996). Since freshwater systems may be used directly by anadromous fish, and they may also discharge into coastal waters, the quality of these waters has considerable bearing on many commercially and recreationally important aquatic resources and their habitats, including EFH. The nutrient inputs from central Florida agriculture (i.e., sugar) to Lake Okeechobee, the St. Lucie estuary, and Indian River Lagoon are suspected to have caused algal blooms, seagrass die-offs, and notable bivalve and fish kills in 2005-2006. In addition, the nutrient inputs are also suspected to have adversely impacted reefs located just outside the St. Lucie Inlet (e.g., Peck's reef).

In extreme situations living resources may be temporally or permanently displaced due to shifts in the aquatic food web, or by the physical presence of certain plant life. Excessive plant growth may also impede requisite functions (e.g., photosynthesis) of desirable plant life, hence EFH, as in the case of SAV where leaves may become covered with dense growths of algae, diatoms, and other biota such as bacteria and fungi.

Agriculture is believed to be the single largest contributor of nutrients into southeastern watersheds. The largest human additions of nitrogen result from an increased use of inorganic fertilizers (NRC 2000). In the Tar-Pamlico Estuary Basin in North Carolina, agriculture is responsible for approximately 45% of total nitrogen loading to the estuary, and 55% of phosphorus loading (NCDEHNR 1997a). An additional 33% of nitrogen and 17% of phosphorus comes from atmospheric sources that include, but is not limited to agriculture (NCDEHNR 1994, 1997a). In the adjacent Neuse River Basin, 54% of nitrogen is estimated to arise from agricultural sources (NCDEHNR 1993, 1997b). These two tributaries discharge into Pamlico Sound, the nation's second largest estuary, and the largest in the southeast.

Animal production is a threat to southeastern estuarine nutrient balances. The current usual management practice for manure from swine and other confined domestic mammals is storage and treatment in anaerobic lagoons followed by land application. This process relies on volatilization of nitrogen to account for roughly 80% of the total produced nitrogen, with concomitant downwind delivery in a zone of influence of roughly 100 kilometers (Rudek 1997). Airborne deposition of nitrogen into coastal waters in the region has been verified from field data to be a major source of enrichment in a number of southeastern estuaries. The most complete work at this time is focused on the Neuse River Estuary in North Carolina, where primary production was boosted two to three times by atmospheric deposition at ambient levels (Paerl et al. 1995a, 1995b). Actual plant uptake by crops on land-application fields accounts for no more than 10% of nitrogen use. Surplus nitrogen is delivered to shallow groundwater systems which, in turn, feed warm-season surface flows into adjacent streams and rivers. Thus, the vast majority of this material is redeposited on land and in surface waters.

Studies by Barker (1997) and Barker and Zublena (1995) also show that many North Carolina coastal counties are receiving swine-based nitrogen and/or phosphorus at levels in excess of total crop-plant growth needs. This analysis actually underestimates the problem, because it considers only direct land-applied nutrients and ignores swine-based atmospheric deposition in these counties. A report compiled for Senator Tom Harkin (D-IA) analyzed manure production patterns nationally by county and found zones of very high production in coastal North Carolina and in individual counties in the other three southeastern states. That document also reports excessive production above crop growth needs in many areas (Minority Staff 1997).

A recent estimate of agricultural emissions of ammonia from the North Carolina coastal plain is about 200.3 million lbs of nitrogen from animal waste, and 15 million lbs of nitrogen from fertilizers. Hogs alone contribute about 135 million lbs of nitrogen emissions in coastal North Carolina; larger than the entire National Atmospheric Deposition Program estimate of airborne deposition from all sources in the North Carolina coastal plain (Rudek 1997).

In response to nutrient enrichment problems and public concern, the North Carolina General Assembly has moved to impose a two-year moratorium on the development of new or enhanced hog farms, pending the replacement of current anaerobic lagoon technology with a more acceptable alternative.

High nutrient loadings also have been documented in other southeastern river basins and estuaries. Among seven river basins in Florida and Georgia examined recently by the U.S. Geological Survey, two in Georgia (the Altamaha and the Satilla) were found to be very high in nitrogen inputs at 5,470 (kg/yr)/km^2 and 5,430 (kg/yr)/km^2, respectively. Animal waste was the dominant source of nitrogen loading in both basins. Fertilizer was the biggest source in the St. Johns River Basin in Florida, and the Ogeechee Basin in Georgia. The most dominant sources of nutrient loading are non-point-source in origin, and predominantly agricultural (USGS 1997).

The National Water Quality Assessment Program is also examining the Santee Basin and nearby coastal drainages in South Carolina. Data from 1994 covering 24,868 square miles in South and North Carolina are being considered for this analysis. Although definitive information is not yet available, nutrient pollution of lakes and the rivers themselves has been identified as a major water quality issue for the program (USGS 1994). The first reports from this program are now available and include an annotated bibliography of water quality databases and recent publications on the water quality of the region (Abrahamsen et al. 1997).

Impacts of sediment from non-point-sources including agriculture and silviculture remain at the top of the water pollution list nationally (USEPA 1990) and in the southeastern states (NCDEHNR 1996b). While sediment-based impacts are typically considered to be most acute in freshwater systems, sediment pollution can also threaten EFH. Because sedimentation is a natural process in most aquatic systems it is generally not problematic except where deposition rates vastly exceed ambient conditions. In these situations, benthic animals and plants and demersal fishes that are unable to adjust or relocate may be buried or undergo disruption in growth and reproduction. Lethal and non-lethal effects of turbidity include ingestion of non-food particles by shellfish and polychaete worms, clogging of pores and gills, erosion of gills and other apparatuses such as fins, tentacles, and cilia that may be used for locomotion and feeding, burial of eggs and juveniles, and burial of substrates that may be needed for cover, attachment, and reproduction. In areas that support SAV, primary production levels may be reduced where light penetration is limited by increased turbidity.

While generally less important as a potential threat to EFH in the South Atlantic region, sediment deprivation may be locally troublesome since subsidence and erosion of wetlands and other habitats may result. Impounded coastal wetlands used for rice culture and other agricultural crop production in North Carolina, South Carolina, and Georgia are notable since large areas have been permanently altered even though tidal flow has been restored in many cases. In the Altamaha River Estuary in Georgia vast areas of freshwater and brackish tidal forested wetlands have been converted to emergent wetlands following construction of dikes and ditches that interrupted both deposition of alluvial materials and other processes.

Sediment pollution from agriculture is widespread in the coastal zone of the southeastern states. For example, North Carolina's "303d list," the listing of degraded water bodies required to be compiled by the Clean Water Act, contains an array of coastal streams degraded at least in part by agricultural sediment pollution. These include tributaries of the northeast Cape Fear River and Black River; Potecasi Creek (Chowan River); Trent River (Neuse Basin); Little River (Pasquotank Basin); Tranter’s, Grindle, Conetoe and Town creeks (Tar-Pamlico Basin); and Newport River (NCDEHNR 1996a).

Pathogens from agricultural sources also threaten EFH, especially shellfish waters. The biggest single threat is probably poorly managed animal waste. A secondary source is land-disturbing activity related to putting new land into agricultural production. This may result in additional delivery of fecal coliform bacteria in quantities of potential concern.

The most dramatic cases of contamination of EFH from agricultural sources include spills of animal waste into coastal watersheds. North Carolina has suffered a number of recent spills,

including many in the summer of 1995. A large swine lagoon rupture in 1995 spilled about 25 million gallons of waste into the New River Estuary causing severe anoxia, stimulating toxic algal blooms, and elevating fecal bacteria concentrations in both the receiving waters and sediments. Effects of this event persisted for over 61 days (Burkholder et al. 1997). Similar, but smaller, events were documented into tributaries of the Cape Fear River Estuary, North Carolina, from both swine and poultry sources. Impacts included large nutrient delivery, algal blooms, and contamination with huge loads of fecal bacteria; including pathogenic *Clostridium perfringens* (Mallin et al. 1997). This study documented 30 animal waste spills in North Carolina in 1995 and 1996.
Bacteria from other agricultural sources also may contribute to contamination of shellfish waters. As wetland landscapes are developed for agriculture, offsite water delivery is enhanced (Skaggs et al. 1980). Many scientists believe that this hydrologic effect may contribute to elevated fecal coliform counts in receiving waters. This is suggested by preliminary studies in Otter Creek, Broad Creek, and the South River, North Carolina (J. Sauber, personal communication).

The variation in the scope and composition of agricultural non-point-source discharges and in the receiving waters creates an almost endless range of possible effects on aquatic resources, including EFH. Exposure of estuarine finfish and shellfish to toxic levels of insecticides, herbicides, and fungicides may occur, resulting in significant declines in populations (Scott 1997). Sublethal effects also are evident. For example, many compounds released by agricultural operations may adversely affect hormones such as estrogen and androgen that are linked to immune suppression (Scott 1997). These compounds usually do not kill the animal immediately, but reduce its life span and often its ability to reproduce.

Agricultural compounds that have been identified as having properties damaging to aquatic organisms include the commonly used herbicides aldicarb and atrazine and others such as, endosulfan, chlorpyrifos, and trace metals such as copper and mercury.
The enormous variation in the scope and composition of agricultural nonpoint source discharges and in the environmental nature of the receiving waters creates an almost endless range of possible effects on aquatic resources, including EFH. As noted in Scott (1997):

"Agricultural nonpoint source (NPS) runoff may result in significant discharges of pesticides, suspended sediments and fertilizers into estuarine habitats adjacent to agricultural areas or downstream from agricultural watersheds. Exposure of estuarine finfish and shellfish to toxic levels of insecticides, herbicides, and fungicides may occur, resulting in significant declines in field populations. Development of new management techniques such as Integrated Pest Management (IPMs), Best Management Practices (BMPs), and Retention Ponds (RP) are risk management tools which have been used to reduce contaminant risk from agricultural NPS runoff."

In association with Scott's (1997) observations, the National Ocean Service (NOS), Charleston Laboratory examined effects of NPS agricultural runoff on living marine resources in an attempt to define impacts on fishery resources and to develop risk reduction strategies to minimize/mitigate impacts. Investigations involving coastal estuarine ecosystems in South Carolina examined several sites used for vegetable farming (e.g., tomatoes, cucumbers, snap beans), where varied levels of risk reduction strategies were employed. The studies used grass shrimp (*Palaemonetes pugio*) and the mummichog (*Fundulus heteroclitus*) as well as other macropelagic populations. These two species represent more than 85% of the total macrofaunal (greater than 15mm) densities in small tidal creek nursery grounds in South Carolina and they are important due to their role in estuarine food webs. The studies demonstrated that pesticide exposure caused fish and invertebrate abundance reductions and mortality. Comparison of field results with laboratory toxicity tests clearly established that implementation of an integrated risk reduction strategy can significantly reduce NPS agricultural pesticide runoff. At intensively managed (IPM, BMPs, and RP) agricultural sites where strict NPS control techniques were administered, instream pesticide (azinphosmethyl, endosulfan, and fenvalerate) levels were reduced by 89-90% (Preceding from Scott 1997).

According to Scott (1997) the commonly used herbicides aldicarb and atrazine are potential endocrine disrupting chemicals (e.g., compounds that adversely affect hormones such as estrogen and androgen) and are linked to immune suppression. A 1992, Texas investigation found atrazine at concentrations greater than 60 ug/L in 98% of surface water samples that were taken on an annual basis. Laboratory toxicity tests of atrazine effects on estuarine phytoplankton revealed that chronic, low level atrazine exposure over multiple generations lead to enhanced sensitivity of phytoplankton and combined alachlor and atrazine exposure caused greater than simple additive toxicity in phytoplankton (Scott 1997).

The chronic effects of agriculture derived non-point source discharge have been extensively studied in Florida where impacts are occurring on a large scale basis. Essentially all of Florida Bay has undergone significant and undesirable biological, chemical, and physical change due to large scale agricultural practices, including hydrologic modification, in the Everglades. While these changes are occurring primarily in waters that lie outside of SAFMC jurisdiction, they are notable because of their size, magnitude, and complexity. Two basic lessons from the Everglades/Florida Bay situation also have application in watersheds found along the South Atlantic. They are: (1) the chronic environmental and ecological effects of regional agricultural practices may be extremely large and devastating and (2) the financial costs associated with analyzing and remedying these effects are likely to be enormous and possibly ineffective.

The factors associated with EFH degradation by agricultural related hypoxia are only poorly understood, but are of concern. Thus far, the extensive hypoxic zones and conditions observed in the Gulf of Mexico have not occurred in the South Atlantic region. Exceptions include relatively small, yet harmful, localized events in portions of North Carolina and South Carolina. In this region, North Carolina’s estuarine waters are particularly vulnerable due to their shallow depths, poor flushing characteristics, and the abundance of hog farms found in the coastal zone. Although the most conspicuous effect of hypoxia is the mortality of larger fish and possibly invertebrates, even greater harm may be occurring with sensitive larval and juvenile forms since they are most vulnerable to oxygen depletion and other forms of environmental perturbation.

6.1.1.2 Aquaculture

<u>Potential Threats to EFH from Aquaculture</u>

Potential threats include: dredging and filling of wetlands and other coastal habitats and other modification of wetlands, submerged bottoms, and waters through introduction of pens, nets, and *other containment and production devices; introduction of waste products and toxic chemicals; and introduction of exotic organisms; in addition to competition with wild stock for food sources.*

Nationwide aquaculture is a vibrant industry with the annual value of product sold exceeding $866 million in 2005, although revenues have declined somewhat over the past 10 years (U.S. Department of Agriculture 2006). Within the Atlantic southeastern U.S., the annual value of product sold amounted to over $94 million in 2005, with Florida ($57.4 million) and North Carolina ($24.7 million) leading Georgia ($4.5 million) and South Carolina ($4.7 million). All aquaculture facilities in these states are located either on uplands or in coastal waters and no offshore aquaculture farms presently exist in the Atlantic southeastern U.S. The primary aquaculture operations in the Atlantic southeastern U.S. are shellfish farms (including hatcheries for production of seed stock), production of marine species in closed-recirculation systems, and production for enhancement of native fishery stocks.

The growing demand for seafood reflects both the growth of the U.S. population and the increased awareness of health benefits that result from a diet that includes seafood (Nesheim and Yaktine 2007). Currently, more than 80% of the U.S. seafood supply is imported, with over 40% of that amount coming from foreign aquaculture operations. Considering the substantial economic incentive to increase aquaculture production in the U.S. and the gradual elimination of technological barriers, expansion of the domestic aquaculture industry is expected over the next decade. Offshore areas may receive particular attention for development (Stickney et al. 2006).

Aquaculture and Fishery Habitats

Aquaculture has long been a source of human food. Within the last century, the technology of aquaculture has changed dramatically allowing application of semi-intensive and intensive farming systems. While this concentrates aquaculture activities to relatively small spatial areas and sets the stage for potential environmental conflicts, these concerns can be mitigated through appropriate management measures (Marine Aquaculture Task Force 2007). Balancing the demand for seafood and economic growth with the need to maintain coastal and marine ecosystems is a challenge that aquaculture accepts.

Nash et al. (2005) used the framework of an ecological risk assessment to examine common perceptions about the impacts of aquaculture on coastal and offshore habitats. The framework for this assessment was developed by the United Nations World Health Organization, has undergone extensive peer review, and is widely applied nationally and internationally. Ten types of potential impacts from aquaculture are noted: (1) increased organic loading from fecal material, uneaten food, and the decomposition of dead fish; (2) increased inorganic loading from fecal material and uneaten food; (3) residual heavy metals from uneaten food (primarily zinc) and from antifouling treatments (primarily copper); (4) transmission of disease to wild populations; (5) transmission of residual therapeutants to wild populations; (6) biological interactions from non-native species or genetically modified organisms with native populations from escapees, eggs, and gametes; (7) physical interactions with native populations through entanglement with nets, moorings, and other structures; (8) physical impacts on habitat from dredging, filling, nets, moorings, or other structures needed to establish a facility; (9) reductions in native populations from use of wild-caught juveniles for grow out; and (10) harvesting of industrial fisheries for use as fish feed. The assessment concludes that the level of risk from these sources is none to low when proper management measures are in place, including siting facilities to avoid areas with low water circulation or high boat traffic, judiciously managing stocking densities and managing waste, carefully selecting grow-out stock, and adhering to best management practices to control fouling, escapes, predation, diseases, and so forth. Use of geographic information systems (GIS) has led to spatial models that aid the examination of alternative sites for aquaculture operations (for an example from the southeastern U.S., see Arnold et al. 2000).

NOAA is building a broad based aquaculture program to enable expansion of all suitable forms of marine aquaculture within the context of complementing seafood production from wild catch, safeguarding environmental resources, and balancing multiple uses. An important objective of this program is to establish a comprehensive regulatory program for marine aquaculture operations. This program will complement existing regulatory programs that already apply to aquaculture operations, such as regulation the U.S. Army Corps of Engineers and U.S. Coast Guard of the placement of structures within navigable waters, regulation of water quality by the U.S. Environmental Protection Agency and individual states, regulation of therapeutants by the Food and Drug Administration, and oversight of interactions with fisheries and endangered species by NOAA's National Marine Fisheries Service.

6.1.1.3 Silviculture

Forested wetlands are the most abundant wetland type along the eastern seaboard. They include such diverse types as black spruce bogs, cedar swamps, red maple swamps, and bottomland hardwood forests (Tiner 1984). Scrub/shrub and forested wetlands account for over 59.4 million acres within coastal counties from North Carolina to Florida (Field et al. 1991). These wetlands also have been the most affected by forestry practices and, to a lesser degree, development. At a national level, from the mid 1950's to the mid 1970's, about 440,000 acres/year of palustrine wetlands (including forested wetlands) were lost (Tiner 1984). About 87% of this loss is accounted for by agricultural development; including silviculture (Tiner 1984). Trends in the southeast follow the national trend with North Carolina and Florida registering the most extensive wetland losses (Tiner 1984).

Potential Threats to EFH from Silviculture

Potential threats include: conversion of wetlands to silviculture production sites or for tree removal and other silviculture related purposes such as roads and irrigation ponds; direct and/or non-point-source discharge of fill, nutrients, chemicals, and surface and ground waters into streams, rivers and estuaries; hydrological modification to include ditches, dikes, irrigation ponds and other similar structures and water control devices; damage to wetlands and submerged bottoms by timber harvest activities; connected actions such as the construction of roads, and cumulative and synergistic effects caused by association of these and other silviculture and non-silviculture related activities.

The southeastern United States produces more industrial timber than any other region of the world. This timber production is from a forest base that includes almost one-half of the world's industrial forest plantations (Lee et al. 2005). Silviculture presents a significant threat to EFH largely due to the concentration of this activity in landscape positions near certain EFH, especially anadromous fish spawning and nursery areas and brackish primary and secondary nursery areas. Although silviculture typically is a less intensive land use activity than agriculture or urban development (Hughes 1996), the periodic intense disturbances associated with harvest, the installation and maintenance of dense drainage systems in wetlands and former wetlands, changes in vegetation, and the use of nutrient supplements and toxicants can significantly and adversely affect surface waters, EFH, and their associated biota.

The most important fundamental change with installation of intensive silviculture pertains to the water management system. Dense drainage systems allow the removal of significant amounts of water from hydric soil sites, intercept rain, and dewater stored groundwater. The effect on the wetlands can be serious if water tables are lowered such that hydric soils lose their water content. Organic constituents of hydric soils can then be oxidized, causing soil subsidence and liberation of previously bonded metals and nutrients. Clearing vegetation from wetland soils may also divert surface water into runoff pathways to the extent that both annual average runoff and event-related peak flows are exacerbated (Daniel 1981; McCarthy and Skaggs 1992). This runoff is a threat because it can change salinity regimes in receiving brackish water systems and it carries excess nutrients and other potential pollutants into sensitive waters and EFH (Pate and Jones 1980).

Conversion of mixed forested wetland and depressional cypress dome areas to silviculture is known to significantly reduce the water table. Studies have shown that slash pine (*Pinus elliottii*) through evapotransport can reduce the water table in an area by up to 36-inches depending on tree maturation. This reduction in subsurface water is higher than wetland canopy species that might have been originally found in a converted wetland area and contribute to soil subsidence and oxidation (value loss). Further this change in land-use (conversion of a wetland to silviculture) and the accompanying hydrological alterations change how these areas are regulated. In Florida, some silviculture areas are not regulated by state or federal agencies as wetlands even though many of the wetland characteristics are still evident (hydric soils, wetland vegetation, and hydroperiod). As a result conversion of these areas to commercial and residential development is expedited and compensatory mitigation for wetland function loss (albeit impaired or reduced) is not sought (Kruczynsky, personal communication).

The sensitivity of EFH to water balance perturbations is variable and poorly understood. Although some important species are highly sensitive to excessive salinity changes at young age classes (e.g., brown shrimp; Hunt et al. 1980), relatively little is known about the overall implications of flow modification from drained silvicultural areas. Limited studies on pumped drainage water in North Carolina showed minor impact to juvenile and adult spot and Atlantic croaker in response to pumping (Broad Creek Study Report). Effects on spring post-larval settlement periods for brown shrimp remain speculative since the effects of rainfall during pumping have not been determined.

In the Altamaha drainage in Georgia, water balance disturbance is thought to be a key factor in declining catch per unit effort of blue crab and shrimp (J. Holland, personal communication) and an in-depth hydrological investigation of that area has been proposed. Livingston et al. (1997) showed that reductions in freshwater inflow to the Apalachicola River Estuary in Florida led to initial turbidity reductions and increased primary productivity. Over time productivity reductions and major food web shifts were observed, probably in response to decreased nutrient delivery. As reported by Livingston et al. (1997) food web shifts remained minor so long as river flow did not greatly exceed natural limits. There is a concern that southeastern watersheds would respond in a similar manner.

Silviculture also has the potential to significantly affect nutrient delivery patterns into EFH, both through soil amendments with nitrogen and phosphorus and through changes in nutrient processing and delivery systems. Modification of these delivery patterns can be a threat to EFH. Typical forestry operations in the southeast add limited nitrogen and phosphorus during the growing cycle (Amatya et al. 1996). In addition, typical wetland soils are effective at removing incident nitrogen through nitrification and denitrification pathways. Wetlands are important sinks for atmospherically derived nitrogen. As such, riparian and isolated wetlands may buffer EFH from vehicle and animal waste-derived nitrogen enrichment. Drainage networks effectively short-circuit this buffering capacity by reducing retention periods and denitrification opportunities (Whigham et al. 1988; EDF and WWF 1992).

The huge areas involved and their proximity to sensitive estuaries makes forestry a major player in nutrient enrichment. For instance, in North Carolina's Neuse River Estuary, forests account for 17% of total nitrogen delivery (NCDEHNR 1993). The adjacent Pamlico Basin reflects a forestry contribution for nitrogen of about 10% (NCDEHNR 1994).

Sediment yields from silviculture in the coastal zone are not considered a substantial threat to EFH. Sedimentation is typically lower than Piedmont or mountain sites as a result of lower terrestrial slopes and enhanced opportunity for deposition in the slower moving receiving waters, including canal systems.

Information is poor on forestry contributions to fecal coliform contamination in the southeast. Initial studies have found relationships between elevated runoff rates after clear cutting and fecal coliform delivery, but other factors were also at work (J. Sauber, personal communication).

Non-nutrient pollution from silviculture is also of concern, though poorly documented. A number of studies have shown release of mercury and other metals from peat soils subjected to intensive drainage (Evans et al. 1984; Gregory et al. 1984). Elevated mercury concentrations also have been found in organic sediments in riparian coastal watersheds (Otte et al. 1987). In North Carolina, fish from the Waccamaw Basin show elevated mercury levels (NCDEHNR 1996b) and metal levels in sediments are elevated throughout the Albemarle-Pamlico Region due to a variety of sources (Riggs et al. 1991). Although not directly related to silviculture, real estate ventures by timber companies have converted large areas of forest land to residential property. This has resulted in much faster rates of surface water runoff and discharge of waters that contain higher concentrations of pesticides and fertilizers. In coastal areas and in inland locations bordering rivers and streams, property values may be greatly increased and the conversion of forest land to residential and commercial property is proceeding at a rapid rate. Further, connected actions, such as the construction of access roads to silviculture sites increase the overall area of impact.

6.1.1.4 Urban/Suburban Development

The southeastern United States has undergone one of the highest rates of landscape changes in the country, in part due to changing demographics and land use practices over the last few decades (Milesi et al. 2003). In particular this trend has been observed in the coastal regions of the southeast. Nine of our nation's ten largest cities are located in coastal watersheds (Bureau of the Census 2002). With its extensive and accessible coastline and mild winter climate the southeast coastal zone is one of the nation's fastest growing regions. The regional growth rate here is more than four times the national average (Chambers 1992) and between 1980 and 2010 the South Atlantic coastal population is expected to increase by as much as 73% (Chambers 1992). While coastal watershed counties comprise less than 25% of the land area in the United States, they are home to more than 52% of the total U.S. population. A study of coastal population trends predicts average increases of 3,600 people a day moving to coastal counties, reaching a total population of 165 million by 2015. These figures do not include the 180 million people who visit the coast every year (U.S. Commission on Ocean Policy 2004).

As the population increases so does urbanization. People require homes and related infrastructure such as roads, schools, water and sewer facilities, power transmission lines, etc. These needs often are met at the expense of EFH since residential growth has led to large scale modification of wetlands and other irreplaceable environments. Research indicates that nearby water bodies can become seriously degraded when more than 10% of the watershed is covered by roads, parking lots, roof tops, and similar surfaces (NRDC 1999). Tiner (1984) estimates that about 8% of the national rate of wetland losses that occurred from the mid 1950's to the mid 1970's resulted from urban development. Other effects of urbanization include increased sedimentation rates during and after construction, loss of surrounding upland recharge areas and wetland biofiltration and habitat functions. These effects could be ameliorated to some extent by maintaining sufficient buffers and less exploitive developmental patterns. The effect could be dampened by constructing within existing land contours and removing only the canopy necessary for project success. Currently in areas under development all existing vegetation is cleared and burned, all contours are removed and wetland soils are removed and replaced or filled over. Buffer ordinances, if they exist, are typically between 30 and 50 feet adjacent to estuarine systems; this width is not strongly supported by scientific literature.

Chemicals produced and used by people also find their way into the waters as point-source and non-point source runoff. Examples include oil from roads and parking lots, and pesticides, herbicides, and fertilizers from golf courses and residential lawns. This has reduced water quality in waters and wetlands adjacent to urban developments. As a result, the quality of EFH is often much reduced and thousands of acres of shellfish waters are closed. The South Carolina Department of Natural Resources' (SCDNR) Tidal Creek Project (TCP) provides insight into the effects of urbanization and suburban development on South Carolina tidal creeks (Holland et al. 1996, 2004; Sanger et al. 1999a,b). This study has implications for other states as well. The study examines developmental effects on salinity, dissolved oxygen (DO), and pollution in tidal creeks having trophic, shelter, and nursery functions required by commercially, recreationally, and ecologically important fish and invertebrates. The study reveals the complexity of the environmental and ecological factors involved and shows correlations between development; changes in tidal creek chemical, physical, and biological characteristics; and alteration of species distribution, composition, and abundance. In general, the physical-chemical characteristics of headwater creeks were significantly altered when the amount of impervious surface exceeded 10-20% and living resources were altered when the amount of impervious surface exceeded 20-30% cover.

The TCP identified salinity as a major factor in controlling the distribution and abundance of living marine resources (Holland et al. 1996, 2004). In watersheds having the greatest areas of roofs, roads, and parking lots it was found that recruitment and colonization by benthic fauna in these areas was less predictable than in more stable environments. TCP confirms that suitable DO concentrations are essential for maintaining balanced indigenous populations of fish, shellfish, and other aquatic biota in tidal creeks and that pollution-related decreases in DO may pose the greatest threat to the environmental quality of estuaries (Holland et al. 1996, 2004). With respect to contaminants, an examination of both metal and organic contaminants taken in connection with the TCP study indicate that metal contaminants were 2-10 times lower in forested watersheds compared to industrial/urban watersheds (Sanger et al. 1999a). Organic contaminants, such as PAHs, PCBs, and DDT were also much lower in forested creeks compared to the industrial/urban creeks.

In another study at larger watershed scales (14-digit Hydrologic Unit Code), Van Dolah et al. (in press), noted significant correlations in the concentrations of inorganic and organic contaminants and fecal coliform bacteria concentrations with the amount of urban suburban development. The correlation between contaminant concentrations and urban/suburban land cover, was stronger in tidal creek habitats within these watersheds, compared to data obtained from larger open water habitats within these watersheds. Additionally the percentage of sites within the watersheds having elevated contaminants and fecal coliform bacteria was much greater in watersheds having greater than 50% urban/suburban development compared with those watersheds having less than 30% urban/suburban cover.

As the linkage between urban and suburban development and declining fish abundance and health or quality is reinforced, the implications of anticipated population growth in coastal areas become even greater. This situation is especially critical in the southeast where recreationally and commercially important species are almost totally dependent on estuaries for their survival and for about $5.5 billion in annual commercial fishery benefits (Chambers 1990).

Potential Threats to EFH from Urban/Suburban Development

Potential threats include conversion of wetlands to sites for residential and related purposes such as roads, bridges, parking lots, commercial facilities, reservoirs, hydropower generation facilities, and utility corridors; direct and/or nonpoint-source discharge of fill, nutrients, chemicals, cooling water, and surface waters into ground water, streams, rivers and estuaries; hydrological modification to include ditches, dikes, flood control and other similar structures; damage to wetlands and submerged bottoms; and cumulative and synergistic effects caused by association of these and other developmental and non-developmental related activities.

Wetlands and other important coastal habitats continue to be adversely and irreversibly altered for urban and suburban development. (Note: certain related activities such as navigation are discussed in later sections). Of major concern is the piecemeal elimination of wetlands by filling for houses, roads, septic tank systems, etc. Wetland filling can directly eliminate or diminish the functional value of EFH and associated areas and resources. While the total area of wetlands affected by development is unknown, the rate of conversion was once estimated at 8% of the national average loss of 458,000 acres or 36,640 acres per year (Tiner 1984). Requests to alter coastal areas remain high and between 1981 and 1996, for example, in the southeast the NOAA Fisheries Service reviewed more than 23,871 proposals requesting to alter wetlands for housing, shoreline structures, docks, roadways, and other related activities. A survey of 5,622 of these proposals involved 19,729 acres of wetlands (see Tables 26, 27, 28, & 29). Between 1996 and 2006, NOAA Fisheries Service reviewed an additional 1,962 applications to fill wetlands to construct housing and 1,886 applications for shoreline modifications. Note that the acreage cited would not include wetland impacts from nationwide permits, dock footprint, loss of bottom area under pilings, or a great percent of shoreline fortification that is designated as "*di minimus*" by the COE and typically can range one to three feet from an existing seawall or bulkhead.

Another major threat posed by urban and suburban development is that of non-point-source discharges of the chemicals used in day to day activities, in operating and maintaining homes, roads, vehicles, etc. In addition to chemical input, changes that affect the volume, rate, location, frequency, and duration of surface water runoff into coastal rivers and tidal waters are likely to be determinants in the distribution, species composition, abundance, and health of southeastern fishery resources and their habitat.
Results of various studies in the South Atlantic Bight indicate that chemical contaminants from industrial, urban/suburban, and agricultural sources may cause impacts in estuarine ecosystems. Highest contaminant concentrations and greatest impacts were observed in the headwaters of small tidal creeks, which are nursery grounds for fish, crustaceans and molluscs. Protection and management of nonpoint-source runoff loading into these watersheds is essential in protecting habitat quality (Scott et al. 1997). In the long-term, impacts of chemical pollution (e.g., petroleum hydrocarbons, halogenated hydrocarbons, metals, etc.) are likely to adversely impact fish (Schaaf et al. 1987). Despite current pollution control measures and stricter environmental laws, toxic organic and inorganic chemicals continue to be introduced into marine and estuarine environments.

Results of the previously mentioned TCP investigation confirm that suitable DO concentrations are essential for maintaining balanced indigenous populations of fish, shellfish, and other aquatic biota in tidal creeks and that pollution related decreases in DO may pose the greatest threat to the environmental quality of estuaries. The study found that:

- DO in tidal creeks fluctuated with phases of the moon, time of day, and tidal stage.
- DO in tidal creeks in developed and undeveloped watersheds often did not meet the state water quality standard of 4mg/L.
- The most stressful DO levels occurred during early morning and at night-time low tides.
- The DO levels in tidal creeks in developed watersheds were less predictable and had greater unexplained variance than those of undeveloped watersheds.
- Point in time DO measurements in tidal creeks do not adequately represent exposure of living resources stressful low DO levels.

- Living resources in tidal creeks in developed watersheds were more frequently exposed to stressful low DO levels than those inhabiting tidal creeks with undeveloped watersheds.
- The factors that contribute to low DO in South Carolina tidal creeks need further study and a DO budget for tidal creeks and associated saltmarshes is needed so that the major factors controlling low DO conditions can be identified and addressed from a management perspective.

With respect to contaminants, bioassays of sediments taken in connection with the TCP study indicate that potentially toxic conditions for living marine resources may occur in the upper reaches of tidal creeks in developed watersheds. Polyaromatic hydrocarbons in sediments were highest where surface runoff from roads was discharged into tidal creeks and sediment bound pesticides were more prevalent in the marsh and near houses.
(Preceding is a summary taken from Holland et al. 1996).

Finally with regard to urban/suburban development, and in particular regard to nonpoint- source discharges, the South Carolina Statewide Water Quality Assessment for FY 1992-1993 (SCDHEC 1994) provides an indication of the role of non-point source discharges in one southeastern state. According to the Assessment:

- Nonpoint-source (NPS) pollution is the most responsible factor for nonsupport of classified water uses in rivers, lakes, and estuaries in the state.
- Of the 26,313 river miles assessed via water quality monitoring stations, 10,534 miles, or 40%, were determined to be partially supporting or not supporting overall use. NPS sources of pollution were identified as the contributing factor 33% of the time. These NPS sources included agriculture, pasture land, silviculture, construction, urban runoff/storm sewers, resource extraction, and hydromodification.
- South Carolina has approximately 945 square miles of estuaries, including marshes. The assessment analyzed data collected from 342 square miles of estuaries. About 30% of the estuarine areas do not fully support overall use. NPS pollution sources were identified as the contributing factor 38% of the time.
- Of the 135 shellfish areas assessed, 63% were impacted by NPS, including marinas, 22% were impacted by point sources, and 27% were unconditionally approved (the percentages totaled exceed 100% due to multiple source impacts).
- The South Carolina NPS Task Force listed the 32 highest priority water bodies/watersheds that are targeted for implementation action. Of these water bodies/watersheds, 15 are located in the coastal zone.
- Sixty-two watershed units are located in the coastal zone. Based on information from the Statewide Assessment and from more recent Watershed Water Quality Management Strategies, 44% of these units have been impaired by NPS pollution; 39% have been impaired by unknown sources of pollution; 24% have been impaired by point sources; 16% have been impaired by natural or other sources; and 30% have no known impairment [The percentages totaled exceed 100% due to multiple source impacts. Also, based on the Statewide Assessment, 38 of the 62 watershed units (or 61%) have not been fully assessed].

Point source discharges related to urbanization derive mainly from municipal sewage treatment facilities or storm water discharges that are controlled through Environmental Protection Agency (EPA)-mandated regulations under the Clean Water Act and by state water quality regulations. Threats related to these discharges are probably less important than the other factors previously discussed because efforts are underway to improve treatment. The primary concerns with municipal point-source discharges involve treatment levels needed to attain acceptable nutrient inputs and overloading of treatment systems due to rapid development of the coastal zone. It is also important to consider that the portion of water entering estuaries from sewage treatment plants is increasing. In locations where treatment is poor, or water conditions are unsuitable for adequate dilution of discharges, EFH may be adversely affected. Of primary concern is excessive nutrification of receiving waters, but other factors such as those associated with nonpoint -source discharges also apply.

The EPA withdrew the storm water Phase II direct final rule published on April 7, 1995 (60 FR 17950) and promulgated a new final rule in its place (60 FR 17958). This action by the EPA instituted changes to the National Pollutant Discharge Elimination System (NPDES) stormwater permit application regulations under the Clean Water Act for Phase II dischargers. Phase II dischargers generally include all point-source discharges of storm water from commercial, retail, light industrial and institutional facilities and from municipal separate storm sewer systems serving populations of less than 100,000. This rule establishes a sequential application process in two tiers for all Phase II stormwater discharges. The first tier provides the NPDES permitting authority flexibility to require permits for those Phase II dischargers that are determined to be contributing to a water quality impairment or are a significant contributor of pollutants to waters of the U.S. “Permitting authority” refers to the EPA or States and Indian Tribes with approved NPDES programs. The EPA expects this group to be small because most of these types of dischargers have already been included under Phase I of the storm water program.
The second tier includes all other Phase II dischargers. This larger group will be required to apply for permits by the end of six years, but only if the Phase II regulatory program in place at that time requires permits. The EPA has stated that it is open to, and committed to, exploring a number of non-permit control strategies for the Phase II program that will allow efficient and effective targeting of real environmental problems. As part of this commitment, the EPA has initiated a process to include stakeholders in the development of a supplemental Phase II rule under the Federal Advisory Committee Act. This rule was finalized March 1, 1999 and determines the nature and extent of requirements that apply to the various types of Phase II facilities prior to the end of the six-year application period defined by the rule.

However, in practice, the EPA’s NPDES for Phase II dischargers program, can be slow to implement and has limited enforcement authority. Further, stormwater requirements in the State of Florida have resulted in the loss/conversion of wetlands as required treatment ponds are commonly placed in wetlands whose capacity to assimilate contaminates far exceeds any benefit provided by the area loss for stormwater abatement. Further conversion of wetlands to stormwater ponds permanently eliminates these areas ability to contribute dissolve and particulate detrital organic carbon and their ecological habitat functions. These conversions are not seen or recorded as wetland losses although the lost ecologically contribution of these areas has an enormous impact on fisheries.

6.1.1.5 Transportation

Transportation projects such as the construction and maintenance of bridges and roadways typically involve long-term planning and permit consultation with NOAA Fisheries Service. Such projects can occur over estuarine waters, within estuarine emergent wetlands, and/or other important wetlands that are hydrologically connected to tidal waters. From 1996 to 2005 NOAA Fisheries Service reviewed 2,352 actions related to transportation.

<u>Potential threats to EFH from transportation projects</u>

Potential threats include fragmentation of the ecosystem by isolation and bifurcation of EFH, storm water discharges and runoff, shading of submerged aquatic vegetation from bridges, and blasting associated with bridge or structure demolition.

Transportation project can lead to habitat fragmentation, which results in the isolation of EFH from certain life history stages of recreationally and commercially important fisheries. This isolation limits the food chain by not allowing certain assemblages of organisms to easily traverse from one ecotype to another. This is especially true for fisheries such as the snapper grouper complex that use mangroves swamps and seagrass beds for one or more life history stages. This fragmentation could also potentially limit movements of catadromous and anadromous fishes by isolating populations from a spawning or nursery ground. Fragmentation can also result in the isolation of large tracts of freshwater wetlands. Through this isolation, the trophic functions provided by these wetlands are limited and allochthonous input is cut off to downstream estuaries and EFH.

Flushing of upstream wetlands and EFH can be impacted by fragmentation. If mitigation measures (e.g., culverts and bridges) are not taken to maintain adequate flow on both sides of a roadway, waters can become stagnant and limit the benefits to commercial and recreational fisheries.

Storm water discharges are a concern where bridges or roadways cross or are adjacent to EFH. Runoff from roadways could impact EFH if water is not collected and treated prior to discharge. The treatment of the storm water, including surface water management systems, should be located outside of EFH.

Blasting and demolition pose threats to EFH and managed fisheries. Direct and indirect impacts to EFH should be avoided and best management practices utilized when demolition occurs. This can include detonating small charges (otherwise known as test blasts or fish scares) to direct fish away from the area where the demolition will take place. Bubble curtains are also used in some cases to minimize fish kills.

Direct and indirect affects to EFH can also result from construction. Submerged aquatic vegetation can be impacted directly or indirectly from the installation of pilings and shading associated with bridges. The areas adjacent to bridges can be impacted as well from the shadow cast from the structure. These impacts must be considered when evaluating the effects of a transportation project on EFH.

6.1.1.6 Industrial/Commercial Activities

The southeastern U.S. is a prime location for industrial siting. The climate is favorable, economic incentives exist, land is readily available and relatively inexpensive, an adequate labor base exists, and the infrastructure for shipping of supplies and products is well developed. Further, the region's many rivers and streams provide an abundance of water needed for textile mills, paper mills, and heavy manufacturing (e.g., steel fabricating) and other similar facilities.

In addition to a favorable setting for industrial development, commercial growth is ever expanding. Although less conspicuous in many areas, the tourism industry also is a vital part of the coastal economy and many of the South's most popular vacation spots are located on or near the coast. With expansion of this industry, new hotels, related businesses, marinas, roads, and other facilities are being built. The increase in visitors and resource users is expected to continually grow and may diminish only when, as a result of overuse and development, the environmental quality of the area is reduced. Population growth and tourism bring many benefits to coastal communities, including new jobs and businesses and enhanced educational opportunities. Burgeoning industries associated with tourism and recreation in coastal areas (such as hotels, resorts, restaurants, fishing and dive stores, vacation housing, marinas, and other retail businesses) have created one of the nation's largest and fastest-growing economic forces (U.S. Commission on Ocean Policy 2004). In just four southeast Florida coastal counties, recreational diving, fishing, and ocean-watching activities generate $4.4 billion in local sales and almost $2 billion in local income annually (Johns 2001) and more than 2.9 million people visit the Florida Keys each year (Leeworthy and Vanasse 1999).

<u>Potential Threats to EFH from Industrial/Commercial Activities</u>

Potential threats include conversion of wetlands to industrial and appurtenant sites such as roads, parking, and administrative and distribution centers; point and nonpoint-source discharge of fill, nutrients, chemicals, cooling water, air emissions, and surface and ground waters into streams, rivers, estuaries and ocean waters; hydrological modification to include ditches, dikes, water and waste lagoons; intake and discharge systems; hydropower facilities; and cumulative and synergistic effects caused by association of these and other industrial and non-industrial related activities. In addition to ongoing activities, previous industrial and commercial activities have, in many locations, led to deposition of harmful materials that are subject to resuspension and reincorporation into aquatic food chains.

Industrial and commercial development can affect EFH in a number of ways. Most apparent is the conversion of wetlands and upland buffers to sites for buildings, plants, parking, storage and shipping or materials and products, and treatment or storage of wastes or by-products. Because of an abundance of hard impervious surfaces associated with industrial and commercial operations they are often major contributors of non-point-source contaminants into aquatic environments, including those that support EFH. Many industries, (e.g., paper mills), consume and pollute large volumes of water needed to sustain a healthy coastal environment. Industries may also produce airborne emissions that contain contaminants. These contaminants have been shown to reappear in coastal waters and EFH. A readily observable example is acidification of waters from atmospheric deposition of industrial emissions and coal fired power plants.

Commercial development along the South Atlantic coast also has been extensive and relatively few coastal areas are free of commercial development. Past development practices were especially detrimental and before adequate regulation it was not uncommon to excavate and fill marshes and shallow water environments for residential, commercial and industrial uses. Such practices have been largely eliminated because most of the coast is either developed or protected from such practices. However, uplands are a decreasing commodity in the coastal zone and the demand for filling wetlands and other aquatic sites is likely to persist. Consequently, proposals aimed at altering wetlands for commercial and other purposes will continue to require local, state, and federal involvement if significant adverse impacts to EFH are to be effectively controlled.

The total amount of EFH that has been eliminated or degraded by commercial and industrial development is unknown, but it is extensive. NOAA Fisheries Service data show that between 1981 and 1996, 1,466 proposals were received for industrial and commercial development in wetlands that are subject to the regulatory provisions of the Rivers and Harbor Act and Section 404 of the Clean Water Act. In association with this, 430 proposals sought approval to alter about 3,202 acres of EFH (see Tables 26, 27, 28, & 29). Between 1996 and 2006, NOAA Fisheries Service reviewed approximately 2,126 applications for industrial and commercial activities and associated wetland impacts in the South Atlantic area.
Point-source discharges from commercial activities may be similar to those associated with urban and suburban development. Accordingly, the information and discussions contained in Section 4.1.1.3 should apply. Pollution and water use may alter the flow, pH, hardness, dissolved oxygen, and chemical composition parameters that affect individuals, populations, and communities (Carins 1980). Within aquatic systems industrial point-source discharges also may alter species and population diversity, nutrient and energy transfer, productivity, biomass, density, stability, connectivity, and species richness and evenness both at the point of discharge and downstream locations (Carins 1980). Growth, visual acuity, swimming speed, equilibrium, feeding rate, response stimuli, predation rate, photosynthetic rate, spawning seasons, migration routes, and resistance to disease and parasites of finfish, shellfish, and related organisms may be altered by chemical and thermal changes. Some industries, such as paper mills, are major water users and associated effluent can dominate and control conditions in substantial portions of rivers and other water bodies where they are located. Usually parameters such as substrate, currents, dissolved oxygen, pH, nutrients, temperature, and suspended materials are key factors affecting the distribution and abundance of EFH. The direct and synergistic effects of other discharge components such as heavy metals and various chemical compounds are not well understood, but current research shows that these constituents may be of greater importance than previously thought. For example, more subtle factors such as endocrine disruption in aquatic organisms and reduced ability to reproduce or compete for food are being uncovered (Scott et al. 1997).

The cumulative effect of many types of discharges on various aquatic systems also is not well understood, but attempts to mediate their effects are reflected in various water quality standards and programs in each state and within the various water systems. Industrial wastewater effluent is regulated by the EPA through the NPDES permitting program. This program provides for issuance of waste discharge permits as a means of identifying, defining, and controlling virtually all point-source discharges. The complexity and the magnitude of effort required to administer the NPDES permit program limit overview of the program and federal agencies. Consequently, the NOAA Fisheries Service and the FWS generally do not provide comments on NPDES application notices. For these same reasons, it is not presently possible to estimate the singular, combined, and synergistic effects of industrial (and domestic) discharges on aquatic ecosystems.

Where chronic non-point-source discharges and accidental releases of harmful or toxic substances mix, especially harmful effects on aquatic life and habitat, including EFH, is likely. An added concern with industrial operations is the release of contaminants into the atmosphere. Such materials may be transported various distances and directly and indirectly deposited into aquatic ecosystems (Baker et al. 1993). In the southeast, surface water acidification and mercury accumulation in sediments are of particular concern since sources of these material lie in other regions and are not subject to local and regional (southeastern) controls. In view of this, the regulation of surface water contamination from atmospheric pollution should be addressed from a local, regional, and international perspective.

6.1.1.7 Navigation

Support for navigation in the southeast Atlantic region has resulted in widespread modification of subtidal and intertidal areas used by commercial and recreational vessels. Significant modification to offshore habitats has also occurred and this is discussed in the Marine/offshore Processes Section. Primary threats to EFH from navigation in estuarine waters include the construction, maintenance, and expansion of thousands of miles of waterways such as the Atlantic Intracoastal Waterway and the myriad of other channels that lead to marinas, ports, turning basins, and harbors. Construction and maintenance of existing ports and recreationally-based marinas and basins have altered substantial areas of EFH. Expansion of existing channels and waterways to accommodate larger vessels, primarily mega-yachts and Post-Panamax vessels, is becoming an increasing threat to inshore EFH, namely seagrasses. Dredged material disposal and disposal of contaminated sediments is also an issue. Filling of wetlands and conversion of EFH from shallow to deep water habitats are persistent threats associated with new facilities and the maintenance and expansion of existing facilities. Where coastal inlets are stabilized and maintained for navigation purposes effects on nearshore environments and fish and invertebrate populations may be substantial in addition to blockages of littoral sediment transport.

A second major concern related to navigation is the host of environmental problems associated with vessel operations. These range from contamination of water by oil, grease, anti-fouling paints, and discharges of sewage, garbage, and debris to the direct destruction of EFH by grounding, anchor damage, propwashing, scarring, etc. Most physical damage is accidental; however, activities such as propwashing could be avoidable for example, through better signage in waterways near shallow SAV habitats and a greater of level of enforcement. However, regarding the latter, it should be recognized that many State and local enforcement programs are severely understaffed and underfunded.

Potential Threats to EFH from Navigation

Navigation related threats to EFH located within estuarine waters can be separated into two categories: Navigation support activities and vessel operations. Navigation support activities include, but are not limited to, excavation and maintenance of channels (includes disposal of excavated materials); construction and operation of ports, mooring and cargo handling *facilities; construction and operation of ship repair facilities; and construction of channel stabilization structures such as jetties and revetments. Potentially harmful vessel operations activities include, but are not limited to: discharge or spillage of fuel, oil, grease, paints, solvents, trash, and cargo; grounding/sinking/prop scaring in ecologically/environmentally sensitive locations; exacerbation of shoreline erosion due to wakes; salt water intrusion into brackish systems; and transfer and introduction of exotic and harmful organisms through ballast water discharge.*

Navigation Support Activities

The most conspicuous navigation-related activity in many estuarine waters is the construction and maintenance of navigation channels and the related disposal of dredged materials. The amount of subtidal and intertidal area affected by new and maintenance dredging is unknown, but undoubtedly great. Orlando et al (1988) analyzed 18 major east coast estuaries from North Carolina to Florida east coast and found over 703 miles of navigation channels and 9,844 miles of shoreline modifications related to navigation works. Between 1981 and 1986 the NOAA Fisheries Service received over 4,877 proposals for new navigation projects in the South Atlantic region. A detailed analysis showed that 1,692 of these proposals involved plans to alter 24,825 acres of EFH through dredging and filling (Tables 26, 27, 28, & 29). From 1996-2006, NOAA Fisheries Service received 1,055 applications for maintenance dredging related activities and 720 application-related to construction of marinas and navigation channels in the South Atlantic area.

However, the potential threats to EFH from widening and deepening navigation channels warrant close examination. In many South Atlantic areas, marina owners and inland navigation districts have submitted applications to the Corps of Engineers for widening and deepening activities to accommodate mega-yachts and provide navigation access for mega-yacht vessels to private interior berthing, testing, and repair facilities located in the vicinity of inlets. Mega-yachts are typically classified as private luxury recreational motor or sailing vessels that are greater than 80 feet in length and there are approximately 735 that would access South Atlantic navigation channels (FWS 2005). In Palm Beach County, Florida alone proposed impacts associated with Atlantic Intracoastal Waterway and other channel expansion projects exceed 30 acres of seagrass habitat within Lake Worth Lagoon and typically involve dredging deeper than the Water Resources Development Act Congressionally authorized depths, for example from -10 NGVD to -16 NGVD. The seagrass habitats located around inlets are typically unique and ecologically significant due to the influence of clear oceanic waters that enter through the inlet and provide water clarity that cannot be found in locations further from the inlet. For example, the seagrass habitat located in close proximity to the Lake Worth Inlet (Florida) allows seagrass to grow at depths of over 10 feet as opposed to more remote seagrass habitat, which may only reach depths of 4 feet.

According to a FWS report, the overriding factor in the decline of estuarine and marine wetlands in the U.S. between 1998 and 2004 was the loss of emergent saltmarsh to open saltwater systems due to and manmade activities such as dredging, water control, and commercial and recreational boat traffic (Dahl 2006). While channel excavation itself is usually visible only from the surface while the dredge or other equipment are in the area, the need to dispose of excavated materials has left its mark in the form of confined and unconfined disposal sites, including those that have undergone human occupation and development. Chronic and individually small discharges and disturbances routinely affect water and substrate and may be significant from a cumulative or synergistic perspective. EFH impacts include, direct removal/burial of organisms as a result of dredging and placement of dredged material; turbidity/siltation effects, including increased light attenuation from turbidity; contaminant release and uptake of nutrients, metals, and organics; release of oxygen consuming substances; noise disturbance to aquatic and terrestrial organisms; and alteration of hydrodynamic regimes and physical habitat.

The maintenance and stabilization of coastal inlets also is a prominent navigation activity. Studies and reports by the COE, the NOAA Fisheries Service, and others link jetty construction to possible changes in plankton movement (USACE 1980; USDC 1991; Miller 1988; Miller et al. 1984). This is a major concern since significant modification of inlet hydrodynamics may diminish the ability of sub-adult fish and invertebrates to reach estuarine nursery grounds. Where significant reductions in recruitment (into estuarine waters) of desirable species is realized, production declines in ecologically, recreationally and commercially important species may result. The use of jetties to stabilize navigation channels at coastal inlets also has been linked to changes in coastal geomorphology that affects nearshore environments. For example, coastal geologists have expressed concern that construction of jetties at Oregon Inlet on the North Carolina Outer Banks could cause catastrophic beach erosion and accelerate barrier island migration (Pilkey and Dixon 1996). Such change could adversely affect the extensive and highly productive submerged vegetation beds which are located behind the coastal barriers.

The relocation of freshwater/saltwater transition zones due to channel deepening may be, in some cases, responsible for significant environmental and ecological change. As an example, salinity shifts after channel deepening and water diversion in the lower Savannah River caused vegetation shifts from freshwater to brackish species in surrounding wetlands. In the lower Savannah River, increased mortality of sub-adult striped bass also has been linked to salinity increases caused by navigation-related modifications such as channel deepening and flow diversion. Modifications that increase estuarine salinities may also create more hospitable conditions for shellfish predators such as boring sponge, oyster drill, and keyhole limpet.

In southeast Florida, increased channelization by dredging and the addition of rocky structures may have favored shifts from estuarine assemblages to reef assemblages because of comparatively higher abundances and diversities of incoming ichthyoplankton, higher inshore salinities, and replacement of vegetation with hard structure that favors reef species (Lindeman 1997). Similar situations are possible in other watersheds where dredging and dredged material disposal are prominent features; however, little documentation of these changes is available. Another example includes the St. Johns River in North Florida. The St. Johns River's watershed encompasses 50% or more of the east coast of Florida flowing north and in the 1800's flowed out onto an alluvial flood plan of shallow non-navigable sand bars. Construction of the Jacksonville Port has deepened and channelized the river mouth, now -52 NGVD. As a result, the amount of salt water intrusion has completely altered the estuarine system of the lower St. Johns River.

The expansion of ports and marinas has become an almost continuous process due to economic growth, competition between ports, and significant increases in vessel numbers and vessel size. Elimination or degradation of aquatic and upland habitats are commonplace since port and marina expansion almost always require the use of open water, submerged bottoms, and riparian zones. Ancillary related activities and development often utilize even larger areas, many of which provide water quality and other functions needed to sustain living marine resources. Vessel repair facilities use highly toxic cleaners, paints, and lubricants that can contaminate waters and sediments. Modern pollution containment and abatement systems and procedures can prevent or minimize toxic substance releases; however, constant and diligent pollution control efforts must be implemented. The operation of these facilities also poses an inherent threat to EFH by adversely affecting water quality in and around these facilities. The extent of the impact usually depends on factors such as flushing characteristics, facility size, location, depth, and configuration. When facilities such as marinas are constructed it is common to restrict shellfish harvest in a set or established zone that may be affected by sewage and other hazardous materials. It is now common practice to consider safe zones with respect to public health and aquatic resources when siting marina and port facilities.

Major ports in the South Atlantic region include Morehead City and Wilmington in North Carolina; Georgetown, Charleston, and Port Royal in South Carolina; Savannah and Brunswick in Georgia; and Fernandina Beach, Jacksonville, Port Canaveral, Port Everglades, Fort Pierce, Palm Beach, and Miami in Florida. Many eastern seaboard ports are subject to proposals to widen and deepen to accommodate Post-Panamax vessels or deep-draft vessels too large to fit through the Panama Canal. Impacts resulting from these projects can be substantial and can involve alternatives to dredge through coral reef, hardbottom habitat, and seagrasses.

In 2005, the Port of Miami, located in Biscayne Bay which is a State of Florida designated Outstanding Florida Water, completed a harbor deepening project that used confined blasting to fracture rock that was too hard to be removed via conventional dredge. In 2004, the Corps of Engineers finalized an Environmental Impact Statement to widen and deepen the entrance channel and other interior areas of the Port to -50 NGVD. The Recommended Plan would impact approximately 415 acres of habitat including over 6.3 acres of seagrass habitat, 28.7 acres of low-relief hardbottom/reef habitat, 20.7 acres of high relief hardbottom/reef habitat, 123.5 acres of rock/rubble habitat, and 236.4 acres of unvegetated bottom habitat (COE 2003).

The COE recently finalized a Reef Report for Port Everglades Outer Entrance Channel Expansion Project that concluded that over 150,000 corals and 21 acres of reef could be lost through proposed expansion activities (COE 2006). This project is in the feasibility phase and the COE proposes to release the draft Environmental Impact Statement in October 2007. In addition to the reef impacts, this project could impact up to 5 acres of seagrass (including one acre of the federally listed *Halophila johnsonii*), 11.55 acres of mangroves (8.48 acres of which are currently held in a conservation easement for impacts from previous Port activities), and 20.09 acres of previously dredged hardbottom, for which no compensatory mitigation is currently proposed (FWS 2005).

Cargo arriving and departing through these ports is diverse and ranges from highly toxic and hazardous chemicals and petroleum products to relatively benign materials such as wood chips. Major spills and other discharges of hazardous materials are uncommon, but are of constant concern since large and significant areas of estuarine habitat and fishery resources are at risk.

Expansion of these facilities and certain operation and maintenance activities are likely to occur at the expense of EFH.

There have been recent positive trends in the development of beneficial uses for clean dredged materials. For example, the deepening of the Wilmington Harbor navigation channel in North Carolina generated rock that is being used for creation of an offshore reef. Similar activities are being investigated in connection with planned deepening of Charleston Harbor in South Carolina. These activities will require monitoring to evaluate their success, but if beneficial other uses of dredged material could be developed. On a cautionary note, conversion of one habitat type to another may not be desirable since associated ecological trade-offs could be harmful to desirable or managed species. The classic example of this is the Winyah Bay, South Carolina dredged material disposal site, where submerged and intertidal bottoms have been converted to emergent marsh without any assessment of the ecological role of the disposal site.

Dredging and disposal of excavated materials is a major component of all southeastern ports and many marinas. Dredged materials are often contaminated and extensive testing for heavy metals and other contaminants is required. At many locations finding suitable disposal sites for dredged materials is also difficult and costly. Whenever contaminated dredged materials are placed in offshore waters, or in locations where decant is discharged into surrounding waters there is high probability that these contaminants will reenter aquatic food webs. As existing upland disposal sites are filled this problem is likely to be exacerbated. Already, direct overboard dispersal of dredged material occurs at some location such as in reaches of the Atlantic Intracoastal Waterway in North Carolina. In other locations such as the Savannah River, Georgia, a technique referred to as “agitation dredging” is used. In this case, about 200,000 cubic yards of materials are resuspended from ship berths each year by bottom dragging or by hydraulic excavation with direct disposal into the adjacent navigation channel. In addition, hydraulic bottom scour systems are presently in place in Wilmington, North Carolina, and experimental use of these devices is planned at one facility in Savannah and at the U.S. Navy’s Kings Bay, Georgia, Submarine Base. The environmental impact associated with the use of this technique is unclear, but significant use of bottom scouring devices could be problematic since planktonic and weak swimming fish and invertebrates could be impinged or entrained in intakes and plumbing, and turbidity and sedimentation could be exacerbated. Of particular concern is those aquatic environments that contain anadromous fish since planktonic and weak swimming fish could be heavily impacted.

An additional, but more limited dredging practice is the prop dredging of bottoms, mostly by recreational vessels, to obtain navigable depths. This practice is generally performed without benefit of state or federal permits and is almost always destructive.

The SAFMC is opposed to open water disposal of dredged material into aquatic systems when adverse impacts to habitat used by fisheries under its jurisdiction are likely. The SAFMC urges state and federal agencies, when reviewing permits considering open water disposal, to identify the direct and indirect impacts such projects could have on fisheries habitat. It is also their view that the conversion of one naturally functioning aquatic system at the expense of creating another (marsh creation through open water disposal) must be justified using the best available information.

Construction of piers and docks also affects EFH, but the degree of the impact is often disputed. Impacts are dependent on the size, location, and number of similar structures in a given area. Pier and dock construction often involves jetting of pilings and this causes temporary and localized affects on EFH due to increased sedimentation and habitat displacement. Sedimentation may be a problem in systems such as SAV that are already stressed and are declining or have marginal value due to low water clarity. The pilings are treated and toxic chemicals are released into the waters and sediments, but this is not perceived to be a major problem since the pilings are eventually covered with encrusting and fouling organisms. Perhaps the greatest threats from piers and docks are those associated with marsh and SAV shading and the erosion, due to wave action, of substrates in the vicinity of support piles. Substantial harm to SAV and benthic communities may also result from secondary effects associated with boat use, including constant grounding due to wave and tidal action.

The overall biological effects of piers and docks has not been well quantified. However, between 1981 and 1996, the NOAA Fisheries Service reviewed requests for almost 6,000 piers and docks along the southeast coast between North Carolina and Florida. Between 1996 and 2006, NOAA Fisheries Service reviewed an additional 7,540 applications to construct docks and pilings. In areas having marginal depths and especially where SAV is present, habitat damage in the vicinity of piers and docks may be substantial and disproportionately large in cases where such structures are abundant (Ludwig et al. 1997). These structures represent a substantial feature in southeastern watersheds and they warrant continued monitoring and regulatory review. In response to this, NOAA Fisheries Service and U.S. Army Corps of Engineers Jacksonville District jointly developed *Dock Construction Guidelines in Florida for Docks or Other Minor Structures Constructed in or over Submerged Aquatic Vegetation, Marsh or Mangrove Habitat* in addition to the *Key for Construction Conditions for Docks or Other Minor Structures Constructed in or over Johnson's seagrass (Halophila johnsonii)* (see http://www.saj.usace.army.mil/permit/hot_topics/Dock_Guidelines/dockindex.htm). In general, these guidelines provide environmentally responsible access to Florida waters.

Vessel Operations

In connection with watercraft operation and support the USEPA (1993) has identified several principal concerns. These include pollutants discharged from boats; pollutants generated from boat maintenance activities; exacerbation of existing poor water quality conditions; pollutants transported in storm water runoff from parking lots, roofs, and other impervious surfaces; and the physical alteration or destruction of wetlands and of shellfish and other bottom communities during the construction of marinas, ramps, and related facilities.

Marinas and other sites where vessels are moored or operate often are plagued by accumulation of anti-fouling paints in bottom sediments, by fuel spillage, and overboard disposal of trash and wastewater. In areas where vessels are dispersed and dilution factors are adequate, the water quality impacts of vessel operations are likely to be offset to some degree. In a study of marinas in North Carolina it was found that marinas may contribute to increases in fecal coliforms, sediment oxygen demand, and chlorophyll a, and decreases in dissolved oxygen (NCDEHNR 1990). In addition, boating and other activities (e.g., fish waste disposal) may contribute to increased water temperature, bioaccumulation of pollutants by organisms, water contamination, sediment contamination, resuspension of sediments, loss of SAV and estuarine vegetation, changes in sediment composition loss of benthic organisms, changes in circulation patterns, shoaling, and shoreline erosion. Pollutants associated with marinas include nutrients, metals, petroleum hydrocarbons, pathogens, and polychlorinated biphenyls (USEPA 1993).

Marina personnel and boat owners use a variety of boat cleaners, such as teak cleaners, fiberglass polish, and detergents and cleaning boats over the water, or on adjacent upland, creates a high probability that some cleaners and other chemicals will enter the water (USEPA 1993). Copper-based antifouling paint is released into marina waters when boat bottoms are cleaned in the water (USEPA 1993). Tributyl-tin, which is a major environmental hazard, has been largely banned except for use on military vessels. Fuel and oil are often released into waters during fueling operations and through bilge pumping. Oil and grease are commonly found in bilge water, especially in vessels with inboard engines, and these products may be discharged during vessel pump out (USEPA 1993).

Sewage and other wastes discharged from recreational boats may be most problematic in marinas and anchorage sites where vessels are concentrated. Despite existing federal and state regulations involving discharges of sewage and other materials, detection and control of these activities are difficult and discharges still occur. According to the 1989 American Red Cross Boating Survey, there were about 19 million recreational boats in the U.S. (USEPA 1993). About 95% of these boats were less than 26 feet in length and a large number of these boats used a portable toilet, rather than a larger holding tank. Given the large percentage of smaller boats, facilities for the dumping of portable toilet waste should be provided at marinas that service significant numbers of boats under 26 feet in length (USEPA 1993).

Increased recreational boating activity may contribute significantly to pollution of southeastern coastal waters by petroleum products. All two-cycle outboard engines require that oil be mixed with gasoline, either directly in the tank or by injection. That portion of the oil that does not burn is then ejected, along with other exhaust products, into the water. In 1990, 52,030 boats were registered in coastal North Carolina (North Carolina Wildlife Resources Commission, personal communication). Based on this number, conservative estimates indicate that about 84,549 gallons per year of oil (in fuel) is discharged annually into North Carolina’s coastal waters (Hoss and Engel 1996). For comparison purposes, hydrocarbon discharges for coastal North Carolina in 1982, from boating and urban runoff are about 470 and 2,270 tons, respectively. Increased use of personal water craft such as jet skis has added to the volume of hydrocarbon being introduced into southeastern waters since the engine exhaust from these vessels is discharged directly into the propellant water jet. Similar problems are inferred for other states and areas having high concentrations of boats.

The chronic effects of vessel grounding, prop and jet ski scarring, and anchor damage are generally more problematic in conjunction with recreational vessels. While grounding of ships and barges is less frequent, individual incidents can have significant localized effects. Propeller damage to submerged bottoms occur in all areas where vessels ply shallow waters. In addition, direct damage to multiple life stages of associated organisms, including egg, larvae, juveniles, and through water column de-stratification (temperature and density), resuspending sediments, and increasing turbidity (Stolpe 1997; Goldsborough 1997) have been observed in connection with vessel operation. This damage is particularly troublesome in North Carolina and Florida, the two South Atlantic states with submerged rooted vegetation in their coastal waters. In North Carolina, no official quantitative estimate of SAV damage has been performed; however, preliminary observations indicate that damage to the state's 135,000 acres of SAV is localized around marinas or other boat access points (R.L. Ferguson, personal communication). Scarring estimates for Florida indicate that about 173,000 of the state's 2.7 million acres of SAV are scarred (Sargent et al. 1995). On the Atlantic coast of Florida there are about 69,360 acres of SAV and 3,770 acres (18%) have been scarred by prop and other water craft action.

The ever increasing number of registered power boats along the South Atlantic coastal zone, and those temporarily entering coastal areas through tourism ensure that this threat is likely increase over time. Power boat registrations on Florida's east coast, not including sailboats, totaled 108,048 vessels in 1992-93. Of these, 95% were pleasure craft (Sargent et al. 1995).

The rapid increase in popularity of jet skis or "personal water craft" is also problematic. While these vessels are not propeller driven, the water jet removes sediment from seagrass roots and rhizomes and can cause damage. Further, these craft can operate in shallower waters and can access seagrass areas with relative ease, in addition to direct impacts to grassbeds. These machines are exceedingly loud and can create large wakes. It is reasonable to hypothesize that the audio and physical environment of shallow nursery areas may be disrupted in manners which stress postlarval life stages. The degree of stress is currently uninvestigated.

Incidences of commercial groundings are few, but where they occur on hard bottom habitats damage may be extensive and long-term. For example, groundings in the Florida Keys National Marine Sanctuary have caused extensive damage to coral reefs and signs of recovery are slow to appear.

The cumulative effect of anchor scarring in seagrass beds is not as damaging as that caused by propeller and jet powered vessels. On coral reefs, however, damage caused by anchoring of recreational boats is significant (Davis 1977). Dragging or pulling anchors through coral beds breaks and crushes the coral, destroying the coral formation. Most reef damage of this type occurs in the Florida Keys and in nearshore waters.

The effects of vessel induced wave damage have not been quantified, but may be extensive. The most damaging aspect relates to the erosion of intertidal and SAV wetlands located adjacent to marinas, navigation channels, and boating access points such as docks, piers, and boat ramps. Wake related erosion in places along the Atlantic Intracoastal Waterway and elsewhere is readily observable and has undoubtedly converted substantial areas of emergent wetlands to less important habitat such as submerged bottom. In heavily trafficked areas bottoms may become unstable and colonization by bottom dwelling organisms may not be possible. Indirect effects may include the resuspension of sediments and contaminants that can affect EFH. Where sediments flow back into existing channels, the need for maintenance dredging, with its attendant impacts, may increase.

The introduction of exotic species by vessel operations is linked largely to the world wide movement of commercial vessels. Exotic species may be brought into the U.S. by several methods, but capture and release in ballast waters is of most concern. With the introduction of the zebra mussel into the Great Lakes and its rapid dispersal into other waters, considerable attention is being directed at this problem. According to one estimate, two million gallons of foreign ballast water are released every hour into U.S. waters (Carlton 1985). This possibly represents the largest volume of foreign organisms released on a daily basis into North American ecosystems. The introduction of exotic organisms threatens native biodiversity and could lead to changes in relative abundances of species and individuals that are of ecological and economic importance. This has already been observed in other parts of the world. While EFH has not been directly affected, recent introduction of a brown mussel into the Gulf of Mexico is of concern and is being investigated. It is anticipated that technology such as use of filters or open ocean exchange of bilge waters can be used to reduce the spread of non-native species. Considering the extent of port development and shipping along the South Atlantic, addressing this issue is of paramount importance.

6.1.1.8 Inshore Mining

Inshore mining, as a category of EFH threats, is generally confined to a few specific locations where associated effects may be substantial. Between 1981 and 1996 the NOAA Fisheries Service received only 434 of these proposals for review. Of these, 307 were from Florida and involved phosphate mining. While these activities undoubtedly have a dramatic effect on local landscapes and wetlands, the majority are well inland of most EFH locations. Where these activities occur along the coast, phosphate rock, sand, gravel, stone, and marl are generally mined. Phosphate rock is sought mostly for fertilizer production and the other materials are used mostly for fill, roadbed construction, and concrete production. The products of mining operations may eventually be transported to other locations and construction and operation of shipping facilities and navigation channels could involve EFH.

Threats to EFH from Inshore Mining Activities
Potential threats include conversion of wetlands to mine pits and uplands, or to reclaimed aquatic sites and uplands that lack pre-mine habitat and fishery production values; direct and/or non-point-source discharge of fill, tailings, chemicals, cooling and processing water, and surface and ground waters into streams, rivers and estuaries; hydrological modifications including those associated with ditches, dikes, water and waste lagoons, intake and discharge systems; and cumulative and synergistic effects associated with other mining and non-mining activities. Related shipping, storage, and processing facilities also can threaten EFH.

Where mining activities occur in areas identified as EFH, the local effect is often dramatic and extremely damaging. In eastern North Carolina phosphate mining has essentially eliminated an entire estuarine creek ecosystem in Beaufort County. The only phosphate mine in North Carolina is found in Beaufort County and located adjacent to the estuarine waters of Pamlico and South Rivers which are tributaries of Pamlico Sound. A 2006 proposal for continuation of mining would result in the loss of about 3,000 acres of wetlands of a variety of types, including the loss of approximately 30 acres of fresh and brackish estuarine emergent wetlands and freshwater/brackish water submerged aquatic vegetation located in the upper reaches of 5 estuarine creeks whose headwaters would be within the proposed mine expansion’s footprint. Wetlands losses of this magnitude are significant on an ecosystem scale and the extent to which mitigation would offset these losses is uncertain at best. Alternative mining plans are available to the applicant that would be less damaging to wetlands and EFH; however, the company was opposed to these alternatives based on economic issues including profit margin.

In Dade and Monroe Counties, Florida, limestone removal operations have converted large areas of wetlands to open pits. The majority of these operations occur in the “Lake Belt”, which is an approximately 57,515-acre area that was established by the Florida Legislature in 1997 for the purpose of implementing the Miami-Dade County Lake Belt Plan. The area lies west of Miami and east of Everglades National Park. To date, mining in the Lake Belt area has thus far converted approximately 4,900 acres of freshwater wetlands into lakes. The Clean Water Act Section 404 permits authorized by the COE require the mining industry to fund acquisition, restoration, and long-term management of lands in the Pennsuco wetlands, which is the area sandwiched between the Lake Belt and the Florida Everglades.

While most state and federal regulations require restoration of mine sites, such action is costly and often fails to produce environments that are similar in ecological character and productivity to those that were destroyed. EFH designation could further fishery management opportunities in certain locations and in the case of certain mining activities. In locations where suitable mitigation cannot be provided, the creation of new mines and expansion of existing operations may be curtailed or prohibited. Other less intrusive mining operations, such as minor removal of sand and gravel, are likely to continue, but needed environmental protection measures (e.g., seasonal work restrictions) could be specified to minimize impacts to fishery resources and prevent significant harm to EFH. However, this is not always the case as illustrated by a proposed 750 acres mineral mining project in New Hanover County, North Carolina that would adversely impact about 300 acres of tidally influenced forested wetlands located adjacent to the northeast Cape Fear River. The wetlands to be impacted and the adjacent waters in the river are designated as fish management areas by the North Carolina Division of Marine Fisheries and are therefore EFH. While approval of wetland losses of this type is unlikely, the frequency of this type of mining activity is likely to increase given the increase in development in coastal states and the need for aggregate fill for highway and commercial construction.

The construction and operation of mining-related facilities such as storage, processing, and shipping facilities and other related infrastructure such as roads, also presents a threat to EFH. Discussions found in Sections 6.1.1.6 and 6.1.1.7 address these factors.

6.1.1.9 Hydrologic Modifications

Alteration of freshwater flows into coastal marine waters, typically via the construction of canals, has changed temperature, salinity, and nutrient regimes, reduced the extent of wetlands, and degraded estuarine and nearshore marine habitats (Reddering 1988; Whitfield and Bruton 1989). The following summary is largely taken from Serafy et al. (1997). Profound changes to the south Florida ecosystem have occurred with the construction of an extensive inland and coastal canal system by the COE which began as early as 1917 (Hoffmeister 1974; Teas et al. 1976). Today, the system constitutes a 1400-mile network of canals, levees, locks and other flood control structures which modulates fresh water flow from Lake Okeechobee, the Everglades, and coastal areas. These areas, which serve as nursery areas for a wide diversity of organisms, have experienced drastic changes in both the amount of freshwater they receive, and in the fashion in which it is delivered. For example, in southern Biscayne Bay, Florida, canal locks are all that separate this occasionally hypersaline lagoon from the entirely freshwater canal systems. When the locks open, the salinity of marine waters downstream often drops 20 ppt within 60 minutes before recovering as rapidly (Wang and Cofer-Shabica 1988). This may occur several times a day and over several months, particularly during the rainy season (i.e., May to October) when water temperatures are also at maximum levels.

Potential Threats to EFH from Hydrologic Modifications

Most hydrologic modifications are performed with other activities that are identified as having potential to adversely impact EFH. As such, the activities involved are similar or identical to those identified in other sections. Other threats are possible with mosquito control, aquaculture, wildlife management, and flood control projects and activities. Hydrologic modification can involve entire watersheds and drainage basins for large scale water diversion projects, where silviculture and/or agriculture activities are large in scale and/or intensity, and where runoff from urban and suburban development is substantial. Threats related to hydrologic modification can involve any activity that alters water quality or the rate, duration, frequency, or volume at which water enters or moves through an aquatic system. Consequently, activities associated with industrial, urban, and suburban development (including those occurring on uplands), ditching, draining, diking, and impounding may all qualify as hydrologic modification related threats.

Rapid salinity fluctuations can represent a significant stress for a marine organism, depending on its osmoregulatory ability and/or its behavioral response (Serafy et al. 1997). In fishes, abrupt salinity changes can cause mineral imbalances in the blood which tends to become diluted as salinity drops, and concentrated as it rises -- either of which can be lethal (Mazeaud et al. 1977). Rectification of proper osmotic balance in response to salinity stress requires energy expenditure, often at the cost of growth, reproduction and/or resistance to other stressors, including high temperature (Moore 1972; Schreck 1990). The combination of high temperatures and low salinity pulses on marine organisms has received only limited attention (Moore 1972; Albertson 1980).

Only one study has examined the combined effects of high temperature and freshwater pulses on subtropical marine fishes of the Western Atlantic. Serafy et al. (1997) combined a field survey of nearshore fishes in Biscayne Bay, Florida, with a series of laboratory-based freshwater pulse experiments. A 13-month trawl project was supplemented with high temperature - low salinity challenge experiments on eight fishes: five species that dominated canal-influenced habitats (*Eucinostomus gula*, *Lagodon rhomboides*, *Haemulon sciurus*, *Opsanus beta*, and *Lucania parva*) and three species that were less common in these areas (*Cynoscion nebulosus*, *Haemulon favolineatum,* and *Cyprinodon variegatus*). Of the five fishes that dominated the nearshore habitats, three exhibited no mortality when subjected to freshwater pulses, while *L. rhomboides* and *L. parva* exhibited 12.5% and 50% mortality rates, respectively. Mortality was 100% for the three species that were less common in habitats influenced by canals. These laboratory and field results support the hypothesis that anthropogenic changes to fresh water delivery regimes can play a partial role in determining the species compositions of nearshore fish assemblages within Biscayne Bay, Florida.

Holland et al. (1996) found that salinity was a major factor in controlling the distribution and abundance of living marine resources in South Carolina estuaries. In watersheds having the greatest areas of roofs, roads, and parking lots it was found that surface water discharges tended to be “flashier” and that recruitment and colonization by benthic fauna in these areas was less predictable than in more stable environments.

Mosquito control activities and associated threats to EFH have become better understood in recent years. Between 1996 and 2006, NOAA Fisheries Service reviewed 203 applications for mosquito control and related activities in the South Atlantic area. Although efforts to alleviate the hydrologic modifications resulting from this activity are underway (27,000 acres of reconnected impoundments in the Indian River Lagoon) much of the area altered by ditching and draining of saltmarsh throughout the east coast has not been addressed. Although tidal water still flows into most of these saltmarsh areas it flows in prescribed dredged channels and does not interact with much of the marsh surface expect through extreme high tide events. Without sheet flow of water across the marsh surface much of the ecological benefit of saltmarsh is underutilized. Some of these areas are receiving hydrological restoration but efforts have been under funded and go largely unrecognized.

6.1.1.10 Dams, Impoundments, and Other Barriers to Fish Passage

Natural river systems throughout the world have been extensively modified for a variety of societal purposes including withdrawals for irrigation, public water supplies, navigation, flood control, and hydroelectric power. Over half of the world’s large river systems (172 of 292) are affected by dams constructed in the past century (Nilsson et al. 2005). Approximately 800,000 dams have altered riverine habitats worldwide, with approximately 2 major dams constructed each day for the past 50 years (World Commission on Dams 2000). In the United States the total number of dams built during 1700- present is not known with certainty. The National Inventory of Dams (FEMA and U.S. Army Corps of Engineers 1994, 1996) listed approximately 76,000 dams including those deemed to be a threat to life and property downstream, those greater than 6 feet high with more than 50 acre-feet of storage, and those 25 feet or greater in height with more than 15 acre-feet of storage. The National Research Council estimated well over 2.5 million dams existed in the United States in 1992. All of the watersheds tributary to the South Atlantic Shelf Ecosystem are highly affected by large mainstem flood control and hydropower dams and many small dams constructed for various purposes. Bush, et al. (1998) in a review of existing dam location data identified 6,944 dams in South Atlantic watersheds (North Carolina to Florida).

Thousands of wetland acres have been impounded each year in the southeast for purposes such as waterfowl habitat creation, aquaculture, agriculture, flood control, and mosquito control. Historically, large areas of wetlands were impounded in South Carolina for rice production. Projects range in size from minor, such as repair of existing embankments, to large-scale projects where constructing dikes and water- control structures may affect relatively large wetland tracts.

Numerous dams and other structures have been built on major rivers for industrial water uses, hydropower facilities, reservoirs, and as part of flood control projects. Those facilities near the coast can have an adverse effect by blocking fish passage, and modifying hydrology and sediment and nutrient flows to coastal waters. Dams affect or disrupt many natural processes including upstream and downstream movements of fish and other aquatic species, export of organic carbon, natural hydrological variability and seasonal flow patterns, seasonal temperature, dissolved oxygen and nutrient export patterns, and riverine, estuarine, and coastal geological processes (Freeman et al. 2003; World Commission on Dams 2000).

Potential Threats to EFH from Dams, Impoundments, and Other Barriers to Fish Passage
Direct effects of impoundments and other barriers are removal of habitat, conversion of habitat away from historic usage, alteration of hydrology, and modification of water quality by modification of temperature, salinity, and nutrient and sediment fluxes. Flow regimes often are controlled and differ substantially from pre-impoundment flows. This can adversely affect anadromous fish migration and spawning as well as food production for prey species needed by larvae and juveniles. Riverine, estuarine, and coastal marine ecosystems have evolved in synchrony with natural seasonal river flow variability and discharge patterns. Species life cycles, reproduction, and sustainable populations may be disrupted by man-made barriers and their many effects as described previously.

Large acreages of coastal wetlands have been impounded along the southeast Atlantic. Reasons vary, but include aquaculture, waterfowl production, mosquito control, and in the Old South prior to 1912, rice production. The overall amount of impounded coastal wetlands is not known, but probably exceeds 200,000 acres. Between 1981 and 1996, the NOAA Fisheries Service reviewed 721 proposals of varying sizes that blocked or impounded EFH (Tables 26-29). A review of 190 of these projects revealed that about 7,131 acres of EFH would be adversely altered through these projects. From 1996-2006, the NOAA Fisheries Service Habitat Conservation Division received 465 applications for barriers and impoundments.

A primary biological concern for barriers and impoundments is the impact on estuarine-dependent marine fisheries production. Most impoundments are managed for resources other than fish (e.g., waterfowl). The management regimes, based largely on seasonal consideration, may exclude or severely restrict access by fish and invertebrates. This decreases habitat area and proportionately, the production of fishery resources. Even if fisheries gain access, conditions within impoundments may not be hospitable and organisms may not be able to escape and enter harvestable and reproductively active populations found in surrounding waters. Other management regimes, such as marsh burning, may adversely affect fishery resources. Water quality and nutrient outflow also may be compromised.

However, it is important to note that existing impoundments can be managed to reduce their impacts on estuarine habitat, although some impacts may remain, (e.g., blockage of ingress-egress, reduction of carbon and nutrient export). New impoundments pose a potential risk to EFH and fish production and must be carefully evaluated. However, within the South Atlantic, some positive aspects are evident related to existing impoundments. Because wetlands have been extensively damaged, these areas (especially old rice fields) provide a wealth of available habitat. Further, production of fisheries organisms within these areas is often excellent. Crab production, for example, has been shown to be high in some areas and the production of many estuarine-dependent species has been observed.

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The effects of riverine dams and impoundments on riverine and coastal ecosystem processes, habitats, and health may be profound. Ecological functions of riverine ecosystems affected by dams may be grouped into five primary components: hydrology, biology, geomorphology, water quality, and connectivity (Instream Flow Council 2002). Each of the five components is strongly linked with physical habitat structure, important nutrient and carbon cycles, and health and productivity of estuarine and coastal marine ecosystems. Explained in simplest terms, the effects of dams are manifested through the broad impact categories of habitat fragmentation and flow regulation, in addition to alteration of morphological processes.

With respect to coastal ecosystems and managed fisheries, arguably the most critical effects of dams include blockage and consequent reduction in available reproductive habitat for sea-run diadromous fishes, and large-scale alteration of the distribution and periodicity of freshwater inflows.

Diadromous fishes including shad, herring and other alosines are important components of estuarine and marine food webs. Prior to construction of dams in Atlantic river basins large annual spawning runs of shad and herring and other diadromous species supported important coastal and river fisheries. Early accounts described annual spawning runs of shad and river herring in rivers including the Potomac, Susquehanna, Roanoke, and Savannah in the tens of millions (Baird 1887) with landings in individual river basins exceeding today's total Atlantic Coast managed fishery landings by a wide margin. Baird was among the first marine scientists to suggest the relationship between diadromous fish biomass and support for stocks of other commercially important marine species. Construction of dams in Atlantic Coast river basins began soon after European colonization in the early 1700s and continued in cycles through the early 1970s (Watson 1996). Nearly all large river basins in the South Atlantic were closed to significant diadromous fish spawning runs by mainstem dams by the 1960s and 1970s. Busch et al. (1997) estimated the reduction in Atlantic Coast riverine habitats for diadromous species due to construction of dams. In the North Atlantic region (Maine to Connecticut) stream access for diadromous species has been reduced by 91%, and the corresponding reduction for the South Atlantic Region (North Carolina to Florida) is 77%. As dam construction progressed, along with unregulated exploitation and increasing pollution, the Atlantic Coast shad fishery remained one of the most economically important fisheries into the 1940s prior to construction of the last major mainstem dams after the Second World War (Hightower 1997). Today the formerly large spawning runs of shad, river herring, striped bass and sturgeon are reduced to small remnant populations or have disappeared entirely in some rivers. Because of the drastic reductions in abundance of shad and other alosine species, their importance in food web support has also diminished and may represent a significant limiting factor in recovery of some federally managed species.

The timing, duration, and frequency of river flows are critically linked to the health and function of riverine, estuarine and coastal marine ecosystems and fisheries (Taylor et al., 1990). Estuarine and coastal marine wetlands and deepwater habitats are highly dependent upon inputs of freshwater and associated nutrients and sediments from rivers (Berkamp et al. 2000). Seasonal periods of increased river discharge and consequent inflow to estuaries and coastal waters may serve as biological triggers for fish and invertebrate migrations and reproductive cycles. More prominent examples include upstream spawning movements of shad, striped bass, and sturgeon to spawning habitats in river channels; and movements of spawning blueback herring and Atlantic menhaden into floodplain forested wetlands and deepwater sloughs (Rulifson 1982; Pardue 1983; Meador 1982). Natural seasonal patterns and variations in freshwater inflows to estuarine and coastal marine habitats provide suitable salinity and nutrient conditions for reproduction and growth of oysters, blue crabs, shrimp and many estuarine-dependent species. Regulation of river flows by dams, particularly for flood control and hydropower production, may significantly alter natural patterns of river discharge to which many species life cycles have adapted during their evolutionary history. River regulation may affect seasonal salinity patterns over large areas of estuarine and coastal marine habitats. Dams with large storage capacity can reduce downstream flows during critical late winter and spring diadromous fish migrations, resulting in reduced water level and duration and areal extent of inundation, severely limiting fish production.
Dams and reservoirs trap river-borne sediments, resulting in reduction of nutrient-rich sediment deposition in downstream floodplain wetlands and alluvial deltas. Resulting disruption of alluvial delta and wetland formation processes may cause large scale floodplain and wetland subsidence, adversely affecting habitat stability and productivity for estuarine and coastal marine fisheries.

Thermal stratification of large reservoirs during summer months often results in biological oxygen depletion of the cooler water of the hypolimnion, with consequent discharge of cooler water with low dissolved oxygen downstream of the dam. Fish and other aquatic life may be eliminated or adversely affected in riverine or estuarine areas downstream as far as the deoxygenation persists. Large, shallow impoundments lacking thermal stratification may result in solar warming with consequent release of water with elevated temperatures to downstream riverine and estuarine habitats. During warmer summer months, the resulting elevated water temperatures may exceed the tolerance levels for fish species adapted to naturally occurring seasonal temperature regimes.
Where dams and river regulation have been in place for many years, the continuing cumulative effects of habitat fragmentation, altered flows, water temperatures, and dissolved oxygen conditions may result in shifts in aquatic species community structure and composition. Populations of federally managed diadromous, estuarine and marine species may be limited by the continuing effects of dams and river regulation.

Dams and other barriers have been constructed on almost every major southeastern river. They serve multiple purposes including hydropower production, water supply, and flood attenuation. Dams located on the Roanoke and Neuse Rivers in North Carolina, the Cooper and Santee Rivers in South Carolina and on the Savannah River on the South Carolina-Georgia border are major impediments to anadromous fish migrations, as mentioned above. Most of these structures are old and were built either before their effects on fish and other wildlife were known, or at a time when environmental concerns were of lesser importance than economic and political factors. Considering the present level of knowledge of their effect on fish migration and production, water quality, and flow alteration, it is unlikely that major new structures will be built. The present challenge is to revisit older structures to determine their usefulness and where their negative impacts outweigh their benefits, they should be removed or modified. An example is removal of the Quaker Neck Dam on the Neuse River in North Carolina. Where removal is not feasible then consideration must be given to providing for, or improving fish passage and for modifying flow regimes to mimic pre-impoundment flows. These considerations will rely on new research and improvements in fish passage technologies.

6.1.1.11 Other sources of nonpoint-source pollution

<u>Potential Threats to EFH from Other Sources of Nonpoint Source Pollution</u>
Potential threats include reduced water quality, erosion, increased contaminants, increased sedimentation, and disease.

The more common sources of NPS pollution include runoff from agriculture, pasture lands, silviculture, mining, and developed areas as well as erosion created from modifying rivers, streams, and shorelines. These sources have separate sections in the Fishery Ecosystem Plan. Three additional sources of NPS runoff deserve brief mention and include construction sites, marinas, and septic systems

Runoff from construction sites can be considerable sources of NPS pollution (Carpenter et al. 1998). Construction sites occupy a relatively small percentage of land surface area, but rates of erosion from these sites can be high leading to a large amount of pollution coming from these small areas. Erosion rates from watersheds under development can approach 50 times the rate from agriculture lands and 500 times the rate from areas with undisturbed plant cover. Eroded material from construction sites contributes to siltation of water bodies as well as eutrophication. Best management practices for controlling runoff from construction sites are well known and should be followed to avoid impacting fishery resources.

Understanding NPS pollution associated with marinas can be difficult because marinas can be both a source of pollutants generated by activities occurring within the marina as well as the place where pollutants generated elsewhere collect (Flory 2005; USEPA 2001). Construction of the basins, docks, jetties, and bulkheads needed for marina operations typically reduce water circulation, and this reduced circulation promotes the settling of fine sediments that often have organic material, metals, or other pollutants attached to them. These materials concentrate in marina sediments and, at times, also can concentrate in marina waters. The pollutants that might be generated at a marina or accumulate within a marina basin include nutrients and pathogens (from pet waste and overboard sewage discharge), sediments (from parking lot runoff and shoreline erosion), fish waste (from dockside fish cleaning), petroleum hydrocarbons (from fuel and oil drippings and spills and from solvents), toxic metals (from antifouling agents and debris from boat maintenance), and liquid and solid wastes (from engine and hull maintenance and general marina activities).

Many contaminants generated from boat maintenance and general marina use (e.g., oil and grease drippings from cars) are insoluble in water. In the slow flowing, protected waters of the marina, the fine particles that these materials adhere to settle and accumulate in the sediments. While these sediments may then release their contaminants into the water in response to physical disturbance (such as dredging, propeller wash, or storms) or from changes in water chemistry (such as pH or dissolved oxygen concentration), effects upon benthic organisms and fishery resources are of greatest concern. Most benthic organisms either burrow into the sediment or feed by sorting through large volumes of sediment in search of prey items or detritus. Both behaviors bring benthic organisms into close contract with any contaminants that may be present and these contaminants can then accumulate in the bodies of the benthic animals. Fishery species that feed upon these benthic organisms are then exposed to concentrated doses of the contaminants, which may reduce the health or reproduction of the fishery individuals or make them unsuitable for consumption by humans.

Pollutants from marinas can cause pollution problems in the water column. These problems usually take the form of decreased levels of dissolved oxygen and increased levels of metals and petroleum hydrocarbons. Pollutants that cause these problems get into the water through storm water runoff, discharges from boats, and spills of fuel or bilge water. Low levels of dissolved oxygen can be a problem any place where organic material accumulates. The decay of organic material consumes oxygen from surrounding water. If the low circulation promotes accumulation of organic material while at the same time hindering exchange with oxygen-laden waters outside the marina, the result can be insufficient oxygen for fishery species.

In addition to pollutants that reduce the quality of sediment or the water, marinas often are associated with silt that can impair seagrass, oyster, or other habitats that support fishery resources. Increased boat traffic within and near a marina can erode shoals and the shoreline suspending large amounts of sediment into the water that fall upon fishery habitats. Waves generated by boat wakes can wash away seagrass that is loosely rooted in sediments and the benthic organism living at the sediment surface.

NPS pollution associated with marinas can be reduced by ensuring marinas are designed to flush regularly with adjacent waters; locating marinas close to tidal inlets and away from the headwaters of tidal creeks is part of these design decisions. Shorelines should be vegetated to reduce erosion. Stormwater runoff can be controlled by well designed and maintained stormwater management systems. Marina fueling and sewage collection stations should be maintained and designed to make cleanup of spills easier.

Septic systems include the underground system of pipes and tanks designed to use naturally occurring bacteria and microorganisms to treat bathroom, kitchen and laundry wastewater. In older homes, a septic system may be little more than a cesspool and a pipe that connects the cesspool to the house. In newer homes, a septic system usually includes a septic tank, distribution box, drain field, and pipes that connect these elements. Passing sewage and household wastewater through a septic system protects the environment from contamination.

Microorganisms and insects living within the drain field help decontaminate waste materials by consuming leftover waste particles. Improperly maintained septic systems can allow nutrients and pathogens to enter ground waters and surface waters that flow into coastal ecosystems. The excess nutrients can lead to eutrophication and low levels of dissolved oxygen, both of which can impair habitats used by fishery species. The pathogens can spread disease that reduce the health of fishery species.

NPS pollution from septic systems can be reduced by ensuring the systems are inspected annually and pumped regularly. Pumping out every three to five years is recommended for a three-bedroom house with a 1,000-gallon tank; smaller tanks should be pumped more often. Storm drains should not be diverted into septic systems because the extra load on the systems will overwhelm its ability to process nutrients and eliminate pathogens. Any measure that decreases water use within a home can help a septic system protect coastal water quality by reducing the likelihood of overflow from the system.

6.1.1.12 Non-native or nuisance species

<u>Update on Aquatic Invasive Species Management in the Southeast-March 2008</u>
Marilyn Barrett-O'Leary Southeast Aquatic Resources Partnership (SARP)

Aquatic invasive species are a part of fisheries and wildlife management in all of the Southeast Aquatic Resources Partnership (SARP) states. Many of the states manage specific species cooperatively, but we do not have comprehensive regional management. For example, Texas and Louisiana partnered with some federal agencies to bring massive chemical control to reduce a giant salvinia infestation on Caddo Lake, a popular angling lake on the two states' shared border. Florida, a state with better funding resources than many of its neighbors, routinely shares research results and outreach products (on many invasive plants and animals) to promote regional control. All of the states are members of at least one regional Aquatic Invasive Species (ANS) panel, providing biannual meetings to share information and committees to work on problems regionally.

Every SARP state has developed an ANS management plan. Most have completed that process, which involves forming a task force, gathering information, identifying overlapping jurisdictions, setting priorities, and devising action plans. Most important, these activities lead to governor's buy in and signature, interagency agreements such as MOUs, and continuation of the task force in some form to facilitate management. As of this date, every SARP state has at least one agency person with ANS as part of his/her scope of work. Some have individuals with ANS as his/her exclusive scope of work. The states of Louisiana, Texas, Florida, Virginia and Missouri have officially accepted plans. Kentucky, South Carolina, Alabama, Tennessee and Mississippi are in the final, official stages of seeking national acceptance of their plans. They have effectively identified the problem and are already integrating solutions into their agency activities. Oklahoma, Georgia, North Carolina, and Arkansas are still developing their plans. Both Georgia and North Carolina are developing plans that combine management of terrestrial and aquatic invasive species. All states are aware of the need to work in that direction. All of these states face similar issues. Below are a few of them:

1. Invasive species are not all bad or all good – they may cause problems in certain circumstances but actually benefit certain groups or situations. Management (treatment, regulation, education) requires ecological and economic evaluation on local, regional, and national levels and cooperation among state, local, and federal agencies.

2. Invasive species almost always alter the ecosystem; they seldom simply slip into an unfilled niche. They thrive in disturbed systems. Therefore, ecological management can contribute to invasive species prevention and control. Unfortunately, states are not funded or equipped to manage all state waters at that level, and every state has many water bodies that are managed privately or by federal agencies.

3. The general population has only fleeting knowledge of this problem, and often, unwittingly, contributes to it. Consistent, continuous education is needed over the long term. SARP agencies are trying to educate one of the most involved segments of the population – the recreational fisher – to clean off boats before leaving the dock, place unused live bait into the trash rather than dumping it into the water, and to refrain from moving live fishes in an attempt to 'stock' for certain fish. Similar, targeted education efforts need to be made towards many other population segments. Tax dollars need to be earmarked for this management.

6.1.2 Marine/offshore processes

6.1.2.1 Navigation

Offshore maintenance dredging for navigation is mainly limited to inlet bar channels and other port entrances; (e.g., Port Canaveral, Florida). The sediments are typically coarse and the bottom communities are low diversity reflecting the dynamic nature of these areas. Bottom organisms occupying this zone are generally sparse and adapted to the dynamic nature of the habitat they occupy. As such, dredging in these locations generally does not pose the same magnitude or type of impact incurred when working in nearshore environments. The same is true for vessel operations, although to some degree the problems discussed in Section 4.1.1.6 also apply. Vessel operation impacts are mainly linked to sinking, grounding, routine disposal trash and wastes, and the accidental release or spillage of cargo and fuel.

However, offshore new dredging, namely widening and deepening existing port entrance channels to accommodate super-carriers, i.e., Post-Panamax vessels an impact complex hard bottom communities along channel walls in addition to reef trends. For example, the Jacksonville District COE in conjunction with Port Everglades is presently completing a feasibility study in part to evaluate the widening and deepening of the Port Everglades Outer Entrance Channel. The project could impact offshore marine habitats, including hard bottom and coral reef communities located offshore Fort Lauderdale, Florida (Broward County). In total, 11.9 acres of hard bottom habitat on the outer reef (Reef 3) may be removed during construction (COE 2006).

Potential Threats to EFH from Navigation

Potential threats include excavation and burial of EFH in connection with creation, expansion and maintenance of navigation channels; elevation of turbidity and resuspension of toxic and harmful components of dredged materials (includes material that cause elevated sediment and dissolved oxygen demands); interruption of coastal sand movement and sub-adult fish migration through construction of channel stabilization structures such as jetties; potentially harmful vessel operations such as discharge or spillage of fuel, oil, grease, paints, solvents, trash, and cargo; grounding/sinking/prop scaring in ecologically/environmentally sensitive locations; exacerbation of shoreline erosion due to wakes; and transfer and introduction of exotic and harmful organisms through ballast water discharge.

With a few exceptions, offshore dredging is performed using hopper dredges. Hopper dredges generally dump accumulated material through a split hull; however, the use of these dredges in connection with pipelines and vessel pump out is becoming more commonplace, especially where sand is needed for beach fill. Closer inshore, sidecast dredges may be used where wave amplitude is slight and dredging volumes are relatively minor. In protected waters pipeline dredges are almost always used since they provide the most effective and efficient means for removing and redepositing bottom sediments. On rare occasion, as in the case of the Cape Canaveral Ship Channel, pipeline dredges may be used in open waters but their vulnerability to wave damage generally precludes this. Bucket dredges and scows are employed in some locations, but such use is usually limited to situations where other dredges cannot operate due to water depth and pumping distances (for pipeline dredges).

In connection with offshore waters, threats to EFH are most significant in terms of possible burial of benthic communities in the vicinity of dump sites and in connection with turbidity from dumped materials. Contamination of the water column and bottoms is also possible if the dredged material is contaminated. Sediments may also be re-dispersed after being dumped in offshore sites and burial of productive bottoms is possible. On occasion, designated dump sites are not adequately studied or they change and high quality benthic habitat may be damaged or destroyed.

Although most ports are located in estuarine waters, navigation related threats can also be severe in offshore waters. As the shipping industry moves towards super containerships, the many eastern seaboard ports are evaluating the need to widen and deepen offshore entrance channels. Currently, only a limited number of ports can accommodate Post-Panamax vessels. The Port of New York/New Jersey is the only port along the Atlantic seaboard that is undergoing expansion work to support super-carriers.

Additional threats to EFH from offshore navigation occur through the overboard disposal of trash, cargo, and wastewater from ocean going vessels, and disposal of dredged material (see Section 7.4.2.1). Although comparisons are unavailable, it is likely that most vessel-related disposal occurs on the open ocean, rather than in estuarine and nearshore waters where such activities are likely to be observed.
Within Florida waters, particularly in the Florida Keys and Fort Lauderdale, vessel groundings represent a chronic threat to live coral habitat. Anchoring is also a problem, however, it has become less of a threat through wide spread use of single point mooring buoy systems. Vessel groundings can be broken into two broad categories: large vessel and ship groundings that often

result in severe injury to live coral colonies and non-living reef framework; and small recreational boat groundings that result in numerous strikes to individual coral colonies in both inshore and offshore areas. Large vessel and ship groundings occur infrequently, but result in far more significant injury to coral reefs and other habitat types. Recreational boat groundings are much more frequent. Between 1993 and 1997, 2089 groundings were reported in the Florida Keys National Marine Sanctuary. Many more are likely unreported.

Table 6.1-1 Reported Vessel Groundings* in Florida Keys National Marine Sanctuary (FKNMS) 1993 to 1997.

Year	Total Reported Vessel Groundings
1993	280
1994	550
1995**	400
1996**	399
1997**	460
Total	2089

*Data from FKNMS & Florida Marine Patrol Computer Assisted Dispatch Report
** Grounding data for 1995 through 1997 are incomplete and require further data analysis.
Note: The above numbers do not represent coral reef groundings alone. Reported groundings occur in all types of habitats found in the FKNMS.

Accurate baseline data for live coral coverage exist mainly for reefs in the Florida Keys but not for the remaining habitat that contains stony corals that do not form reefs. In some cases though, sufficient data are available to allow calculation of the actual extent of a grounding incident. For example, on August 10, 1994, the R/V *Columbus Iselin*, a 154-foot research vessel, was conducting survey work for the University of Miami when it struck Looe Key, a spur and groove reef. Approximately 345 square meters of living coral and 338 square meters of non-living coral reef framework were destroyed.

Injuries to coral from groundings take several forms and include crushing, splitting and fragmentation, dislodging colonies, and depending on the severity of the incident, sedimentation and/or burial. In general, groundings occur on or near the reef crest where coral formations are closest to the water surface. Species commonly injured in the reef crest include elkhorn coral (*Acropora palmata*), staghorn coral (*A. cervicornis*), fire coral (*Millepora complanata*), starlet coral (*Siderastrea siderea*), mustard hill coral (*Porites astreoides*), and knobby zoanthidean (*Palythoa mammillosa*). Species that inhabit deeper areas such as brain coral (*Diploria strigosa*), star coral (*Montastrea annularis*), and large star coral (*Montastrea cavernosa*) are at risk from deep draft vessels. Small individual groundings may recover over time, but the loss of live coral coverage is likely to take decades. Catastrophic groundings involving large ships or freighters may never fully recover.

Since 1994, there have been at least 10 reported large-scale groundings near the existing anchorage off Port Everglades (in Florida) that have collectively damaged over 3 acres of coral reef habitat. The existing shallow water anchorage is located between two lines of reef. Dozens of undocumented anchor and anchor chain drag impacts have also occurred damaging an undetermined amount of reef. The U.S. Coast Guard has proposed anchorage rulemaking to revise the existing anchorage locations to strengthen existing anchoring requirements and guidelines in order to provide a higher degree of protection to the reef resources.

6.1.2.2 Dumping

Dredged material disposal in ocean waters generally involves disposal of sediments dredged from inshore areas such as port facilities. Where navigation approaches from offshore and inlets are involved these materials may also be placed in offshore sites. Most of the sediments taken from inshore areas are fine, contain some degree of contamination, and produce at least short-term impacts such as turbidity plumes when removed or deposited. The overall effects of dumping on or near EFH can range from immeasurable to significant and are not well studied. Therefore, dredging and disposal are typically evaluated on a case-by-case basis. The SAFMC policy on dumping provides additional detail on the subject. The principal authority for designating ocean disposal sites for placement of dredged material is the Regional Administrator of the EPA. The EPA develops and publishes Environmental Impact Statements (EIS) and the rule making paperwork for ocean dredged material disposal site (ODMDS) designations. Corps of Engineer Districts provides the EPA with the necessary information to prepare the EIS and to identify significant issues to be addressed in the site designation process. Information required from the Districts includes: zone or siting feasibility data, justification for the need for ocean disposal, and alternatives to ocean disposal. The purpose of the EPA site designation process is to establish sites that minimize impacts to the environment, economize disposal site management and monitoring activities, and support multiple users (C. McArthur personal communication).

Under provisions of the Marine Protection Research and Sanctuaries Act (MPRSA), ocean disposal of hazardous and toxic materials, other than dredged materials, is prohibited by U.S. flag vessels and by all vessels operating in the U.S. territorial sea and contiguous zone. The EPA may issue emergency permits for industrial waste dumping into ocean waters if an unacceptable human health risk exists and no other alternative is feasible. The MPRSA assigns responsibility the ocean disposal of dredged material to the EPA and the COE. This involves designating ocean sites for disposal of dredged material; issuing permits for the transportation and disposal of the dredged material; regulating times, rates, and methods of disposal and the quantity and type of dredged material that may be dumped; developing and implementing effective monitoring programs for the sites; and evaluating the effect of dredged material disposed at the sites (C. McArthur, personal communication).

To date, offshore ocean dumping sites have been approved for ports at Wilmington, North Carolina; Brunswick and Savannah, Georgia; Georgetown, Charleston and Port Royal, South Carolina; and Miami, Palm Beach, Port Everglades, Fort Pierce, Jacksonville, and Fernandina Beach, Florida (C. McArthur, personal communication). The COE has identified Jacksonville Harbor as possibly needing a new or expanded ODMDS.

Table 6.1-2 Region IV of the U.S. Environmental Protection Agency identifies the following concerns in connection with existing South Atlantic Ocean Dredged Material Disposal Sites (ODMDS):

Ocean Dredged Material Disposal Site	Site Specific Concerns
Charleston, SC ODMDS	Live bottom areas proximal to the site subject to possible impact.
Miami, FL ODMDS	Effect of disposal plumes on nearshore coral reefs are under investigation.
Port Everglades, FL ODMDS	Burial of deepwater hard bottoms and shelf edge zones that support managed species. Conversion of sediment type could affect tilefish burrows. Possible presence of deepwater corals (e.g. *Oculina varicosa*).
Palm Beach, FL ODMDS	Burial of deepwater hard bottoms and shelf edge zones that support managed species. Conversion of sediment type could affect tilefish burrows. Possible presence of deepwater corals (e.g. *Oculina varicosa*).
Fort Pierce, FL ODMDS	Offsite transport of disposed dredged material and subsequent burial of nearby hard bottom communities is of concern to local community.
Jacksonville, FL ODMDS	Lies within Northern Right Whale Critical Habitat and site may be undersized.
Fernandina, FL ODMDS	Lies within Northern Right Whale Critical Habitat.
Brunswick, GA ODMDS	Lies within Northern Right Whale Critical Habitat.
Wilmington, NC ODMDS	Wood debris in dredged material suspected of migrating off site into shrimping grounds.

Dumping of trash, wastewater, and unwanted cargo is more likely to occur on the open seas since it is less observable here than in inshore waters. Prior to passage of the Marine Plastic Pollution Research and Control Act (MPPRCA) of 1987 (PL 100-220), an estimated 14 billion lbs of garbage were being dumped into the ocean each year. More than 85% was believed to have come from the world's shipping fleet in the form of cargo-related wastes. See section 6.1.2.2.3 below.

Potential Threats to EFH from Dumping

Potential threats include burial of habitats and their flora and fauna, introduction of contaminants and toxic substances into waters and substrates, increased and harmful turbidity levels, and creation of hazards to fishing and navigation.

Threats associated with ocean dumping sites include covering of live bottom or hard bottom areas in or near a dump site; disposal of fish processing wastes; converting the sediment type in areas that support tilefish; impacts to nearshore coral reefs and live bottoms by disposal plumes; offsite transport of disposed dredged material and subsequent burial of nearby hard bottom communities; designated sites that are too small to handle the load; migration of debris (e.g., wood) to fishing grounds; derelict vessel disposal; and the location of dumping sites within critical habitat of endangered species such as the northern right whale.

Because monitoring of disposal activities is sometimes inadequate, there are reports of dredged material dumping outside of designated dump sites (short dumping). One recent example of a possible short dumping event involves the excavation associated with the Fort Pierce Harbor, Florida, expansion project. In this case, over 400,000 cubic yards of dredged material from this project was dumped at a mid-shelf site. Numerous complaints arose thereafter from fisherman and divers that the fill was short-dumped and large areas of reef habitat had been covered. These sites had previously served as productive snapper/grouper fishing locations. EPA Region IV undertook a number of studies into this issue. EPA monitoring reports are available at http://www.epa.gov/region4/water/oceans/sites.htm#ftpierce. Reed (1996) summarizes information available at the time regarding the mud deposits potentially derived from this event.

Another documented example of dumping occurring outside the designated ODMDS occurred during the Charleston Harbor Deepening Project. A total of 53 documented incidents of unauthorized disposal activity outside the ODMDS were reported subsequent to dredging for the Charleston Harbor Deepening Project. The unauthorized dumps were first detected during a routine assessment of the ODMDS and surrounding area using side scan sonar (Jutte et al. 2001). The documented dumps placed large quantities of mud and clay on sandy bottom habitat, with some located very near hard bottom reef habitat. Subsequent surveys over a four year period to determine whether movement of material from these sites or the ODMDS was having an adverse impact on nearby reef habitats did not identify clear loss of habitat with the exception of one site located closest to the ODMDS. The abundance finfish and large sessile invertebrates, such as sponges and corals also did not appear to be adversely affected during the survey period (Crowe et al. 2006).

In areas that have been suspect of short-dumping, such as the ODMDS located offshore the Port of Miami, the EPA Region IV and NOAA Fisheries Service habitat office have developed additional permit conditions that include:
1. The permittee shall use an electronic positioning system to navigate to and from the ODMDS;
2. The permittee shall certify the accuracy of the electronic positioning system proposed for use during disposal operations at the ODMDS;
3. The permittee shall not allow any water or dredged material placed in a hopper dredge or disposal barge or scow to flow over the sides or leak from such vessels during transportation to the ODMDS;
4. A disposal operations inspector and/or the captain of any tug boat, hopper dredge, or other vessel used to transport dredged material to ODMDS shall ensure compliance with disposal operation conditions defined in this permit;

5. If the disposal operations inspector or the captain detects a violation, he or she shall immediately report the violation to the relevant county Seaport Department, the Corps of Engineers District, and to NOAA Fisheries Service;
6. When dredged material is disposed, no portion of the hopper dredge or disposal barge or scow shall be farther than 500 feet of the center of the ODMDS;
7. The permittee shall use an automated disposal verification system that will continuously track (1 minute intervals) the horizontal location and draft condition of the disposal vessel (hopper dredge or disposal barge or scow) to and from the ODMDS;
8. The required digitally recorded data should include: date, time, vessel name, dump number, beginning and ending coordinates of the dredging area for each load, location at points of initiation and completion of disposal, description of material disposed (rock rubble, sand, clay or silt), volume of load, and disposal technique;
9. The permittee shall conduct a bathymetric survey of the ODMDS within 30 days following project completion;
10. The number and length of the survey transects shall be sufficient to encompass the ODMDS and a 0.25 nautical mile wide area around the site. The transects shall be spaced at 500_foot intervals or less;
11. Vertical accuracy of the survey shall be ±0.5 feet; and
12. At the dredge site, barges must be either lashed to dredges or cables must be floated to avoid impact to submerged resources.

Similarly, at the Charleston ODMDS site a number of constraints similar to those used in Miami were adopted, and it also included limiting the barge traffic to areas that were outside know hard bottom habitat.

Even with the use of approved practices and disposal sites, ocean disposal of dredged materials is expected to cause environmental harm since contaminants will continue to be released, productive bottoms will still be buried, and localized turbidity plumes and reduced oxygen zones will persist. Further, analyses are needed for use in dump site designation. For example, there have already been observed cases (e.g., at Charleston) where dump sites were designated and then, after dumping had been initiated, it was determined that valuable hard bottom habitats were located in or near the dump site. However, at the Charleston Harbor site, while it was determined that valuable hard bottom habitat is located adjacent to the dump site, monitoring has confirmed that construction of a berm along the edges of the disposal site is containing the majority of the dredged material, with the exception of occasional missed targeting and these are generally in the vicinity of the adjacent channel from which the vessel is traversing.

The effects of new disposal techniques such as creation of nearshore berms and “beneficial uses” of dredged material such as creation of shallow water habitats and emergent wetlands are, in many cases, unclear and may cause long-term geomorphological and ecological change that is harmful to certain species and environments. In the Charleston ODMDS, the deepening project included the construction of large berms along the border of the ODMDS that were composed primarily of cooper-marl material that would stay in place. The logic for constructing these berms was to inhibit significant movement of the disposed material within the ODMDS to sensitive bottom habitats located nearby. This effort appeared to be successful based on subsequent monitoring activities (Crowe et al. 2006). The SAFMC recognizes offshore berm construction as a disposal activity. As such, its policies regarding disposal of dredged materials apply. The SAFMC also recommends that research should be conducted to quantify larval fish and crustacean transport and use of inlets prior to any consideration of placement of underwater berms. Until the impacts of berm creation in inlet areas on larval fish and crustacean transport are determined, the SAFMC recommends that disposal activities should be confined to an approved ODMDS. The SAFMC further believes that new offshore and near shore underwater berm creation activities should be reviewed under the most rigorous criteria and on a case-by-case basis.

In the absence of MPRSA and MPPRCA repeal or weakening, major dumping threats to EFH within federal waters should be limited mostly to illegal dumping and accidental disposal of material in unapproved locations. However, many agencies lack sufficient staff and funds to carry out mandated responsibilities and the opportunity for illegal and accidental dumping may be substantial. The effect of insufficient monitoring and enforcement is evident by the tons of debris, sometimes including hazardous materials such as syringes and medical wastes that are deposited along the nation's beaches every year.

As noted in Section 7.4.2.1 the SAFMC has developed Policies for disposal of dredged material in waters under its jurisdiction. With regard to use of ODMDSs, the policy provides that:

- The ODMDS should be designated or re-designated so as to avoid the loss of live or hardbottom habitat and minimize impacts to all living marine resources.
- Notwithstanding the fluid nature of the marine environment, all impacts from the disposal activities should be contained within the designated perimeter of the ODMDS.
- The final designation of the ODMDS should be contingent upon the development of suitable management plans and a demonstrated ability to implement and enforce that plan.
- The Council encourages EPA to press for the implementation of such management plans for all designated ODMDSs.
- All activities within the ODMDS are required to be consistent with the approved management plan for the site. The Council's Habitat and Environmental Protection Advisory Panel when requested by the Council will review such management plans and forward comment to the Council. The Council may review the plans and recommendations received from the advisory sub-panel and comment to the appropriate agency.
- ODMDS management plans should specify those entities/ agencies which may use the ODMDS, such as port authorities, the U.S. Navy, the Corps of Engineers, etc. Other potential users of the ODMDS should be acknowledged and the feasibility of their using the ODMDS site should be assessed in the management plan.
- Feasibility studies of dredge disposal options should acknowledge and incorporate the ODMDS in the larger analysis of dredge disposal sites within an entire basin or project. For example, Corps of Engineers' analyses of existing and potential dredge disposal sites for harbor maintenance projects should incorporate the ODMDS as part of the overall analysis of dredge disposal sites.

6.1.2.3 Marine Debris

One of the more conspicuous byproducts of commercial and recreational boating activities in coastal environments is the discharge of marine debris, trash, and organic wastes into coastal waters, beaches, intertidal flats, and vegetated wetlands. The debris ranges in size from microscopic plastic particles (Carpenter et al. 1972), to mile-long pieces of drift net, discarded plastic bottles, bags, aluminum cans, etc. In laboratory studies, Hoss and Settle (1990) demonstrated that larvae of estuarine-dependent fishes including Atlantic menhaden, spot, mullet, pinfish, and flounder consume polystyrene microspheres. Investigations have also found plastic debris in the guts of adult tuna, striped bass, and dolphin (Manooch 1973; Manooch and Mason 1983). Based on the review of scientific literature on the ingestion of plastics by marine fish, Hoss and Settle (1990) conclude that the problem is pervasive. Most media attention given to marine debris and sea life has focused on threatened and endangered marine mammals and turtles, and on birds. In these cases, the animals become entangled in netting or fishing line, or ingest plastic bags or other materials. Recently, a 35-foot- long sperm whale stranded and died in North Carolina due to ingestion of a plastic float, plastic jugs, a large piece of rubber, 50 feet of nylon rope, and a large plastic bag (D. Engel, personal communication).

The production of plastic resin in the U.S. increased from 6.3 billion lbs in 1960 to 47.9 billion lbs in 1985. The increased production, utilization, and subsequent disposal of petro-chemical compounds known as plastics has created a serious problem of persistent marine debris. Marine ecosystems have, over the years, become the final resting place for a variety of plastics originating from many ocean and land-based sources including the petroleum industry, plastic manufacturing and processing activities, sewage disposal, and littering by the general public and government entities (commercial fishing industry, merchant shipping vessels, the U.S. Navy, passenger ships, and recreational vessels) (Department of Commerce 1988c).

Effective January 1, 1989, the disposal of plastic into the ocean is regulated under the Plastic Pollution Research and Control Act of 1987, implementing MARPOL Annex V. Recognizing worldwide concern for preservation of our oceanic ecosystems, the Act prohibits all vessels, including commercial and recreational fishing vessels, from discharging plastics in U.S. waters and severely limits the discharge of other types of refuse at sea. This legislation also requires ports and terminals receiving these vessels to provide adequate facilities for in-port disposal of non-degradable refuse, as defined in the Act.

The utilization of plastics to replace many items previously made of natural materials in commercial fishing operations has increased dramatically. The unanticipated secondary impact of this widespread use of plastics is the creation of persistent marine debris. Commercial fishing vessels have historically contributed plastics to the marine environment through the common practice of dumping garbage at sea before returning to port and the discarding of spent gear such as lines, traps, nets, buoys, floats, and ropes. Two types of nets are routinely lost or discarded drift gill nets and trawl nets (Department of Commerce 1988c). These nets are durable and may entangle marine mammals and endangered species as they continue to fish or when lost or discarded.

An estimated 16 million recreational boaters utilize the coastal waters of the United States (Department of Commerce 1988c). Disposal of spent fishing gear (e.g. monofilament fishing line), plastic bags, tampon applicators, six pack yokes, styrofoam coolers, cups and beverage containers, etc. is a significant source of plastic entering the marine environment.

In the mid 1970s, the National Academy of Science (NAS) estimated that approximately 14 billion lbs of garbage was disposed of annually into the world's oceans. Approximately 85% of total trash is produced from merchant vessels, with 0.7% of that total, or eight million lbs annually being plastic. The use of plastics has risen dramatically since the NAS study. In 1987, 20% of all food packaging was plastic and by the year 2000 this figure was expected to rise to 40% (CEE 1987).

The main contribution of plastic to the marine environment from cruise ships is the disposal of domestic garbage at sea. Ships operating today carry between 200 and 1,000 passengers and dispose of approximately 62 million lbs of garbage annually, of which a portion is plastics (CEE 1987).

The U.S. Navy operates approximately 600 vessels worldwide, carrying about 285,000 personnel and discharging nearly four tons of plastic refuse into the ocean daily (Department of Commerce 1988a). The U.S. Coast Guard and NOAA operate 226 vessels which carry nearly 9,000 personnel annually and have internal operating orders prohibiting the disposal of plastic at sea. MARPOL Annex V does not apply to public vessels although the Plastic Pollution Research Control Act of 1987 requires all Federal agencies to come into compliance by 1994 (CEE 1987).

6.1.2.4 Offshore Sand and Mineral Mining and Beach Fill

To date, offshore mining for minerals has not been a significant issue in the South Atlantic region (oil and gas mining is discussed separately). However, several pending proposals are under regulatory consideration. Earlier consideration of mining for manganese nodules and removal of useable materials and metals from seawater have not materialized, probably due to market conditions. Recent discovery of large phosphate deposits in waters off North Carolina could eventually lead to requests to mine these deposits. As readily available upland sources of minerals and other materials are depleted, the extraction of marine deposits will become more feasible and likely to occur.

The mining of sand for beach nourishment presents a large, complex, and politically charged threat to EFH in the southeast. Between 1981 and 1996, the NOAA Fisheries Service reviewed more than 200 dredge proposals to nourish beaches. Between 1996 and 2006, NOAA Fisheries Service reviewed an additional 312 dredge proposals to nourish beaches. Most of these projects are large in scope and affect miles of coastline and nearshore habitats. Where sand is removed from nearshore environments, channels, and inlets, additional EFH alteration is possible due to a number of factors such as down drift erosion and removal of materials that eventually nourish shallow waters located behind barrier islands. A survey of 120 of the more than 200 beach nourishment projects received by the NOAA Fisheries Service showed that about 5,735 acres of aquatic sites were subject to excavation and filling.

The Federal Outer Continental Shelf (OCS) contains large sand deposits that MMS anticipates could serve as long-term sources of borrow material for beach nourishment projects. In the last few years, the potential for exploitation of these resources has rapidly grown with identification of suitable sand resource areas in some OCS regions. At the same time, the demand for high quality sand suitable for beach nourishment, coastal protection, and other public and private projects is anticipated to increase during coming years (Hammer et al. 2004). However, the SAFMC is concerned that excavation of the offshore shoals could have significant adverse consequences to the shoreline and living marine resources.

<u>Potential Threats to EFH from Offshore Sand and Mineral Mining</u>
Potential threats include: removal of substrates that provide habitat for fish and invertebrates; creation (or conversion) of habitats to less productive or uninhabitable sites such as anoxic holes or silt bottom; burial of productive habitats in the vicinity of the mine site or in nearshore disposal sites (as in beach nourishment); release of harmful or toxic materials either with actual mining, or in connection with machinery and materials used for mining; creation of harmful turbidity levels; and modification of hydrologic conditions that cause erosion of desirable habitats.

Offshore mining of sand for beach nourishment has steadily increased along the South Atlantic coast. Presently, sand mining and beach nourishment activities are performed along the entire South Atlantic coast from North Carolina to Florida. Major projects include those at Wrightsville Beach, North Carolina; Myrtle Beach and Folly Beach in South Carolina; and many of Florida's beaches such as Palm Beach, Boca Raton, Fort Lauderdale and Miami Beach. Large-scale beach nourishment has also been performed at Tybee Island in Georgia; however, the material for that project was obtained from the Savannah Harbor deepening project. In addition to the larger projects that can involve millions of cubic yards of material, a substantial number of smaller projects involving beach scraping and removal of nearshore and inlet sand deposits are performed annually. While most of the larger projects are publicly funded and performed by the COE, many of these smaller projects are paid for with local revenues and/or private funds.

Although some of the environmental effects of sand mining and beach nourishment are documented there is much that is not known or studied (National Research Council 1995). NOAA Fisheries Service and the FWS began raising questions over related effects as long as twenty years ago. In North Carolina and South Carolina concern over nearshore populations of mole crab (*Emerita talpoida*) and donax (*Donax spp.*) was raised with several projects. Although frequently requested, no long term studies on impacts to these and other beach fauna were ever performed. The fate of these species, from a population perspective, is of concern since they are important food items for transitory and resident fishes (e.g., Florida pompano, kingfishes, and spot) that are of economic and recreational importance (Hackney et al. 1996). Limited studies performed by Reilly and Bellis (1978) showed significant reductions in occurrence and biomass of mole crabs and Donax at nourished beaches. Considering that many miles of southeastern beach front are now filled and/or subjected to scraping and sand relocation each year the cumulative effect of this activity could be substantial. Reviews of numerous beach nourishment projects suggest that the overall infaunal communities recover relatively rapidly (months to less than 1yr) although some species may remain adversely affected (NRC 1995).

Much depends on the compatibility of the material placed on the beach relative to what was present prior to the project.

In Florida, beach nourishment projects require the dredging and filling of millions of cubic yards of fine sediments among shallow cross-shelf habitats, repetition or these activities at 3-10 year intervals, and tens of millions of dollars in annual expenditures (ACOE 1996). A U.S. Fish and Wildlife report (2004) prepared pursuant to Resolution 4 from the 8th Coral Reef Task Force meeting held on October 2-3, 2002, in San Juan, Puerto Rico, concluded that projects involving filling and dredging for beach nourishment and port development have caused the most impacts to coral reef habitats in southeast Florida since 1985. Among mid-shelf sand plains, often having nearby reef habitats, dredges create large craters and increased turbidity. At both dredge and fill sites, acres of shallow water hard bottom, worm reef, seagrass, or other habitats can be directly buried or subjected to elevated turbidity. Nearshore reefs buried or indirectly affected by dredging in south and central Florida can be utilized by over 325 invertebrate species (Nelson 1989), 190 fish species, and serve as nursery habitats for many managed species (Lindeman et al. 2000). The timing of burial and anthropogenic turbidity spikes may have important effects upon the recruitment of settlement-stage fishes and invertebrates. Early spring through early fall dredge related burial of hard bottom may eliminate habitat required by larvae of many marine organisms during peak recruitment periods (Hackney et al. 1996; Lindeman and Snyder 1999).

Based primarily on summary tabulations of data for southeast Florida within ACOE (1996), Lindeman (1997) estimates that:

- At least 47 large-scale offshore dredge and inshore fill projects have occurred since 1960.
- Approximately 97 additional large-scale dredge projects are conservatively planned to occur between 1997 and 2046.
- Over 48,000,000 cubic yards of offshore sediments have been dumped within an intertidal/subtidal corridor of approximately 500 feet x 110 miles in the last 36 years.
- Over 80,000,000 additional cubic yards of excavated offshore material may be dumped within the same corridor of subtropical southeast Florida in the next 50 years.

Long-term estimates of mean turbidity values under natural conditions are not available for most areas. Therefore, the percentages of affected animals and algae that can tolerate repetitious (e.g., 2 to 4 hours to 4 to 6 times a day for three months) sedimentation and elevated turbidity events (that may approximate continuous three-month storms), are unknown. With exception of hurricanes, highly turbid nearshore conditions in southeast Florida are typically the product of winter storms and heavy runoff during the rainy season. Near Miami, Florida turbidity in the nearshore hard bottom habitat is highly variable, and affected by winds, longshore currents, swell condition and upland runoff. Summer-fall months normally show lower turbidity levels of 1-4 NTUs (Nephelometric Turbidity Units) and winter-spring months show higher average levels (3-7 NTUs) (Miami-Dade DERM unpublished). Direct effects of dredging activities on corals have been discussed by Marszalek (1981), Goldberg (1988) and Blair et al. (1990). Although sublethal effects of elevated turbidity are poorly known in tropical marine environments, some information is available. Bak (1978) showed that a relatively short period of dredge-induced turbidity stress created an abrupt decrease in growth in two species of hard corals (*Agaricia* and *Madracis*). From both the magnitude and duration of suppressed calcification, he concluded that such metabolic shock may have long-term consequences on reproduction. Long-term resuspension of bottom sediments has been shown to adversely affect an important hard coral, *Montastrea annularis* (Dodge et al. 1974). Teleniski and Goldberg (1995a; 1995b) have recently demonstrated negative effects of sediment loads on hard corals at turbidity levels of approximately 18 NTUs. This is noteworthy, as the Florida state administrative threshold for temporary shut-downs of dredge operations is substantially higher (29 NTUs). Such work is needed for other taxa and would provide a scientific basis for maximum turbidity thresholds (Goldberg 1988; Teleniski and Goldberg 1995b). Herrnkind et al. (1988) demonstrated that increased siltation can cause direct loss of critical habitat for spiny lobster recruitment. Enhanced resuspension of sediments over time and chronic turbidity may lower key growth and reproduction rates of some algal and invertebrate populations which are a basis for primary and secondary production on an ecosystem scale (Lindeman 1997b). The potential for management decisions to multiply over time and impact unintentionally large spatial scales is of concern (Odum 1982; Rothschild et al. 1994) and is particularly relevant when affected species are also over harvested (Ault et al. in press).

Adopting 15 NTU above background as a threshold level for turbidity in Florida and other areas where waters are naturally not turbid is supported by sound science and appropriate for the following additional reasons:

1. Research associated with investigations by Telesnicki and Goldberg (1995) examined the effects of turbidity measured as an absolute value. In southeast Florida, turbidity standards are based on relative conditions (i.e., above background conditions);
2. We do not have adequate statistical competency to conclude that turbidity monitoring stations would be positioned in a manner that would capture the densest portion of the turbidity plume. Inherent risks associated with this warrant adoption of a more conservative threshold level; and
3. Although elevated turbidity levels may not directly or instantaneously kill corals, construction-induced turbidity may have long-term adverse impacts on corals (e.g., reduced reproductive health) that cannot be detected without carefully designed long-term monitoring.

In other areas of the southeast where waters are more naturally turbid and sensitive bottom fauna such as reef habitat are not present, a higher NTU criteria may be desired. For example, the South Carolina Department of Health and Environmental Control has adopted a threshold of 25 NTU for impaired versus non-impaired estuarine and marine waters. While monitoring of turbidity plumes associated with beach nourishment operations in South Carolina have been limited, Van Dolah et al. (1994) monitored sediment plumes associated with a beach nourishment operation on Folly Beach, South Carolina to determine the both the amount and extent of turbidity. During calm seas, values of about 100NTU were measured in the surf zone at the pipeline outfall. Turbidity levels dropped to less than 50 NTU in the upcurrent direction over a fairly short distance (less than 200 m), and more slowly in the downcurrent direction 500-1000 m. Under more turbulent conditions of strong winds and rough seas, turbidity levels increased to over 200 NTU directly in front of the pipeline and higher turbidities were documented over a larger extent of the beach. However, turbidities in South Carolina’s surf zone are naturally turbid, and turbidity values of about 100NTU were occasionally recorded at a reference beach in the Folly Beach study.

In addition, resource management agencies are examining the value of integrating Acoustic Current Doppler Current Profile (ADCP) technology into water quality monitoring protocols. ADCP is an instrument with capability of collecting acoustic backscatter data through the full depth of the water column and has demonstrated utility in other projects, especially in areas that are characterized by shifting currents (e.g., a project in Long Island Sound in which ADCP was utilized in the turbidity monitoring program in order to accurately locate the plume so that targeted water column sampling could be accomplished). We note that the nature of a plume in open water can be highly variable both spatially and temporally and can be further complicated by winds and seas. Therefore, to overcome these challenges and position the monitoring in the right place at the right time, full depth profiling with ADCP may be essential to the integrity of the monitoring performed. Use of third party environmental inspectors for water quality monitoring has also been included in recent large scale offshore construction project Corps of Engineers permits.

The SAFMC is concerned that excavation of the offshore shoals could have significant adverse consequences to the shoreline and living marine resources. Between 1995 and 2006, the Minerals Management Service (MMS) provided approximately 14 million cubic yards of material from the Outer Continental Shelf (OCS) for 9 coastal projects in Florida (8) and South Carolina (1). Although many offshore shoals have not been thoroughly studied with respect to fish utilization, SAFMC believes the shoals serve as a benthic nursery area, refuge, and feeding ground for a variety of fishery resources. The SAFMC identifies sandy shoals as EFH for migratory pelagic fish, including king mackerel, Spanish mackerel, cobia, and dolphin. Clarke et al. (1988) and Michel et al. (2001) note the geomorphology of offshore shoals provide a unique assembly of micro-habitats that facilitate high biological productivity.

The MMS and Corps of Engineers are evaluating the St. Lucie Shoal (located offshore St. Lucie and Martin Counties, Florida) as a potential excavation site for beach renourishment in Dade and St. Lucie Counties. Anecdotal evidence suggests that the shoal is biologically unique and diverse, supporting fisheries that are economically and recreationally important, such as the migratory species listed above, sailfish, and prey species consumed by these fishery species.

In South Carolina, a survey of multiple sites dredged for beach nourishment purposes identified that most sites were slow to refill (average of 7 yrs among 5 sites) and generally refilled with non-beach compatible material (Van Dolah et al. 1998).

The SAFMC is concerned that mining shoals for sand may alter the local wave climate bringing about erosion that could affect EFH. Through an evaluation of the potential impacts from dredging linear shoals in the U.S. Gulf and Atlantic continental shelves, Hayes and Nairn (2004) concluded that the deflation of a shoal feature could change wave patterns between the shoal and the shoreline. In turn, such dredging could change longshore and cross-shore sand-transport patterns and erosion and accretion rates along the shore. Kelley et al. (2004) verified this conclusion in their examination of a borrow site offshore Martin County (depths were approximately 8 to 10 m), and recommend application of wave transformation numerical modeling tools that recognize the random nature of incident waves as they propagate onshore when examining incremental and cumulative changes from sand dredging on the continental shelf.

Furthermore, the SAFMC is concerned that excavation of nearshore borrow areas in addition to the placement of fill in nearshore areas could adversely affect hardbottom reefs in the area that are known to support corals and worm reefs colonized by *Phragmatopoma lapidosa*. Nearshore hardbottoms and worm reefs are also identified as EFH and HAPC by the SAFMC. These reefs reduce wave energy and stabilize shorelines (Kirtley 1967; Kirtley and Tanner 1968) and provide structural habitat for hundreds of fishery organisms (Gore et al. 1977; Nelson 1989; Lindeman and Snyder 1999). Avoidance and minimization of impacts to hardbottom resources is needed. Due to the importance of these concerns, SAFMC recommends that MMS and the COE continue to coordinate closely with the NOAA Fisheries Service Habitat Conservation Division to ensure the EFH assessments and NEPA documents contain sufficient detail to support federal decision making.

Other offshore mineral and mining does not presently occur along the South Atlantic coast. Extensive phosphate deposits have been located in Onslow Bay in North Carolina and large quantities of mineral nodules containing manganese and other metals are abundant along the continental shelf floor. It is reasonable to conclude that mining of these and other materials could become economically feasible. If initiated, mining of marine bottoms would cause substantial bottom disturbance that could impact productive hard bottom communities, shellfish beds, and wintering grounds for demersal fish. Since related port and processing facilities do not presently exist, new mooring and dockside facilities would be needed and related secondary impacts would be expected. These impacts are discussed in detail in Section 7.4.2.1 of this document.

6.1.2.5 Oil and Gas Exploration, Development, and Transportation

Extensive areas of the South Atlantic have been designated and blocked off for oil and gas development. Prior to 2003, this activity had been relatively dormant, unlike the pipelines and liquefied natural gas (LNG) facilities that proliferate in the Gulf of Mexico. Initial exploration in the vicinity of Cape Hatteras several years ago did not advance due to environmental and other concerns including consistency issues associated with North Carolina's Coastal Zone Management Program. As of this writing, interest in the potential for renewed oil and gas exploration off North Carolina is again being considered. Environmental Impact Statements have been prepared for Mid-Atlantic Sale 121 and South Atlantic Sale for the exploration of oil and gas offshore of Cape Hatteras, North Carolina. Should gas or oil be found, the laying of pipe to North Carolina's shoreline facilities would likely have to traverse barrier islands and associated wetlands. As oil and gas levels decline, exploration will undoubtedly resume and if economically viable reserves are located, this activity could expand and inshore and offshore EFH could be at risk.

There are currently three natural gas pipeline proposals in Florida that propose to construct pipelines from the Bahamas to southeast Florida. Between 1996 and 2006, NOAA Fisheries Service reviewed 548 applications and support documents associated with pipelines in the South

Atlantic area. The NOAA Fisheries Service Southeast Region Habitat Conservation Division (HCD) office is engaged in three separate EFH consultations for natural gas pipeline projects proposed to be constructed from southeast Florida to the Bahamas. One of three projects (AES Ocean Express) has received Department of the Army (DA) authorization and a Federal Energy Regulatory Commission (FERC) license to proceed with construction. However, to our knowledge, all of these projects are still awaiting the necessary approvals from the Bahamian government.

One pipeline company (Calypso), recently filed an application with the U.S. Coast Guard to construct a deepwater port located approximately 5 to 10 off the eastern coast of Florida to the northeast of Port Everglades in a water depth of approximately 640 to 950 feet.

<u>Potential Threats to EFH from Oil and Gas Exploration, Development, and Transportation</u>
Potential threats include elimination or damage to bottom habitat due to drill holes and positioning of structures such as drilling platforms, pipelines, anchors, etc., water intake and impacts to ichthyoplankton, release of harmful and toxic substances form extracted muds, oil, and, gas and from materials used in oil and gas recovery; discharges of potentially large volumes of drilling fluids (muds) used during the well drilling process and produced (brine) water from the extraction phase; damage to organisms and habitats due to accidental spills; damage to fishing gear due to entanglement with structures and debris; and damage to fishery resources and habitats including deep water habitats, due to anchoring and effects of blasting (used in platform support removal); and indirect and secondary impacts to nearshore aquatic environments affected by product receiving, processing, and distribution facilities.

The various threats to EFH that would result from natural gas pipeline installation and construction depend on project location and construction methods proposed. Horizontal directional drilling was one of the primary nearshore construction methods evaluated, but eventually ruled out due to concerns that pertain to frac-outs, which are generally caused when the drill head moves through an area of unconsolidated sediments. Frac-outs are typically monitored through monitoring the hydrostatic pressure differential. Considering that frac-outs can occur anywhere along or near the pipeline route, pressure monitoring alone was not sufficient in areas that support reef. Frac-outs can occur as a slight release of mud or an uncontrolled flow of drilling muds.

According to Stauber et al. (2003), with sufficient geotechnical information it is possible to calculate a maximum allowable borehole pressure curve for a given HDD bore profile. Using this information, preliminary bore plans could be developed that provide reasonable assurance that the bore could be completed without incident. Therefore, SAFMC recommends that pipeline applications include an HDD Risk Analysis to ensure that the bore paths identified are the least likely to contribute to a frac-out.

Other threats to EFH could occur as a result of offshore dredging of exit pits and direct burial of resources through the pipeline placement, movement, and/or articulated concrete mats which are typically proposed for use in water depths of less than 200 feet for pipeline stabilization. In addition, drilling muds and the use of additives, such as Envis (a mixed metal hydroxide) or StaFlo (a polyanionic cellulose) are commonly used during drilling operations to control drilling mud flow and fluid loss. Another potential threat is hydrostatic testing which is typically proposed to verify that the pipeline was properly installed and structurally sound. Chemicals may be proposed for use in hydrostatic testing and can include corrosion inhibitors, biocides, oxygen scavengers, and leak detection dye that would be used for pipe treatment and as seawater additives.

Another nearshore construction approach involves tunneling, which is preferred over HDD but has not been tested yet in nearshore areas of southeast Florida. Tunneling poses less risk to the marine environment because it may be possible to conduct operations independent of weather and it reduces or eliminates the risk of frac-outs because the operation is conducted under much less pressure and at greater depths. However other issues are still being evaluated, such as the potential for localized slumping or heave, tunnel failure, a higher probability of a frac-out near the tunnel exit location, and hydrostatic testing, as mentioned above.

To date, only one deepwater LNG port has been proposed in the South Atlantic. However, the Federal Energy Regulatory Commission has received three applications (including Calypso) to construct pipelines from southeast Florida to the Bahamas. To date, none of the applications has received approval from the Bahamian government to construct regassification facilities. Therefore, SAFMC is concerned about the potential for multiple deepwater ports to be proposed offshore southeast and east-central Florida.
The September 2006 Calypso application states that approximately 273 acres of deepwater habitats could be impacted as a result of anchoring activities. Benthic organisms may be adversely affected from direct crushing and disturbance of sediments in the immediate vicinity of the anchors. The Calypso LNG terminal is proposed to be located on or adjacent to the Miami Terrace, which is a proposed deepwater coral HAPC. Hardbottom and coral resources found along the Miami Terrace and Escarpment are identified as EFH and HAPC by the SAFMC. Reed et al. (2006) characterized the fauna on the Miami Terrace and Escarpment as consisting of gorgonacean octocorals, colonial scleractinian corals (including thickets of *Lophelia pertusa*, *Madrepora oculata*, and *Enallopsammia profunda*), stylasterine hydrocorals, and Antipatharia. Diverse populations of the sponges Hexactinellida and Demospongia also occur along the Miami Terrace and Escarpment. In addition, based on studies conducted for the Calypso Pipeline Final Environmental Impact Statement, side-scan sonar results from the area show highly reflective signatures, which suggests the substrate is hardbottom mixed with medium carbonate sands and silty sands.

Unlike the open loop LNG facilities proposed and in operation in the Gulf of Mexico, the Calypso LNG facility is proposed to be a closed loop system (it should be noted, however, that Calypso could have chosen to use open loop regasification technologies and, given cost considerations, so might any other LNG company that looks at the Atlantic coast off Florida). Open loop systems use seawater for the regasification of LNG and water intakes can exceed 100 million gallons of water per day. However water intake associated with closed loop systems is only for engine cooling and can range from approximately 30-60 million gallons per day depending on the number, type, and duration of vessels at Port. With the closed loop system proposed in the South Atlantic, the discharge water would be approximately 13 degrees Fahrenheit warmer than the intake water.

Applications for LNG facilities should adequately consider potential impacts to fishery resources and the project's proximity to the Gulf Stream. The conditions and flow of the Gulf Stream are variable on time scales ranging from two days to entire seasons. Important spawning locations can occur along the Gulf Stream front (e.g., *Coryphaena, Xiphius*) (SAFMC 1998). Movement of the Gulf Stream front also affects the distribution of adult fishes (Magnuson et al. 1981); hook-and-line fishermen and longliners target much of their fishing effort in these frontal zones.

Biological and economic analyses of impacts related to impingement and entrainment of the various life stage histories of fishery resources are needed to allow the SAFMC, public, and NOAA to assess the costs of lost fisheries production from the water intake/discharge component of the Calypso LNG deepwater port. Such examinations should include detailed comparisons of the environmental impacts and environmental costs of alternative closed-loop regasification technologies to understand more fully the potential impacts to fishery resources. Analyses should be based on an assumption of 100% zooplankton mortality that would result from water intake, unless the applicant can show applicable studies demonstrating otherwise. In addition, surveys of the ichthyoplankton communities within project areas are needed because in many areas, including water off Fort Lauderdale, there are no site-specific data regarding ichthyoplankton resources. Such surveys should be designed to provide a quantitative assessment of the impacts to fishery resources. In addition, the surveys should be designed to support the monitoring of impacts from port operations on fishery resources so that adjustments to those operations can be made in a timely manner. Although the continental shelf of the South Atlantic Bight has been the focus of moderate interest for exploration of oil and gas resources, there are presently no ongoing related activities in the region with exception of that mentioned above.

In addition to what is presented above and considering the current status of the industry, a brief overview of the facilities that might be emplaced on the Outer Continental Shelf (OCS) to facilitate oil and gas exploration, development, and production is also presented. This includes drilling vessels (jack-ups, semi-submersibles, and drill ships), production platforms, offshore moored terminals, and pipelines.

Oil and gas related activities are inherently intrusive and pose a considerable level of threat to marine and estuarine ecosystems, including EFH. As discussed below, exploration and recovery operations may cause substantial localized bottom disturbance. Where large scale development is undertaken the area of impact may be greatly expanded and become regional in scale. The toxic nature of hydrocarbon products and certain drilling materials (e.g., drilling muds), spill cleanup chemicals, and the large volume of unrefined and refined products that must be moved within the coastal zone places large areas and resource bases as risk.

Structure emplacement can be expected to disturb some bottom area and, if anchors are deployed, the area of disturbance could be expanded. Jack-up rigs and semi-submersibles are generally used in water depths not exceeding 400 meters and disturb about 1.5 ha (3.7 ac) of bottom each. Conventional fixed platforms are also employed where water depths are less than 400 meters and they disturb about 2 ha (4.9 ac). Where water depths exceed 400 meters, dynamically-positioned drill ships may be used and sea floor disturbance is usually limited to the well site. Tension leg platforms may also be employed at these depths and the potential bottom disturbance area associated with these structures is about 5 ha (10.25 ac).

Each exploration rig, platform, terminal, and pipeline emplacement on the OCS can be expected to disturb surrounding areas. Exploration rigs, platforms, and pipe laying barges use an array of eight 9,000 kg anchors to position a rig and barge, and to move the barge along the pipeline route. These anchors are continually moved as the pipe laying operation proceeds and the total area actually affected by the anchors will depend on water depth, wind, currents, anchor chain length, and the size of the anchors and chain (MMS 1996). With conventional, fixed multi-leg platforms, which are anchored to the sea floor by steel pilings, explosives are generally used to sever conductors and pilings. These support structures are substantial in size since they must withstand hurricane conditions and have an average lifespan of about 20 years. The Minerals Management Service requires severing support structures at five meters below the sea floor surface so as to preclude interference with commercial fishing operations.

Possible injury to biota from use of explosives extends horizontally to 900 meters from the detonation site, and vertically to the surface. Based on MMS data, it is assumed that approximately 80% of removals of conventional fixed platforms in the Gulf of Mexico, in water less than 400 meters in depth, will be performed with explosives (MMS 1996). Alternative methodologies such as mechanical cutting and inside burning are often ineffective and are hazardous to workers.

Associated bottom debris commonly associated with over water oil and gas operations includes cable, tools, pipe, drums, assorted trash, and structural parts of platforms. The amount of bottom debris deposited around a site may vary and may be measured in tons. Extensive analysis of remotely-sensed data within developed lease blocks indicates that the majority of ferromagnetic bottom debris falls within a 450 meter radius of the site. The Fisherman's Contingency Fund, which was established by the oil and gas industry, provides recourse to commercial fishing interests for recovery of equipment losses due to shrimp net entanglement (MMS 1996).

Blowouts occur when improperly balanced well pressures result in sudden, uncontrolled releases of petroleum hydrocarbons. Blowouts can occur during any phase of development: exploratory drilling, development drilling, production, or workover operations. About 23% of all blowouts will have associated oil spills, of which 8% will result in oil spills greater than 50 barrels, and 4% will result in spills greater than 1000 barrels. In subsurface blowouts, sediment will be resuspended and bottom disturbance will generally occur within a 300 meter radius. Whereas larger grain sediment will settle first, fined grained material may remain in suspension for periods of up to thirty days or longer. Fine grained material may be redistributed over a significantly large area depending on the volume of sediment disturbed, bottom morphology, and currents (MMS 1996).

The major operational wastes associated with offshore oil and gas exploration and development include drilling fluids and cuttings, and produced waters. Other important wastes include: from drilling--waste chemicals, fracturing and acidifying fluids, and well completion and workover fluids; from production--produced sand, deck drainage, and miscellaneous well fluids; and from other sources--sanitary and domestic wastes, gas and oil processing wastes, ballast water, storage displacement water, and miscellaneous minor discharges (MMS 1996). Major contaminants or chemical properties of materials used in oil and gas operations may include those that are highly saline; have a low ph.; contain suspended solids, heavy metals, crude oil compounds, organic acids, priority pollutants, and radionuclides; and those which generate high biological and chemical oxygen demands. Pierce et al. (1980) documented that wild fish have been injured by petroleum pollutants. Grizzle (1983) suggested that larger liver weights in fish collected in the vicinity of production platforms versus control reefs could have been caused by increased toxicant levels near the platforms. He also suspected that severe gill lamella epithelium hyperplasia and edema in red snapper, vermilion snapper, wenchman, sash flounder, and creole fish were caused by toxicants near the platforms. These types of lesions are consistent with toxicosis.

Accidental discharge of oil can occur during almost any stage of exploration, development, or production on the OCS or in near shore base areas. Oil spills may result from many possible causes including equipment malfunction, ship collisions, pipeline breaks, human error, or severe storms. Oil spills may also be attributed to support activities associated with product recovery and transportation. In addition to crude oil spills, chemical, diesel, and other oil-product spills can occur with OCS activities. Of the various potential OCS-related spill sources, the great majority are associated with product transportation activities (MMS 1996).

As of this writing, only test wells have been drilled in the South Atlantic Bight area and these have been confined to inshore areas. All of these wells were capped immediately after drilling. No production or transportation facilities such as offshore terminals and pipelines have been built, nor are any such facilities currently planned in South Atlantic Bight waters. Despite this, millions of barrels of crude oil and refined product transit South Atlantic Bight waters by tank vessel every year and the potential exists for the discharge of thousands of barrels of oil due to vessel collision or sinking. Discharge of untreated ballast water from transiting vessels is also a chronic low level source of petroleum-based pollution.

6.1.2.6 Commercial and Industrial Activities

Direct physical encroachment into offshore environments by industrial activities is relatively limited along the South Atlantic seaboard. Notable exceptions include thermal intake and outfall structures associated with power plants in North Carolina and Florida, and sea walls that are used to protect commercial and industrial development. Several municipal sewage outfalls which discharge commercial and possibly light industrial wastes also exist. Although direct physical impacts may be minor on a regional scale, water quality effects are largely unknown. Indirect effects, such as those associated with point and nonpoint-source discharges are thought to be substantially greater since it has been shown that discharges, including trash and debris, from land based activities may reach coastal waters and food webs.

Commercial development for hotels, motels, and related infrastructure along the South Atlantic shoreline has been extensive. Because many of these developments are located on unstable and shifting coastlines, maintaining associated buildings, revetments, bridges, causeways, beaches etc. has, and will continue to have an adverse effect on nearshore and offshore processes and environments.

Potential Threats to EFH from Commercial and Industrial Activities

Potential threats include: direct and/or non-point-source discharge of chemicals, placement of intake structures, and protective sea walls (often used in connection with commercial establishments), and cumulative and synergistic effects caused by these and other industrial and non-industrial related activities.

Future exploration and recovery of marine resources and placement of offshore mooring and unloading facilities could substantially threaten offshore EFHs. Although none of these activities or facilities are presently being planned, it is likely that continued economic growth, depletion of limited natural resources, and use of limited coastal lands will eventually lead to greater exploitation of offshore resources.

Electric power generation is needed for commercial and industrial development, and for residential purposes (See Section 4.1.1.4). Between 1996 and 2006, NOAA Fisheries Service evaluated 85 proposals to construct new or expand existing electric generation facilities. When located in coastal waters, power generation facilities may adversely affect EFH and associated biota. Potential threats include direct displacement of wetlands, submerged bottoms, and vegetated upland buffer areas for generation facilities and ancillary uses such as fossil fuel storage, cooling towers, and water intake and outfall structures; construction of navigation channels and docks for unloading coal, oil, and other materials needed for operation of generators and equipment; discharge of toxic substances from air emissions; cooling waters (e.g., chlorine); and from point and nonpoint-source discharges emanating from impervious surfaces and coal and slag piles; discharge of thermal discharges that may be lethal to flora and fauna, or that serve as attractants that subject fish, invertebrates, and marine mammals to thermal stress when changes in plant operation or weather occur; and entrainment and impingement of living marine resources in which organisms succumb to or are damaged as a result of entrapment in intake structures or capture on screens.

An example of an electric power generation plant and threats to EFH is the Florida Power and Light's Turkey Point Power Plant, located along Biscayne Bay in Dade County Florida, which directly impacted over 24 acres of estuarine emergent wetlands, including mangrove wetlands, seagrass, and open water habitat in order to construct a natural gas-fired electric generating facility to provide electricity to meet the projected 2007 demand in southeast Florida. An additional 10.7 acres of wetlands were impacted through secondary effects. The wetlands at the subject site are high quality, uncommon, and provide direct benefits to the fishery resources of Biscayne Bay. The bay's extensive seagrass beds, mangrove wetlands, and hardbottom communities support a diverse array of fishes and invertebrates including over 512 species of fishes and over 800 species of invertebrates which have widely variable environmental requirements for growth and reproduction.

Although relatively minor in its present scale, the commercial harvest of *Sargassum* from coastal waters off North Carolina is of concern. *Sargassum* weed lines and associated frontal zones provide cover, trophic, and other attributes needed to sustain endemic fish and invertebrates of the pelagic *Sargassum* community and associated fauna. The weed lines may be especially important during early life stages of sea turtles and certain fish and they are important sites for the North Carolina and South Carolina offshore recreational fishery.

The occurrence of methyl mercury in the flesh of the large piscivorous fish such as king and Spanish mackerel and other large pelagic and demersal species such as amberjack, wahoo, snapper, and grouper has been documented and is of concern largely with respect to human consumption of these species (D. Engel, personal communication). The probable source of these contaminants is atmospheric input from worldwide inventories associated with emissions from incinerators, fossil fueled power plants, automobiles, and industry. As such, the regulation of surface water contamination from atmospheric pollution may require local, regional, and international efforts.

Effects related to commercial development are similar to those from urban and suburban development and the discussions in Section 4.1.1.4 apply. Further, effects of shoreline modifications such as beach nourishment are found in Section 4.1.2.3.

6.1.2.7 Artificial Reefs

Artificial reef construction in the South Atlantic has substantially increased over the last 10 years. Project scales range from single family homeowners applying to place reef balls under docks for lobster recruitment to 3,000 acre areas located in offshore areas. Project applications typically state that the purpose of the project is to "further develop three artificial reef sites to increase the marine flora and fauna within the area for local fishermen and SCUBA divers without detriment to the existing reef structures or fish populations." However, artificial reefs are also constructed to replace natural reef habitats. Construction at the larger scale sited typically involves the placement of a variety of materials including concrete, limestone boulders, submerged vessels, and other approved items.

Potential Threats to EFH from Artificial Reefs

Potential threats to EFH include permanent conversion of one habitat type to another, introduction of predators, possible increased fishing activity and relic gear on structures.

Although the SAFMC recognizes and appreciates applicant's efforts to provide additional marine habitat, information regarding the level of impact this project would have on EFH resources is needed in the application process. This information need includes a thorough assessment of environmental impacts and details concerning its design and specifications.
The type of information that should be contained in an artificial reef application includes:

- It should be demonstrated that the project will provide enhanced marine fisheries habitat. This may be achieved through (but not limited to):
    - Identifying the specific fisheries and life history stages that will be enhanced by the proposed work.
    - Demonstrating a clear link between the structural design and the fisheries the artificial reef will support.

- The applicant should demonstrate full consistency with NOAA's *National Artificial Reef Plan* (1985) and the draft plan revision (2001)[1], including, but not limited to, the following provisions:
    - Demonstrated consistency with the applicable state's artificial reef plan (e.g., the State of Florida's Artificial Reef Plan). Through this, the applicant should:
    - Have a specific objective for fisheries management or other purpose stated in the goal of the statewide, or site-specific plan;
    - Have biological justification relating to present and future fishery management needs;
    - Have minimal negative effects on existing fisheries, and/or conflicts with other uses;
    - Have minimal negative effects on other natural resources and their future use;
    - Use materials that have long-term compatibility with the aquatic environment;
    - Conduct monitoring during and after construction to determine whether the reef meets permit terms and conditions and is functioning as anticipated.
- The applicant should ensure that the proposed artificial reef structure will not threaten the integrity of natural habitats in the area, including live/hardbottoms, corals, seagrasses, and macroalgae;
- The application should verify that any vessels deployed have been cleaned in accordance with Environmental Protection Agency Guidelines;
- The constructed reef should remain stable during a 100-year storm event;
- The applicant should identify the most extreme sea state and wave surge conditions under which work will be undertaken; and
- An entity should be identified to demonstrate the capability of assuming long-term financial liability for the deployment, biological and stability monitoring, and maintenance of the artificial reef.

Artificial reefs can serve as effective fishery management tools (when coupled with additional fishery management measures, for example the designation of no-take zones) to attract fish and, in some situations, mitigate for anthropogenic and natural damage to coral and hardbottom reefs. The SAFMC concurs with the leading artificial reef researchers in this region (see Bohnsack 1989) that artificial reefs are unlikely to benefit heavily exploited or overfished populations without other management actions. Conversely, if not properly sited they may have only minimal habitat value and could even degrade existing reef resources if placed on or in close proximity to such habitats. Artificial reefs are also constructed as mitigation reefs. A U.S. Fish and Wildlife report (2004) prepared pursuant to Resolution 4 from the 8th Coral Reef Task Force meeting held on October 2-3, 2002, in San Juan, Puerto Rico, concluded that projects involving filling and dredging for beach nourishment and port development have caused the most impacts to coral reef habitats in southeast Florida since 1985. The 26 Florida projects (16 completed; 10 pending) reviewed in this report impacted 217 acres of reef, and mitigated with 113 acres of artificial reef. However, a study is needed that would provide information as to impacts to hard bottom communities of shoreline projects, including whether proposed mitigations are adequate to offset the environmental impacts of the activities. General practice in Florida is to permit

[1] National Artificial Reef Plan (revised 2001). National Marine Fisheries Service. Available on-line at: http://www.nmfs.noaa.gov/irf/Revised_PLAN_11_16.pdf

mitigation for shallow hard bottom communities in deeper waters is contributing to a substantial net loss of the shallow communities and related functions.

6.1.2.8 Alternative Energy Technologies

Sections below excerpted from MMS Alternative Energy Synthesis report: Michel, J., Dunagan, H., Boring, C., Healy, E., Evans, W., Dean, J.M., McGillis, A. and Hain, J. 2007. Worldwide Synthesis and Analysis of Existing Information Regarding Environmental Effects of Alternative Energy Uses on the Outer Continental Shelf. U.S. Department of the Interior, Minerals Management Service, Herndon, VA, MMS OCS Report 2007-038. 254 pp. <u>See Report for references in following sections.</u>

Offshore wind turbines

An offshore wind farm is a set of turbines that generate electricity from the mechanical force that the wind imparts upon an object and are specifically designed for their oceanic location. Each modern oceanic turbine is capable of producing up to 4.5 megawatts of power (some older turbines installed in the 1990s produced less than 1 megawatt, newer turbines under development may produce 5 to 10 megawatts), and the hub of the turbine is 180 feet or more above the sea surface. Present proposals include systems with blades that will reach more than 510 feet above the sea surface. The number of turbines in a farm varies and will be affected by economics, space, and demand for the electricity generated. The number of turbines in proposed farms ranges from three units in a proposed research setting to over 150. The turbines need to be separated from each other by a distance of 0.25 mile or more in order to reduce the effect one turbine has upon the wind field experienced by adjacent turbines. Wind farms include a distribution platform that serves as a hub for the cables that collect power from each turbine and the fewer, but larger, cables that carry the power to shore.

A recent study conducted by the Minerals Management Service (MMS 2007) cites the following as the current primary economic and technical feasibility determinants that affect the choice of sites for offshore wind parks:

- Availability of a substantial, relatively constant wind resource
- Shallow water (less than 30 meters deep)
- Proximity to an area of high electricity consumption
- Distance to shore

Water depth is a critical design element that currently limits installation in deeper waters because of technology and economic constraints. Existing wind parks in Europe are installed in very shallow water (up to 15 m deep). Most North American wind resources are in water greater than 30 m deep, requiring development of economically feasible new technologies for wind turbine structures that can withstand wave and wind action in deeper areas (MMS 2007).

In addition to the water depth limitations of technology as of 2007, significant economic concerns are associated with the distance from shore and the length of subsea electrical cable required to reach the onshore electrical grid. Although available wind turbine designs allow installation in waters less than 30 m deep, wind parks operating in Europe are in shallower coastal areas (water depths of approximately 15 m). In the United States, wind parks are likely to be developed along the Atlantic seaboard and the Gulf of Mexico (MMS 2007).

The Cape Wind project offshore of Massachusetts and the Long Island Offshore Wind Park (LIOWP) offshore New York are in the environmental impact statement (EIS) stage, and other projects are planned along the northern and central U.S. coast. In addition, two leases have been granted by the State of Texas to develop wind parks off the coastline of Padre Island and Galveston Island. Additional projects are in the early planning stages along the U.S. east coast and Gulf of Mexico (MMS 2007).

<u>Potential threats to EFH from Offshore Wind Turbines</u>
Operational characteristics of each turbine design and its size are influenced by the minimum sustained winds occurring in an area and needed to make the wind farm profitable. Studies from the northeastern U.S. conclude a minimum wind speed of 16 mph or more is needed, studies from the southeastern U.S. conclude wind speeds of 11 to 13 mph are sufficient (Stewart 2005). Analyses are not simple; wind persistence, direction and natural turbulence can limit a turbine's ability to produce electricity even though its blades are spinning. Analyses must also consider the efficiency of the turbines and the number of days in a year when the wind reaches or exceeds the minimum speed required to produce electricity. Other factors that influence the feasibility of establishing a wind farm include proximity to an established electrical grid and water depth, because market availability and water depth affect construction cost. Some authorities suggest 180 feet is a maximum depth; developers of the wind farm off Cape Cod, MA, actively sought waters less than 50 feet deep. Lloyd's Insurance has set 12 fathoms as their insurance risk limit. The occurrences of high winds are an issue since they can damage the turbine systems. Wind speeds that cause the blades to rotate above 14 revolutions per minute trigger most systems to shutdown.

In the United States, there are no offshore wind farms in operation, although six projects are currently being considered (Dennehey 2006; Ludwig 2006). Two are off the coast of Cape Cod, MA, two of the coast of Texas, one off the coast of Long Island, NY, and one is being considered off the Pacific Northwest Coast. Evaluations of the general environment off North Carolina and Georgia by universities conclude that wind farms warrant further investigation in these areas (Halks et al. 2005; Stewart 2005). Offshore wind farms have been established in Europe, especially in Denmark, and business forecasts indicate additional farms are likely due to tax and business incentives that focus on renewable energy (Danish Energy Authority 2005, see also http://home.planet.nl/~windsh/offshoreplans.html).

There are three general designs currently in use for anchoring turbines to the sea bottom, and the design chosen affects the extent of the environmental impacts (Danish Energy Authority 2005). A gravity foundation uses a large base (much broader than the pylon) with supplemental mass being placed on the base structure to anchor the pylon on the seafloor. A monopile base is a piling driven deep into the sea floor to create the stable anchor and is similar in diameter to the pylon itself; monopiles are currently used in water depths up to 60 feet. Multi-pole bases consist of piling systems similar to those used in small offshore oil and gas platforms; pilings are driven into the sea bottom over an area that is broader than the pylon that supports the turbine and the pylon is attached to a framework and platform that links the pilings. When commenting on a proposal by Cape Wind Associates for a wind farm on Nantucket Sound, MA, NOAA Fisheries Service indicated a preference for the 46-ft diameter, monopole design because it impacts less sea bottom and fishing gear is less likely to snag on this type of structure. Research being done in Europe is examining the feasibility of floating foundations and hybrids between monopile and gravity foundations that will allow farms to be located in deeper water without requiring a foundation that occupies a large amount of sea bottom. One of the wind farms proposed for New York plans to investigate the stability of a jack-up barge as its base, and the wind farms proposed for Texas are exploring use of oil and gas platforms that are no longer needed by the petroleum industry.

Long-term impacts to coastal ecosystems from wind farms are unclear because only a few offshore wind farms have existed for more than 10 years. However, all the wind farms recently constructed or authorized in Europe include substantial monitoring programs, so lack of data should not remain a problem for long. U.S. Army Corps of Engineers (2004) and the Danish Energy Authority (2005) provide initial lists and summaries of the impacts that can be expected from an offshore wind farm and the latter also provides Internet links to Web sites planned for distributing future study results.

Direct impacts to coastal ecosystems include usurpation of seafloor habitat(s) by the pilings, distribution platforms, and cables that connect the turbines to the onshore power grid. Especially when the monopile design is used, the cumulative area impacted is small; for example, Cape Winds Associates estimates the pylons from their farm of 130 turbines would occupy less than one acre of sea bottom. Construction equipment impacts during cable and system installations would add to this acreage. Direct effects to the sea bottom also may occur from alteration of current fields moving past the foundations, but these impacts to be manageable in most circumstances.

The most obvious affect of the pilings on marine biota will be from the structures serving as fish habitat. Many fish are attracted to any structure that provides relief from the otherwise featureless sea floor. Benthic organisms, which may adhere to a pylon or its base, depending on local conditions and construction materials, may add to the attractiveness of the structure to fish. Although unlikely to be an issue, there is some concern that electromagnetic fields (EMF) may disrupt the movements of sharks and other aquatic resources that navigate by sensing the earth's electromagnetic fields. Wind farms can transmit direct current, which has a greater capacity than alternating current to create localized EMF. Recent research indicates the severity of this impact may be small. Vibrations transmitted from the structures and systems to the water column and affecting the behavior of fish is a concern but not much is known about the severity of this impact. Monitoring in Europe has not found evidence of either EMF or vibration impacting aquatic resources (Ludwig 2006). Indirect impacts to marine biota may result from wind farms shifting navigation away from preferred routes into areas where marine mammals or fishery resources are more concentrated. The Federal Aviation Administration and military have recently identified that wind farms create a shadow effect on near ground, tracking radars.

Socioeconomic impacts have been controversial. Many members of the public object to the expected deteriorations in the vistas caused by the wind farms as well as wind farms occupying preferred fishing grounds. However, the Europeans have experienced a sharp increase in ecotourism at their wind farm sites. The public also has been focused on impacts to seabirds, although impacts to birds seem uncommon based on preliminary evidence (Danish Energy Authority 2005).

Ocean current technology

(Excerpted from MMS 2007 report)
Ocean current technology is similar to wind technology, only underwater. Instead of wind, ocean current pushes turbine blades to transfer kinetic energy. Similar to wind turbines, the blades of the current turbines move at a very slow speed. For example, one type of design has vertical turbine rotors that rotate 10 to 30 revolutions per minute, which is approximately 10 times slower than ship propellers. Although the rotors move slowly, they produce a significant amount of energy because of the density of water moving them.

In the United States, no operating commercial systems using ocean current technology are connected to an electrical grid at this time (MMS 2006). However, the technology to harness ocean current energy as an alternative energy source is in the developmental stage. Demonstration and pilot studies of different prototypes are taking place throughout the world. Marine current velocities are lower than those of wind, but because water is 835 times denser than air, a 3-knot current has the kinetic energy of 161 km/h wind. The total potential energy contained in marine currents worldwide is estimated at approximately 5,000 GW (MMS 2006).

Available data indicate that current velocities between 2 and 5 meters per second (m/s) would be required to make ocean current energy technology economically viable at a particular site (MMS 2006).

In the United States, the most promising sources of ocean current energy include the Florida Current (part of the Gulf Stream) and the California Current (MMS 2006). These ocean current resources are located relatively close to shore and near centers of high electricity demand, making ocean current energy an attractive resource. In addition, ocean currents tend to be significantly more constant than wind resources, which can fluctuate greatly over relatively short periods of time.

A number of turbine designs exist, some of which have been through field testing while others are still in the development phase (MMS 2007). Florida Hydro is testing a disk-like design called the Open Center Turbine for use in the Florida Current (**Figure 6.1-1**).The moving parts of this technology are encased within the unit. Designed to produce 2.5 MW, the turbine was tested off Palm Beach, FL.

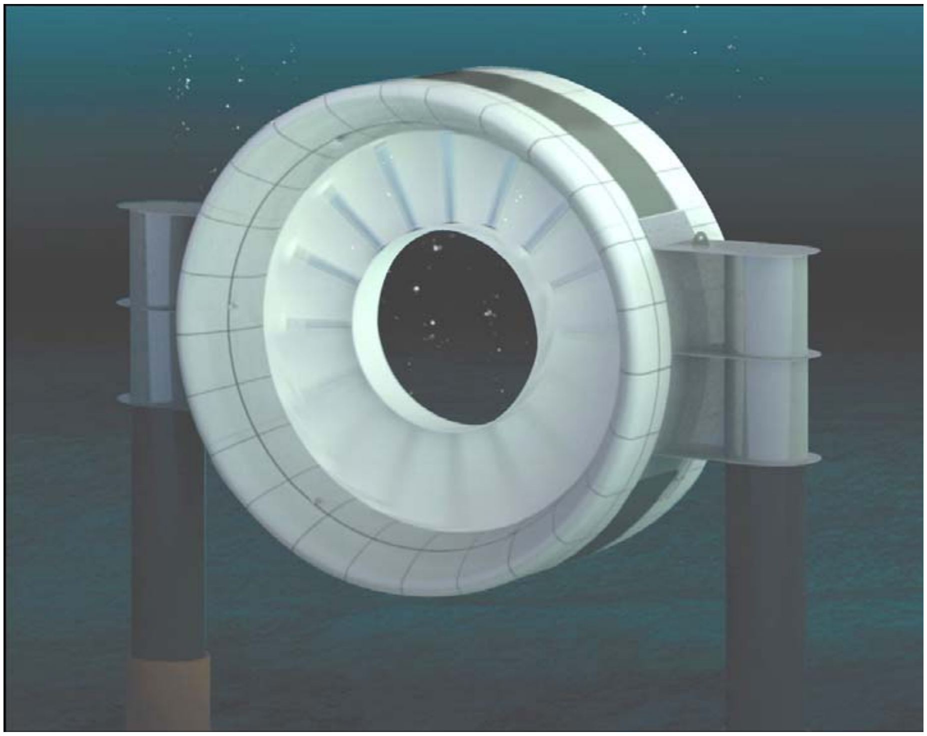

Figure 6.1-1. Open center current/tidal turbine with encased moving parts (Source: Open Hydro Group Limited).

Several other ocean current technologies are being developed. Those designs are tethered to the seabottom using anchors or on poles that extend from seabed foundations (ABP, 2004). These technologies are in the very early stages of development; however, they may be the most promising design for deeper, offshore applications on the OCS.

Solar technology

(Excerpted from MMS 2007 final report)
Solar energy technology has been producing useable energy from land-based, full-scale, grid connected power plants for more than a decade, but use of solar energy technology on the OCS is very limited. Economically feasible installation of full-scale solar energy projects on the OCS will depend on producing significant amounts of transmittable energy.

The possibilities for solar technology are not limited to large offshore solar plants; solar energy technology could be collocated with other alternative energy technologies. For example, solar collectors could be installed near the base of a wind turbine, and then used to augment energy output. Solar technology also could be installed as an alternative use for decommissioned oil and gas platforms on the OCS. Already some small, unmanned oil and gas platforms use solar panels for electricity needs. Solar panels are also used on buoys, platforms, and meteorological stations.

The potential for annual average solar power varies greatly by latitude and cloud cover; solar radiation is significantly greater in the lower latitudes. In the United States, solar radiation is greatest in southern parts of the country. A literature review yielded no information on solar radiation levels offshore and along the OCS (MMS 2006). However, unpublished solar radiation data may exist as shipboard information collected during routine or research operations.

Solar energy is converted into useable energy through two basic technologies: thermal and photonic. Thermal technologies convert solar energy to heat. Photonic technologies absorb solar photons, which are then converted into electricity through photovoltaic (PV) cells. Technology is also in the early stages of development to store the photonic energy as hydrogen for later use, rather than convert it directly to electricity (MMS 2006).

Some solar technologies use concentrating mechanisms to focus heat or photonic solar energy into a collector. Technology and application of concentrated PV are not as advanced as concentrated thermal technology, but it is under development. Concentrated PV and thermal systems use mirrors or lenses configured to concentrate solar radiation on receiving panels.

Current solar energy technology has limited application on the OCS. It is distributed only to power buoys, weather stations, and small, unmanned oil and gas platforms. A literature review revealed no solar energy projects on the OCS at any stage of planning or development. Any offshore solar energy project would need to be mounted onto some sort of large floating or fixed structure (MMS 2006). The number of solar panels, and therefore, the size of the structure necessary to support an offshore commercial solar energy facility would vary depending on the solar radiation level at the location, the orientation of the panels, and weather conditions.

Thermal solar technologies require dry, warm locations, and thus, current technologies likely would not be feasible on the OCS where humidity is high. PV solar technology surface area requirements also limit their application at OCS locations, where a floating platform would be required. Approximately 8 to 12 square meters is required for each kilowatt of capacity, meaning 0.8 to 1.2 hectares (0.008 to 0.012 km^2) of PV cells would be required for each 1 MW of power output (MMS 2006). Concentrated PV systems developed for thermal solar projects are in early development. Efficient concentrated PV technologies may increase the economic feasibility of OCS solar applications because PV is more effective in humid environments.

Hydrogen Technology

Hydrogen technology would be used on the OCS as a transport or storage mechanism for energy produced by one of the other alternative energy technologies (wind, wave, current or solar). No projects were identified at any stage of planning or implementation for this type of technology. The best source of information on the possibilities of using hydrogen technology for storage or transport of energy on the OCS is the MMS (2006) white paper. Since the application of hydrogen technology is so undefined at this stage, and because there are no current plans or prototypes for OCS application, the potential impacts were not included in the MMS report (2007).

6.1.2.9 Non-native or nuisance species

Indo-Pacific Lionfish

Lionfish (*Pterois volitans*/*miles* complex) are venomous coral reef fishes from the Indian and western Pacific oceans, that are now found in the western Atlantic Ocean (Whitfield et al. 2002; Hare and Whitfield 2003; Meister et al. 2005; Ruiz-Carus et al. 2006; Whitfield et al. 2006). Adult lionfish have been observed from the Turks and Caicos Islands throughout the northern Bahamas and from Florida to Cape Hatteras, North Carolina, including Bermuda. There is also recent evidence to suggest that lionfish have been found near Tampa Bay, Florida in the Gulf of Mexico (Ramon Ruiz-Carus, pers. Comm.). Juvenile lionfish have been observed in increasingly high numbers off New Jersey, New York and Rhode Island, generally in the fall of the year. Lionfish reports from the public (beginning in 2000) combined with quantitative surveys conducted from Florida to North Carolina (2004-2006) suggest that the number of lionfish continues to increase along the east coast and their distribution is expanding both in the northern (juveniles in northeast) and southern range (Whitfield et al. 2006; Whitfield unpublished data). Due to the large geographic range now inhabited by lionfish this invasion is likely irreversible as removal of this invader across this region would be expensive and take unprecedented resources.

Introductions of marine species occur in many ways. Ballast water discharge is a very common method of introduction for marine invertebrates, and is responsible for many freshwater fish introductions. In contrast, most marine fish introductions have resulted from intentional stocking for fishery purposes. In the case of lionfish, all evidence points to an unintentional or intentional aquarium release (Hare and Whitfield 2003).

Currently no management actions have been taken to limit the effect of lionfish on the southeast United States continental shelf ecosystem. Under this scenario we predict that; 1) the lionfish population and geographic range will continue to increase; 2) as a result of this increasing abundance, the impacts of lionfish on the southeast United States continental shelf ecosystem will become more noticeable; 3) eventually, human impacts from lionfish 'stings' will occur along the southeast United States coast (Hare and Whitfield 2003; Whitfield et al. 2006).

The introduction and success of lionfish along the east coast may change the long-held perception that marine fish invasions are a minimal threat to marine ecosystems. The magnitude of this invasion as a stressor on marine ecosystems presently has not been quantified, but NOAA scientists have made a great deal of progress in understanding the lionfish introduction into the Western Atlantic. We have also made significant inroads in our understanding of many aspects of lionfish biology and ecology including reproduction, diet, population demographics and genetics. This section summarizes the current state of knowledge regarding the Atlantic lionfish population within five main topic areas: 1) Description and Distribution, 2) Reproduction, 3) Development, growth movement patterns and genetics, 4) Ecological relationships/Potential Impact and 5) Abundance and status of the stock.

<u>Description and Distribution</u>

The Indo-Pacific lionfish (*Pterois volitans/miles* complex, Scorpaenidae) is a venomous predator (Halstead 1970) native to the sub-tropical and tropical regions of the South Pacific, Indian

Oceans and the Red Sea (Schultz, 1986). Lionfish are generally well known and recognized as a popular aquarium fish. Lionfish have venomous dorsal, anal, and pelvic spines, similar to other members of the family Scorpeanidae. The venomous spines are not known to be used in prey capture but are generally thought to be for self-defense and male/male agonistic displays during spawning (Fishelson 1975).

The present distribution (October 2006) of Indo-Pacific lionfish within the Atlantic is from southeast Florida to North Carolina, including Bermuda, the Bahamas, Turks and Caicos and along the northeast U.S. shelf as juveniles. Lionfish may have originated off the east coast of Florida in the early 1990's, but the actual source of the lionfish invasion remains unknown. In 2000, lionfish were first reported in North Carolina and Bermuda. In 2004, lionfish were first reported in the Bahamas, and in 2006 they were reported in the Turks and Caicos. Public reports combined with quantitative surveys suggest that both the number and geographic extent of the population continues to grow (Whitfield et al. 2006).

Within their native range lionfish are found on coral reefs and rocky outcrops from the surface to 50 meters (Schultz 1986). Within the South Atlantic Bight lionfish are widespread in abundance, found on all types of habitat (low relief hard bottom to high relief artificial structures) within water depths from 115 to 300 ft deep (Whitfield et al. 2006). By all accounts lionfish were already established (reproducing and dispersing) by the time the first surveys were conducted in 2004 and lionfish captures by hook and line are also on the rise within the past two years but these captures still vastly under-represent the extent of the lionfish population within the Atlantic. The large geographic extent of the lionfish distribution and the speed with which they occupied this area (since 2000) suggest they are very successful colonizers and competitors within their 'new' ecosystem (Atlantic).

At present the primary factors that can potentially limit their distribution are available habitat, availability of prey and winter bottom water temperatures. Both habitat and prey appear to be plentiful, especially with the potential increase in prey resources made available through overfishing of many grouper species (likely competitors for prey) (Huntsman et al. 1999; NMFS 2004). Thus the minimum bottom water temperatures remain the single most important factor in controlling the present lionfish distribution within the Atlantic. This is not only evidenced by the shift in depth distribution from their native habitat (shallower) to the Atlantic (deeper) but also by winter bottom water temperature data collected in both nearshore (colder) and offshore (warmer; Gulf Stream influenced) locations (Whitfield et al. 2002; Whitfield et al. unpublished data). Minimum winter bottom water temperatures collected from locations where lionfish are known to over-winter support the thermal minimums found in laboratory studies (Kimball et al. 2004). Based on laboratory thermal minimums, lionfish would not survive water temperatures that dip below 10º C (Kimball et al. 2004). In North Carolina, this equates to an inshore depth limit of approximately 80 to 90 ft, depending on winter temperatures overall. Nevertheless, lionfish can still recruit into shallower areas but they are not expected to over-winter in shallow water (less than 80-90ft) north of Florida (see Figure 5, Kimball et al. 2004). However, since the thermal tolerance of fishes is known to change with changes in fish size and age (Wootton 1992), a series of mild winters could interact with the advancing size and age of Atlantic lionfish, eventually establishing subpopulations inshore of those currently surveyed. Therefore, the actual inshore limit remains unresolved off the Mid-Atlantic states. At their southern limit (southeast

Florida, Bahamas, Turks and Caicos and Gulf of Mexico) there are no such depth or temperature constraints as water temperature remains warm year round. Thus lionfish have been reported in water depths as shallow as 3 ft in the Bahamas and Jacksonville, FL (Ruiz-Carus et al. 2006).

It is important to mention that although connectivity between the Bahamas and the Caribbean is low, there are certain locations such as the Turks and Caicos where connectivity is higher (Cowen et al. 2006). Since lionfish have free-floating eggs and larvae even minimal larval connectivity from the southeast U.S. and Bahamas could lead to invasion of the Caribbean and the Gulf of Mexico through a stepping-stone effect (Carr & Reed 1993; Cowen et al. 2006).

<u>Reproduction</u>

Lionfish can be characterized as gonochoristic, iteroparous, asynchronous, indeterministic batch spawners. This mode of reproduction is consistent with other members of the *Pterois* and *Dendrochirus* genera. Lionfish appear to be summer spawners off North Carolina with a resting period lasting throughout the winter. The lionfish spawning season is likely to increase at the southern range of their distribution (i.e., Florida/Bahamas).

From observations in the Red Sea, Fishelson (1975) has reported that lionfish are pair-spawners exhibiting a complex courtship during mating. Laboratory and shipboard observations indicate that lionfish release two buoyant egg balls during each spawning event consisting of a batch fecundity of approximately 30,000 eggs. Lionfish eggs are released while encased in a gelatinous mucus which breaks apart releasing the developing embryos within 48 hours. Lionfish do not exhibit sexual dimorphism; however, males do grow significantly larger than females. Sex ratio of lionfish in the Atlantic is approximately 1:1. Female lionfish appear to be sexually mature within two years of age corresponding to approximately 150 mm standard length (Morris, J.A., Jr., pers. comm.).

In their native range lionfish are reported as being solitary defending their home range against conspecifics; groups were typically observed only during mating (Fishelson 1975). In contrast within the Atlantic, lionfish are regularly found in groups, but, to our knowledge no mating behavior has been observed (Whitfield, pers. obs.).

<u>Development, growth, age, movement patterns and genetics</u>

The early life history stages of lionfish are poorly known. Mito and Uchida (1958) and Fishelson (1975) describe the development and early larval stages of congenerics, while Imamura and Yabe (1996) describe five *P. volitans* larvae collected in the water column off of northwestern Australia. Lionfish settle from the water column to benthic habitats at about 10-12 mm. Laidig and Sakuma (1998) reported a larval growth rate of 0.3 mm d-1 for *Scorpaena*, a genus in the same family as lionfish, Scorpeanidae. Using this growth rate, the estimated planktonic larval duration (PLD) of lionfish is 25 to 40 d, which means that larvae may be in the water column and susceptible to transport by ocean currents for approximately one month. However, confirmation of PLD specific to *P. volitans* is needed as PLD can vary widely, even within members of the same genus (Victor 1986).

In 2004, a total of 149 lionfish were collected off North Carolina for life history analyses, These ranged in length from 5 to 45 cm (average length = 30.5 cm) and in weight from 25 to 1380 grams (3 lbs) with average wt of 480 grams. Several lionfish collected in this study were larger (45 cm) than the reported maximum length from their native range (38 cm) (Schultz 1986; Randall et al. 1997; Myers 1999), suggesting that lionfish growth along the southeast U.S. is not resource limited (Elton 1958). The growth rate of lionfish in the Atlantic or in their native habitat remains unknown.

Although preliminary, analyses of annual zones on sagittal otoliths suggest that the lionfish population off North Carolina is relatively young, (max. age 7 years old; 43 cm specimen). If confirmed, these results would support our general timeline of the invasion which we believe began around the year 2000, off North Carolina. However, age validation is still required to confirm this result.

As in most reef fishes, the major dispersal phase of lionfish probably occurs while eggs and larvae are in the plankton. The northward dispersal (i.e., from Florida to NC) of lionfish is thought to be greatly facilitated by the strong northerly flowing Gulf Stream currents. Dispersal further into the northeast is most likely facilitated by Gulf Stream eddies (e.g., cross shelf transport, Hare and Cowen 1996). Once settled to the benthos, observations from their native habitat suggest that lionfish exhibit site fidelity and do not migrate (Fishelson 1975, 1997; McBride and Able,1998.) In the Atlantic, however, the question of lionfish movement or migration, especially in response to cold water incursions, remains an important area of research but to date is unknown. If lionfish did move offshore in the winter in response to cold bottom water temperatures, this may increase their ability to survive thereby decreasing their natural mortality.

Genetics analyses of the Atlantic lionfish specimens revealed the presence of two closely related sister species *Pterois volitans* and *P. miles* within the Atlantic but 93.5% of collected specimens were *P. volitans*. We also found that the complexity of the haplotype network for Atlantic specimens was greatly simplified when compared to specimens in their native range. Twenty-eight different haplotypes were found within 43 native range *P. volitans* as opposed to 3 haplotypes within the 160 Atlantic *P. volitans* specimens. In addition, 95% of the Atlantic *P. volitans* shared the same haplotype. These data indicate a large decrease in genetic diversity within the Atlantic population most likely caused by a small founder population, but of no less than 3 female specimens. These data may indicate that a small release in the right environment can result in an invasion of impressive proportions.

<u>Ecological relationships – Potential Impact</u>

Within their native habitat the ecology of lionfish is not well known. A few studies on lionfish found they consumed a wide variety of smaller fishes, shrimps and crabs (Fishelson 1975), and occupy the upper levels of the food chain (Fishelson 1997). Moreover, few predators of lionfish have been reported in their native range (but see, Bernadsky and Goulet 1991; Moyer and Zaiser 1981). Although, potential lionfish predators along the southeast United States have no experience with the venomous spines of the lionfish (Ray and Coates 1958; Halstead 1967) there are other native venomous fishes such as scorpionfishes (same family as lionfish) which are consumed by native predatory fishes (Randall 1967; Ebert et al. 1991; Roel and Macpherson 1998; Bowman et al. 2000). However, the potential role of predation in decreasing the number of lionfish is unknown, as is the effect of lionfish on predators.

Lionfish could impact native ecosystems through direct predation, competition and overcrowding. Preliminary data on the diet of Atlantic lionfish specimens suggest that they are primarily generalist piscivores, similar to their native counterparts. The Atlantic lionfish diet is comprised mainly of prey from a variety of fish families including members of the Serranidae, Pomacentridae, Labridae, Scaridae, Blenniidae, Bothidae, Carangidae, and Monacanthidae. Ninety eight percent of stomachs examined contained fishes, and other prey items (decapod crustaceans, cephalopod and bivalve mollusks) make up only a fraction of prey contents by volume (approx. 0.5 % or less). The small serranids (sea basses) were substantially more important in terms of volume than other families of fishes (41% vs. 15% and lower for other prey families) (Munoz et al. in prep). Since lionfish are opportunistic predators feeding primarily on smaller fishes, there is potential for trophic overlap with native fishes (Sano et al. 1984; Naughton 1985; Matheson et al. 1986; Fishelson 1997) such as groupers in the genus Mycteroperca. Groupers comprising this genus feed almost exclusively on fishes (Dodrill et al. 1993). In particular, gag (*Mycteroperca microlepis*) and scamp (*M. phenax*) groupers are present in significant numbers off the North Carolina coast and scamp occur at size classes that appear to overlap size classes of lionfish. Serranids form one of the most important food items in the scamp diet (Matheson et al. 1986) so similarly sized scamp and lionfish may be targeting similar prey. In addition, lionfish have been confirmed to prey upon scad (Carangidae), one of the dominant fish species in the diet of gag (Naughton & Saloman 1985). If these prey fishes are already or became a limiting resource, a growing lionfish population could negatively impact the scamp and gag populations via competition for food resources. The style of lionfish predation, (i.e., ambush predator) is not unique on southeast United States reefs and wrecks (e.g., red grouper, frog fish, scorpion fish), but the lack of experience of prey species may increase the predation efficiency of lionfish. Moreover, continued mortality of groupers and other native predators through overfishing (Huntsman et al. 1999; NMFS 2004) may open niche space and further increase resources for lionfish (Davis 2000).

Lionfish may also affect the use of habitat by other species through physical overcrowding and aggressive tendencies. Lionfish are often described as ‘standing their ground’ and male-male aggression is extremely high prior to and during reproductive activities, during which lionfish will even threaten divers (Thresher 1984; Myers 1991). If this behavioral characteristic was extended towards other organisms in their introduced range, the threat might be expected to increase with lionfish abundance and potentially cause native species displacement into sub-optimum habitats (Schumacher and Parrish 2005; Taylor et al. 1984).

<u>Abundance and status of the stock</u>

The total population abundance of lionfish in the Atlantic is currently unknown. Quantitative surveys combined with public reports suggest the population is growing in number and increasing in geographic extent and may potentially colonize the entire Caribbean and Gulf of Mexico (Whitfield et al. 2006). Within the last two years quantitative surveys at the same nineteen locations off North Carolina (95 to 150 fsw) indicate that lionfish densities have doubled. Moreover, yearly surveys from the same nineteen locations, off North Carolina, suggest lionfish densities may be similar to many native fish species (i.e., *Cephalopholis cruentatus, Epinephelus guttatus, E. adscensonis, Mycteroperca interstitialis, M. microlepis*) (Whitfield et al. 2006). At this point there is every expectation that the total population and geographic extent of lionfish will continue to increase. More information is clearly needed to determine the status of the entire population, but traditional fishery sampling methods are not appropriate because lionfish are not captured effectively in this manner. More detailed information on the amount and type of benthic habitat within the southeast region combined with a random program of quantitative visual surveys over a broad geographic area (Bahamas to NC) will assist in estimating the total population size of lionfish.

Summary
The southeast United States continental shelf ecosystem is already undergoing change. Many important reef fish predators are overfished (Huntsman et al. 1999). In the Snapper-Grouper Management Unit of the South Atlantic Fisheries Management Council, approximately half of the stocks for which the status is known are classified as overfished. The reef fish fauna of the southeast United States continental shelf is also becoming more tropical (Parker and Dixon 1998). From the 1970's to the 1990's, the number of tropical species and the abundance of individual tropical species increased off the coast of North Carolina. Both of these large-scale changes favor the continued growth and dispersal of the lionfish population along the southeast United States. The effect of climate change, overfishing and invasive species have been implicated in ecosystem decline and collapse in several marine ecosystems, (Harris & Tyrrell 2001; Stachowicz et al. 2002; Frank et al. 2005). Along the southeast U.S. shelf the high number of stressors acting in synergism may eventually have unexpected and irreversible consequences for the native communities and economically valuable fisheries in this region.

6.1.3 Natural Events and Climate Change

<u>Potential Threats to EFH from Natural Events and Climate Change</u>
Potential threats: Coastal and inland storms can cause severe acute and chronic perturbations including habitat erosion, burial of habitat and organisms by sediment deposition; creation of strong currents that alter habitats and remove biota; damage by wind and waves; creation of turbidity levels that can cause physiological damage and disrupt feeding, spawning migration, and other vital processes; and abrupt changes in salinity and other water quality characteristics such as fecal coliform levels and harmful algal blooms. Long-term climatological changes, such as, changes in weather patterns and ocean currents, can bring about similar changes by increasing storm activity, changing fresh water inputs and salinity in coastal systems, increasing ocean acidification which affects coral reef building, and changing water column productivity that can affect certain fish population. For example, the Atlantic Multidecadal Oscillation can cause large scale ecological changes called regime shifts where temperature alterations favor or harm a particular species or group. Changes that cause relocation of frontal boundaries, weed lines, and stratification and temperature boundaries may also cause substantial and undesirable environmental change.

Coastal processes may be dramatically altered by natural events. These include short term events such as severe storms, hurricanes, floods, etc. Effects vary from potentially positive to catastrophic. For example, a moderate storm may provide needed freshwater, flush and recharge stagnant water bodies, and transfer nutrients from uplands and high marsh surfaces to tidal waters. On the other hand, shoreline erosion, wetlands destruction and subsidence and substantial changes in the structure of coral communities (e.g., Bythyell et al. 1993) are possible.

Hurricanes and other severe climatological events and change can drastically alter shorelines and associated environments including wetlands. Some changes may be positive such as the flushing of stagnant systems. However, wind induced erosion and overwash can remove and fill large areas of SAV and emergent wetlands. In overwash areas, newly created "uplands" are often quickly developed and stabilized and geomorphological processes that lead to rebuilding of wetlands and shallow water areas may be precluded. As storm activity increases in severity and regularity, emergency shoreline protection response threatens coastal nearshore habitats primarily through burial by beach restoration efforts. Littoral sand drift has interrupted by the development of stabilized inlet jetties, which has reduced sand budgets. Decreased sand budgets coupled with increased severe storm activity (a known result of increased rates of global warming) necessitate an increase in large-scale beach dredge and fill projects. The direct, secondary and cumulative effects of these activities are known to have a profound effect on EFH through burial of nearshore hard bottom, worm reef, coral reef and sand bottom habitat areas. Loss of habitat areas utilized by various life stages of federally managed species and their prey species will continue to have a negative effect. As the need for such projects increases and the time between projects decreases adverse effects will be amplified.

Hurricanes also cause vertical mixing in coastal waters that results in cooling and nutrient enrichment of surface water and stimulation of algal growth. In estuaries, hurricanes suspend sediment and increase terrestrial runoff that can result in algal blooms and hypoxia in bottom waters (NOAA 2005). Algal blooms and hypoxia can cause fish die-offs and spread disease to other plants and animals.

Climate Change

This section was excerpted from the *Summary Report for Policymakers* based on the assessment carried out by the three Working Groups of the Intergovernmental Panel on Climate Change (IPCC). It provides an integrated view of climate change as the final part of the IPCC's Fourth Assessment Report, released in fall 2007. A complete elaboration of the topics covered in this summary can be found in this Synthesis Report and in the underlying reports of the three Working Groups available online at (http://www.coastalclimate.org/).

<u>Observed changes in climate and their effects</u>

Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level (**Figure 6.1-2).**

Eleven of the last twelve years (1995-2006) rank among the twelve warmest years in the instrumental record of global surface temperature (since 1850). The 100-year linear trend (1906-2005) of 0.74 [0.56 to 0.92]°C 1 is larger than the corresponding trend of 0.6 [0.4 to 0.8]°C (1901-2000) given in the Third Assessment Report (TAR) (**Figure 6.1-2**). The temperature increase is widespread over the globe, and is greater at higher northern latitudes.

Land regions have warmed faster than the oceans (**Figure 6.1-3**). Rising sea level is consistent with warming (**Figure 6.1-2**). Global average sea level has risen since 1961 at an average rate of 1.8 [1.3 to 2.3]mm/yr and since 1993 at 3.1 [2.4 to 3.8]mm/yr, with contributions from thermal expansion, melting glaciers and ice caps, and the polar ice sheets. Whether the faster rate for 1993 to 2003 reflects decadal variation or an increase in the longer-term trend is unclear.

Observed decreases in snow and ice extent are also consistent with warming (Figure SPM.1). Satellite data since 1978 show that annual average Arctic sea ice extent has shrunk by 2.7% (2.1 to 3.3) per decade, with larger decreases in summer of 7.4% (5.0 to 9.8) per decade. Mountain glaciers and snow cover on average have declined in both hemispheres.

From 1900 to 2005, precipitation increased significantly in eastern parts of North and South America, northern Europe and northern and central Asia but declined in the Sahel, the Mediterranean, southern Africa and parts of southern Asia. Globally, the area affected by drought has likely increased since the 1970s.

It is very likely that over the past 50 years: cold days, cold nights and frosts have become less frequent over most land areas, and hot days and hot nights have become more frequent. It is likely that: heat waves have become more frequent over most land areas, the frequency of heavy precipitation events has increased over most areas, and since 1975 the incidence of extreme high sea level has increased worldwide.

There is observational evidence of an increase in intense tropical cyclone activity in the North Atlantic since about 1970, with limited evidence of increases elsewhere. There is no clear trend in the annual numbers of tropical cyclones. It is difficult to ascertain longer-term trends in cyclone activity, particularly prior to 1970.

Average Northern Hemisphere temperatures during the second half of the 20th century were very likely higher than during any other 50-year period in the last 500 years and likely the highest in at least the past 1300 years.

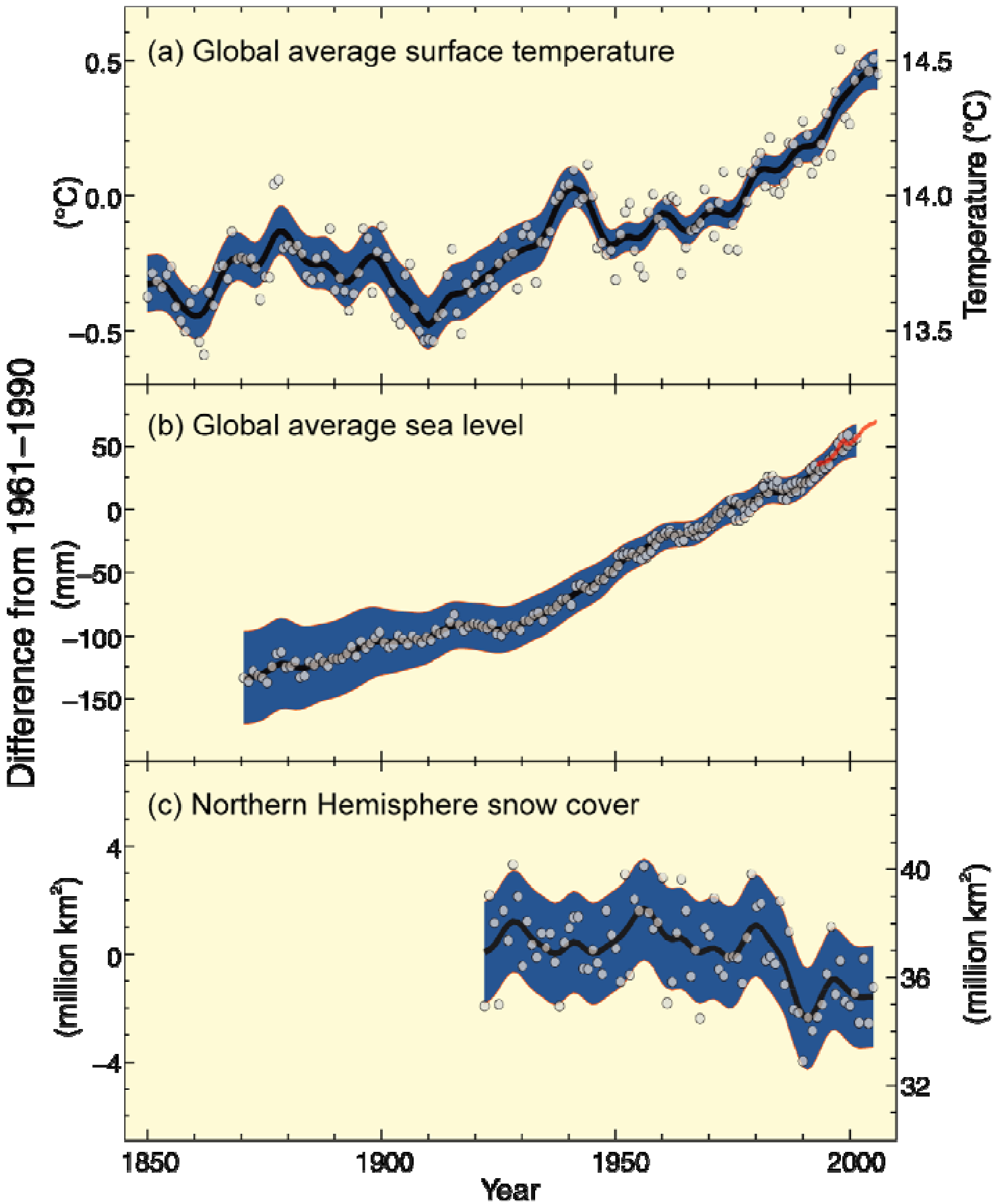

Figure 6.1-2. Observed changes in (a) global average surface temperature; (b) global average sea level from tide gauge (blue) and satellite (red) data and (c) Northern Hemisphere snow cover for March-April. All differences are relative to corresponding averages for the period 1961-1990. Smoothed curves represent decadal averaged values while circles show yearly values. The shaded areas are the uncertainty intervals estimated from a comprehensive analysis of known uncertainties (a and b) and from the time series (c).

Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases. Changes in snow, ice and frozen ground have with high confidence increased the number and size of glacial lakes, increased ground instability in mountain and other permafrost regions, and led to changes in some Arctic and Antarctic ecosystems.

There is high confidence that some hydrological systems have also been affected through increased runoff and earlier spring peak discharge in many glacier- and snow-fed rivers, and effects on thermal structure and water quality of warming rivers and lakes.

In terrestrial ecosystems, earlier timing of spring events and poleward and upward shifts in plant and animal ranges are with very high confidence linked to recent warming. In some marine and freshwater systems, shifts in ranges and changes in algal, plankton and fish abundance are with high confidence associated with rising water temperatures, as well as related changes in ice cover, salinity, oxygen levels and circulation.

Of the more than 29,000 observational data series, from 75 studies, that show significant change in many physical and biological systems, more than 89% are consistent with the direction of change expected as a response to warming. However, there is a notable lack of geographic balance in data and literature on observed changes, with marked scarcity in developing countries.

There is medium confidence that other effects of regional climate change on natural and human environments are emerging, although many are difficult to discern due to adaptation and non-climatic drivers. They include effects of temperature increases on:

- agricultural and forestry management at Northern Hemisphere higher latitudes, such as earlier spring planting of crops, and alterations in disturbance regimes of forests due to fires and pests
- some aspects of human health, such as heat-related mortality in Europe, changes in infectious disease vectors in some areas, and allergenic pollen in Northern Hemisphere high and mid-latitudes
- some human activities in the Arctic (e.g., hunting and travel over snow and ice) and in lower-elevation alpine areas (such as mountain sports).

<u>Causes of change</u>

Changes in atmospheric concentrations of greenhouse gases (GHGs) and aerosols, land-cover and solar radiation alter the energy balance of the climate system.

Global GHG emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004. Carbon dioxide (CO_2) is the most important anthropogenic GHG. Its annual emissions grew by about 80% between 1970 and 2004. The long-term trend of declining CO_2 emissions per unit of energy supplied reversed after 2000.

Global atmospheric concentrations of CO_2, methane (CH_4) and nitrous oxide (N_2O) have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years.

Atmospheric concentrations of CO_2 (379ppm) and CH_4 (1774 ppb) in 2005 exceed by far the natural range over the last 650,000 years. Global increases in CO_2 concentrations are due primarily to fossil fuel use, with land-use change providing another significant but smaller contribution. It is very likely that the observed increase in CH_4 concentration is predominantly due to agriculture and fossil fuel use. Methane growth rates have declined since the early 1990s, consistent with total emissions (sum of anthropogenic and natural sources) being nearly constant during this period. The increase in N_2O concentration is primarily due to agriculture.

There is very high confidence that the net effect of human activities since 1750 has been one of warming.

Most of the observed increase in globally-averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic GHG concentrations. It is likely there has been significant anthropogenic warming over the past 50 years averaged over each continent (except Antarctica) (Figure SPM.4).

During the past 50 years, the sum of solar and volcanic forcings would likely have produced cooling. Observed patterns of warming and their changes are simulated only by models that include anthropogenic forcings. Difficulties remain in simulating and attributing observed temperature changes at smaller than continental scales.

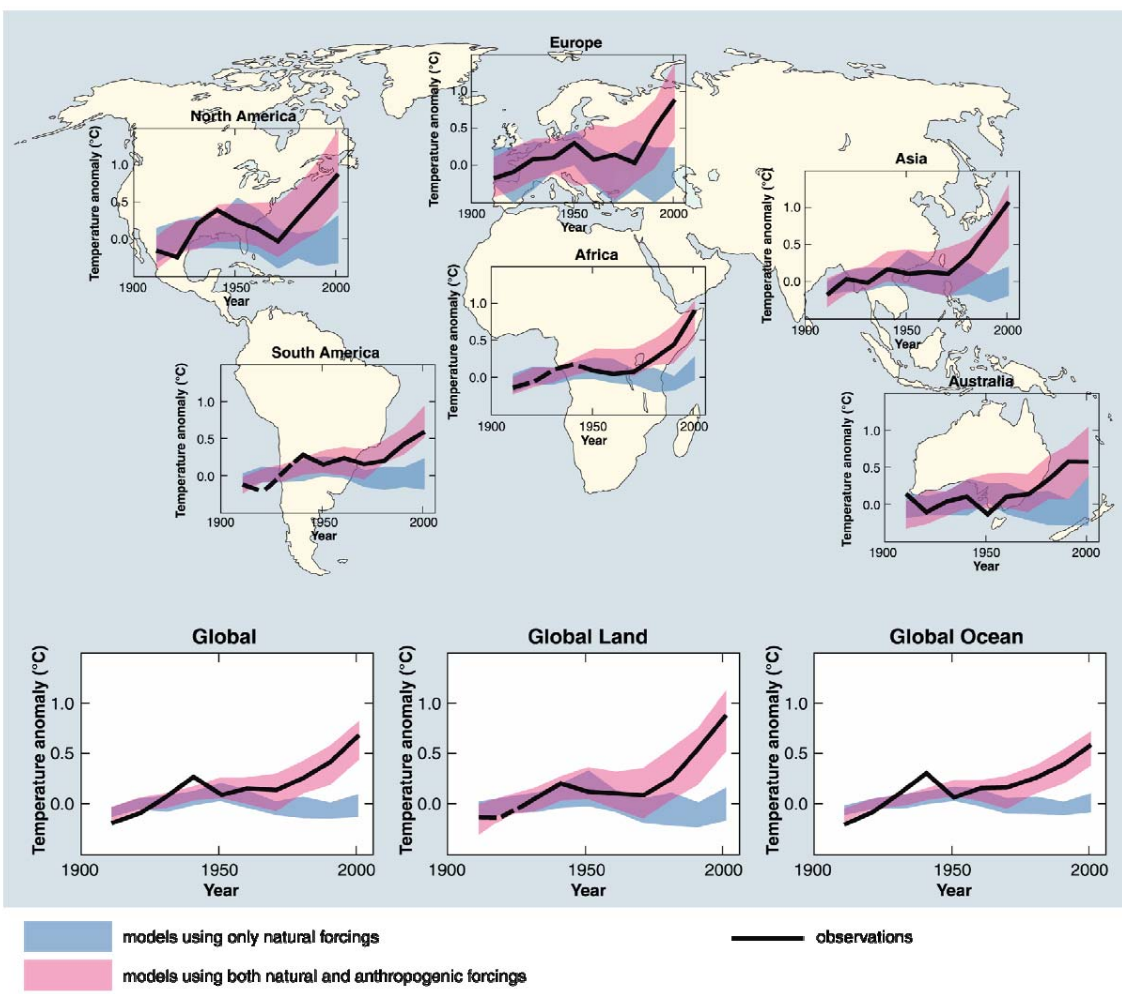

Figure 6.1-3. Comparison of observed continental- and global-scale changes in surface temperature with results simulated by climate models using either natural or both natural and anthropogenic forcings. Decadal averages of observations are shown for the period 1906-2005 (black line) plotted against the centre of the decade and relative to the corresponding average for the period 1901-1950. Lines are dashed where spatial coverage is less than 50%. Blue shaded bands show the 5-95% range for 19 simulations from 5 climate models using only the natural forcings due to solar activity and volcanoes. Red shaded bands show the 5-95% range for 58 simulations from 14 climate models using both natural and anthropogenic forcings.

Advances since the TAR show that discernible human influences extend beyond average temperature to other aspects of climate.

Human influences have:

- very likely contributed to sea level rise during the latter half of the 20th century
- likely contributed to changes in wind patterns, affecting extra-tropical storm tracks and temperature patterns
- likely increased temperatures of extreme hot nights, cold nights and cold days
- more likely than not increased risk of heat waves, area affected by drought since the 1970s and frequency of heavy precipitation events.

Anthropogenic warming over the last three decades has likely had a discernible influence at the global scale on observed changes in many physical and biological systems. Spatial agreement between regions of significant warming across the globe and locations of significant observed changes in many systems consistent with warming is very unlikely to be due solely to natural variability. Several modeling studies have linked some specific responses in physical and biological systems to anthropogenic warming.

More complete attribution of observed natural system responses to anthropogenic warming is currently prevented by the short time scales of many impact studies, greater natural climate variability at regional scales, contributions of non-climate factors and limited spatial coverage of studies.

Projected climate change and its impacts

There is high agreement and much evidence that with current climate change mitigation policies and related sustainable development practices, global GHG emissions will continue to grow over the next few decades.

The IPCC Special Report on Emission Scenarios (SRES, 2000) projects an increase of global GHG emissions by 25-90% (CO_2-eq) between 2000 and 2030, with fossil fuels maintaining their dominant position in the global energy mix to 2030 and beyond. More recent scenarios without additional emissions mitigation are comparable in range.

Continued GHG emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century. For the next two decades a warming of about

0.2°C per decade is projected for a range of SRES emission scenarios. Even if the concentrations of all GHGs and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected. Afterwards, temperature projections increasingly depend on specific emission scenarios.

For an explanation of SRES emission scenarios, see Box 'SRES scenarios' in Topic 3 of this Synthesis Report. These scenarios do not include additional climate policy above current ones; more recent studies differ with respect to UNFCCC and Kyoto Protocol inclusion.

There is now higher confidence than in the TAR in projected patterns of warming and other regional-scale features, including changes in wind patterns, precipitation, and some aspects of extremes and sea ice. Regional-scale changes include:

- warming greatest over land and at most high northern latitudes and least over Southern Ocean and parts of the North Atlantic Ocean, continuing recent observed trends **(Figure 6.1-4)**;
- contraction of snow cover area, increases in thaw depth over most permafrost regions, and decrease in sea ice extent; in some projections using SRES scenarios, Arctic late-summer sea ice disappears almost entirely by the latter part of the 21st century;
- very likely increase in frequency of hot extremes, heat waves, and heavy precipitation;
- likely increase in tropical cyclone intensity; less confidence in global decrease of tropical cyclone numbers;
- poleward shift of extra-tropical storm tracks with consequent changes in wind, precipitation, and temperature patterns; and
- very likely precipitation increases in high latitudes and likely decreases in most subtropical land regions, continuing observed recent trends.

There is high confidence that by mid-century, annual river runoff and water availability are projected to increase at high latitudes (and in some tropical wet areas) and decrease in some dry regions in the mid-latitudes and tropics. There is also high confidence that many semi-arid areas (e.g., Mediterranean basin, western United States, southern Africa and northeast Brazil) will suffer a decrease in water resources due to climate change.

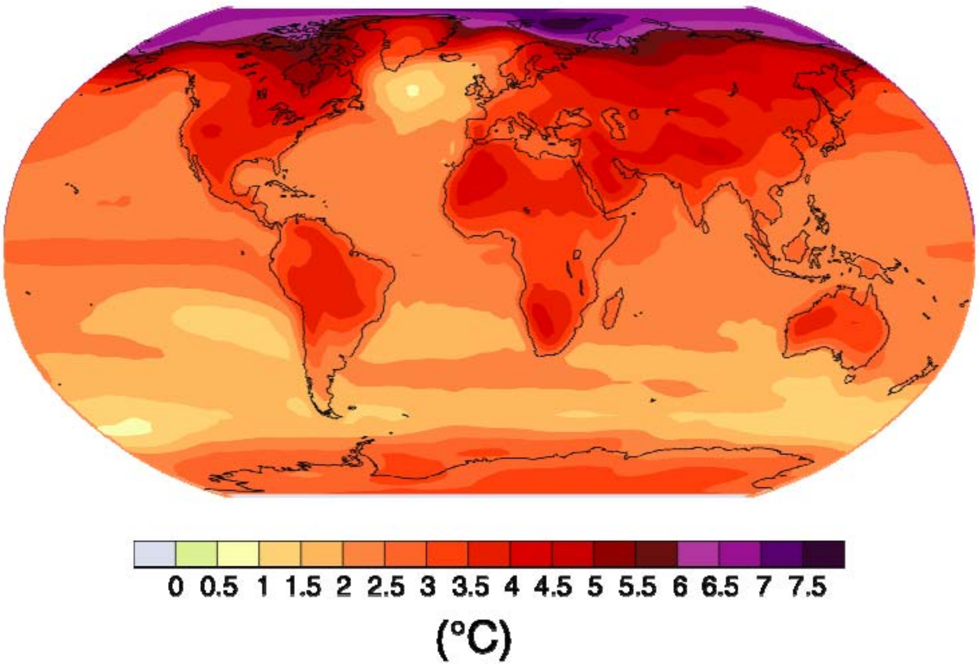

Figure 6.1-4. Projected surface temperature changes for the late 21st century (2090-2099). The map shows the multi- AOGCM average projection for the A1B SRES scenario. All temperatures are relative to the period 1980-1999.

Studies since the TAR have enabled more systematic understanding of the timing and magnitude of impacts related to differing amounts and rates of climate change.

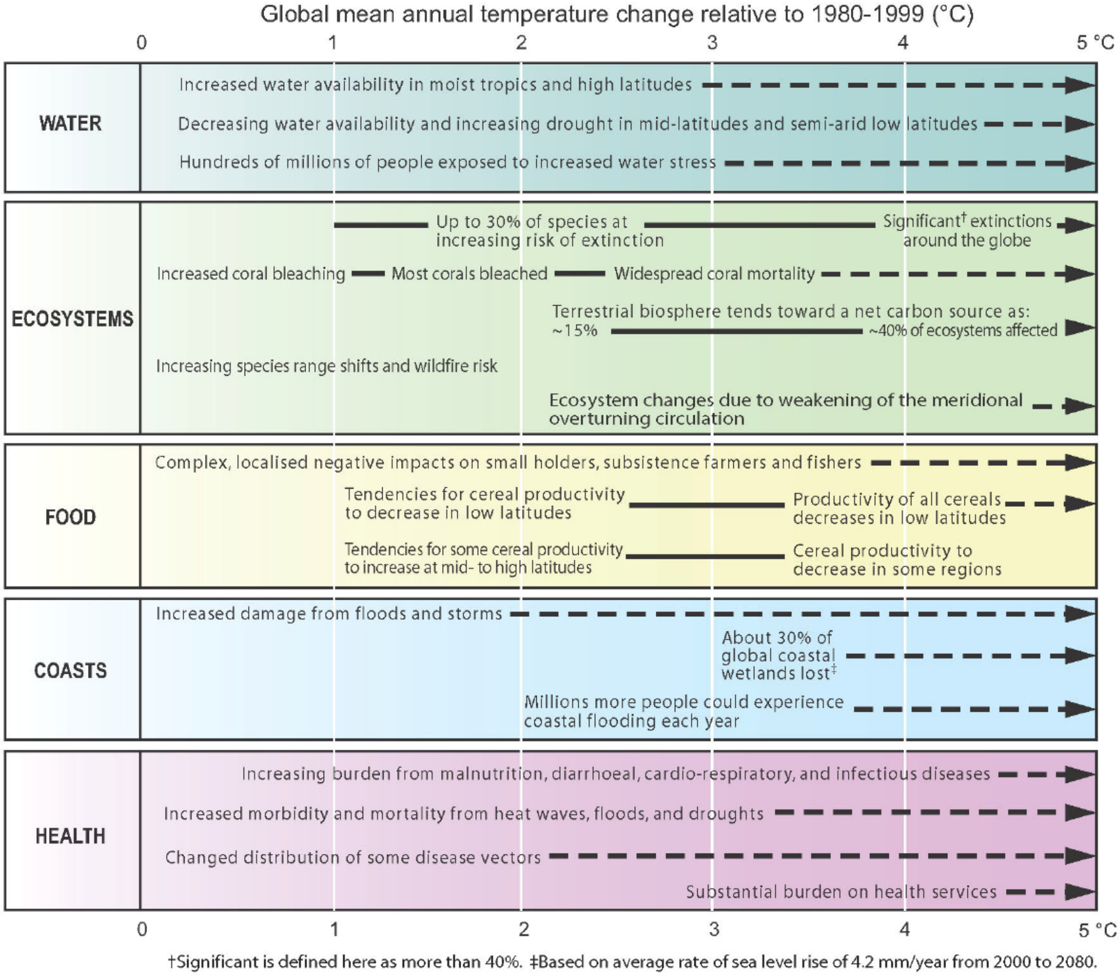

Figure 6.1-5. Illustrative examples of global impacts projected for climate changes (and sea level and atmospheric CO_2 where relevant) associated with different amounts of increase in global average surface temperature in the 21st century.

The black lines link impacts; broken line arrows indicate impacts continuing with increasing temperature. Entries are placed so that the left hand side of text indicates the approximate level of warming that is associated with the onset of a given impact. Quantitative entries for water scarcity and flooding represent the additional impacts of climate change relative to the conditions projected across the range of SRES model scenarios. Adaptation to climate change is not included in these estimations. *Confidence levels for all statements are high.*

Examples of some projected regional impacts in North America:

- Warming in western mountains is projected to cause decreased snowpack, more winter flooding, and reduced summer flows, exacerbating competition for over-allocated water resources.
- In the early decades of the century, moderate climate change is projected to increase aggregate yields of rain-fed agriculture by 5-20%, but with important variability among

regions. Major challenges are projected for crops that are near the warm end of their suitable range or which depend on highly utilized water resources.

- During the course of this century, cities that currently experience heat waves are expected to be further challenged by an increased number, intensity and duration of heat waves during the course of the century, with potential for adverse health impacts.
- Coastal communities and habitats will be increasingly stressed by climate change impacts interacting with development and pollution.

Moreover, some systems, sectors and regions are likely to be especially affected by climate change.

- Particular ecosystems
  - terrestrial: tundra, boreal forest and mountain regions because of sensitivity to warming; Mediterranean-type ecosystems because of reduction in rainfall; and tropical rainforests where precipitation declines
  - coastal: mangroves and salt marshes, due to multiple stresses
  - marine: coral reefs due to multiple stresses; the sea ice biome because of sensitivity to warming
- Water resources in some dry regions at mid-latitudes and in the dry tropics, due to changes in rainfall and evapotranspiration, and in areas dependent on snow and ice melt agriculture in low-latitudes, due to reduced water availability.
- Low-lying coastal systems, due to threat of sea level rise and increased risk from extreme weather events.
- Human health in populations with low adaptive capacity.

Altered frequencies and intensities of extreme weather, together with sea level rise, are expected to have mostly adverse effects on natural and human systems.
Examples for selected extremes and sectors are shown in **Table 6.1-3.** These do not take into account any changes or developments in adaptive capacity. The likelihood estimates in column two relate to the phenomena listed in column one.

Table 6.1-3. Examples of possible impacts of climate change due to changes in extreme weather and climate events, based on projections to the mid- to late 21st century.

Phenomenon[a] and direction of trend	Likelihood of future trends based on projections for 21[st] century using SRES scenarios	Examples of major projected impacts by sector			
		Agriculture, forestry and ecosystems	Water resources	Human health	Industry, settlement and society
Over most land areas, warmer and fewer cold days and nights, warmer and more frequent hot days and nights	*Virtually certain*[b]	Increased yields in colder environments; decreased yields in warmer environments; increased insect outbreaks	Effects on water resources relying on snowmelt; effects on some water supplies	Reduced human mortality from decreased cold exposure	Reduced energy demand for heating; increased demand for cooling; declining air quality in cities; reduced disruption to transport due to snow, ice; effects on winter tourism
Warm spells/heat waves. Frequency increases over most land areas	*Very likely*	Reduced yields in warmer regions due to heat stress; increased danger of wildfire	Increased water demand; water quality problems, e.g. algal blooms	Increased risk of heat-related mortality, especially for the elderly, chronically sick, very young and socially isolated	Reduction in quality of life for people in warm areas without appropriate housing; impacts on the elderly, very young and poor
Heavy precipitation events. Frequency increases over most areas	*Very likely*	Damage to crops; soil erosion, inability to cultivate land due to waterlogging of soils	Adverse effects on quality of surface and groundwater; contamination of water supply; water scarcity may be relieved	Increased risk of deaths, injuries and infectious, respiratory and skin diseases	Disruption of settlements, commerce, transport and societies due to flooding; pressures on urban and rural infrastructures; loss of property
Area affected by drought increases	*Likely*	Land degradation; lower yields/crop damage and failure; increased livestock deaths; increased risk of wildfire	More widespread water stress	Increased risk of food and water shortage; increased risk of malnutrition; increased risk of water-and food-borne diseases	Water shortage for settlements, industry and societies; reduced hydropower generation potentials; potential for population migration
Intense tropical cyclone activity increases	*Likely*	Damage to crops; windthrow (uprooting) of trees; damage to coral reefs	Power outages causing disruption of public water supply	Increased risk of deaths, injuries, water- and food-borne diseases; post-traumatic stress disorders	Disruption by flood and high winds; withdrawal of risk coverage in vulnerable areas by private insurers, potential for population migrations, loss of property
Increased incidence of extreme high sea level (excludes tsunamis)[c]	*Likely*[d]	Salinisation of irrigation water, estuaries and freshwater systems	Decreased freshwater availability due to saltwater intrusion	Increased risk of deaths and injuries by drowning in floods; migration-related health effects	Costs of coastal protection versus costs of land-use relocation; potential for movement of populations and infrastructure; also see tropical cyclones above

Notes:
a) See WGI Table 3.7 for further details regarding definitions.
b) Warming of the most extreme days and nights each year.
c) Extreme high sea level depends on average sea level and on regional weather systems. It is defined as the highest 1% of hourly values of observed sea level at a station for a given reference period.
d) In all scenarios, the projected global average sea level at 2100 is higher than in the reference period. The effect of changes in regional weather systems on sea level extremes has not been assessed.

Anthropogenic warming could lead to some impacts that are abrupt or irreversible, depending upon the rate and magnitude of the climate change. Partial loss of ice sheets on polar land could imply meters of sea level rise, major changes in coastlines and inundation of low-lying areas, with greatest effects in river deltas and low-lying islands. Such changes are projected to occur over millennial time scales, but more rapid sea level rise on century time scales cannot be excluded.

Climate change is likely to lead to some irreversible impacts. There is medium confidence that approximately 20-30% of species assessed so far are likely to be at increased risk of extinction if increases in global average warming exceed 1.5-2.5°C (relative to 1980-1999). As global average temperature increase exceeds about 3.5°C, model projections suggest significant extinctions (40-70% of species assessed) around the globe.

Based on current model simulations, the meridional overturning circulation (MOC) of the Atlantic Ocean will very likely slow down during the 21st century; nevertheless temperatures over the Atlantic and Europe are projected to increase. The MOC is very unlikely to undergo a large abrupt transition during the 21stcentury. Longer-term MOC changes cannot be assessed with confidence. Impacts of large-scale and persistent changes in the MOC are likely to include changes in marine ecosystem productivity, fisheries, ocean CO_2 uptake, oceanic oxygen concentrations and terrestrial vegetation. Changes in terrestrial and ocean CO_2 uptake may feedback on the climate system.

The five "reasons for concern" identified originally in the IPCC's Third Assessment Report (TAR) remain a viable framework to consider key vulnerabilities. These "reasons" are assessed here to be stronger than in the TAR. Many risks are identified with higher confidence. Some risks are projected to be larger or to occur at lower increases in temperature.

Understanding about the relationship between impacts (the basis for "reasons for concern" in the TAR) and vulnerability (that includes the ability to adapt to impacts) has improved. This is due to more precise identification of the circumstances that make systems, sectors and regions especially vulnerable, and growing evidence of the risks of very large impacts on multiple century time scales.

- **Risks to unique and threatened systems.** There is new and stronger evidence of observed impacts of climate change on unique and vulnerable systems (such as polar and high mountain communities and ecosystems), with increasing levels of adverse impacts as temperatures increase further. An increasing risk of species extinction and coral reef damage is projected with higher confidence than in the TAR as warming proceeds. There is medium confidence that approximately 20-30% of plant and animal species assessed so far are likely to be at increased risk of extinction if increases in global average temperature exceed 1.5-2.5°C over 1980-1999 levels. Confidence has increased that a 1-2°C increase in global mean temperature above 1990 levels (about 1.5-2.5°C above pre-industrial) poses significant risks to many unique and threatened systems including many biodiversity hotspots. Corals are vulnerable to thermal stress and have low adaptive capacity. Increases in sea surface temperature of about 1-3°C are projected to result in more frequent coral bleaching events and widespread mortality, unless there is thermal adaptation or acclimatization by corals. Increasing vulnerability of indigenous communities in the Arctic and small island communities to warming is projected.
- **Risks of extreme weather events.** Responses to some recent extreme events reveal higher levels of vulnerability than the TAR. There is now higher confidence in the projected increases in droughts, heat waves, and floods as well as their adverse impacts.

- **Distribution of impacts and vulnerabilities.** There are sharp differences across regions and those in the weakest economic position are often the most vulnerable to climate change. There is increasing evidence of greater vulnerability of specific groups such as the poor and elderly in not only developing but also developed countries. Moreover, there is increased evidence that low-latitude and less-developed areas generally face greater risk, for example in dry areas and megadeltas.
- **Aggregate impacts.** Compared to the TAR, initial net market-based benefits from climate change are projected to peak at a lower magnitude of warming, while damages would be higher for larger magnitudes of warming. The net costs of impacts of increased warming are projected to increase over time.
- **Risks of large-scale singularities.** There is high confidence that global warming over many centuries would lead to a sea level rise contribution from thermal expansion alone which is projected to be much larger than observed over the 20th century, with loss of coastal area and associated impacts. There is better understanding than in the TAR that the risk of additional contributions to sea level rise from both the Greenland and possibly Antarctic ice sheets may be larger than projected by ice sheet models and could occur on century time scales. This is because ice dynamical processes seen in recent observations but not fully included in ice sheet models assessed in AR4 could increase the rate of ice loss.

There is high confidence that neither adaptation nor mitigation alone can avoid all climate change impacts; however, they can complement each other and together can significantly reduce the risks of climate change.

Adaptation is necessary in the short and longer term to address impacts resulting from the warming that would occur even for the lowest stabilization scenarios assessed. There are barriers, limits and costs, but these are not fully understood. Unmitigated climate change would, in the long term, be likely to exceed the capacity of natural, managed and human systems to adapt. The time at which such limits could be reached will vary between sectors and regions. Early mitigation actions would avoid further locking in carbon intensive infrastructure and reduce climate change and associated adaptation needs.

Many impacts can be reduced, delayed or avoided by mitigation. Mitigation efforts and investments over the next two to three decades will have a large impact on opportunities to achieve lower stabilization levels.

Delayed emission reductions significantly constrain the opportunities to achieve lower stabilization levels and increase the risk of more severe climate change impacts.
In order to stabilize the concentration of GHGs in the atmosphere, emissions would need to peak and decline thereafter. The lower the stabilization level, the more quickly this peak and decline would need to occur.

Sea level rise under warming is inevitable. Thermal expansion would continue for many centuries after GHG concentrations have stabilized, for any of the stabilization levels assessed, causing an eventual sea level rise much larger than projected for the 21st century. The eventual contributions from Greenland ice sheet loss could be several meters, and larger than from thermal expansion, should warming in excess of 1.9-4.6°C above pre-industrial be sustained over many centuries. The long time scales of thermal expansion and ice sheet response to warming imply that stabilization of GHG concentrations at or above present levels would not stabilize sea level for many centuries.

Ocean Acidification

another global change issue relates to changes in the earth's carbon budget and cycle. Carbon cycles through the earth's ecosystems in organic and inorganic forms. Recent increasing trends in carbon dioxide in the earth's atmosphere is shifting the cycle of carbon in the ocean and increasing carbonic acid and a gradual decrease in ocean pH and calcium carbonate. Experimental evidence suggests that if these trends continue, key marine organisms, such as corals and some plankton, will have difficulty maintaining their external calcium carbonate skeletons (Orr et al. 2005).

According to the Intergovernmental panel on Climate Change (2007), the uptake of anthropogenic carbon since 1750 has led to the ocean becoming more acidic with an average decrease in pH of 0.1 units. Increasing atmospheric CO_2 concentrations lead to further acidification. Projections based on SRES scenarios give a reduction in average global surface ocean pH of between 0.14 and 0.35 units over the 21st century. While the effects of observed ocean acidification on the marine biosphere are as yet undocumented, the progressive acidification of oceans is expected to have negative impacts on marine shell-forming organisms (e.g., corals) and their dependent species.