6.2 Adverse impacts of fishing activities under South Atlantic Council Fishery Management Plans

(excerpted from Barnette 2001)

All fishing has an effect on the marine environment, and therefore the associated habitat. Fishing has been identified as the most widespread human exploitative activity in the marine environment (Jennings and Kaiser 1998), as well as the major anthropogenic threat to demersal fisheries habitat on the continental shelf (Cappo et al. 1998). Fishing impacts range from the extraction of a species which skews community composition and diversity to reduction of habitat complexity through direct physical impacts of fishing gear.

The nature and magnitude of the effects of fishing activities depend heavily upon the physical and biological characteristics of a specific area in question. There are strict limitations on the degree to which probable local effects can be inferred from the studies of fishing practices conducted elsewhere (North Carolina Division of Marine Fisheries 1999). The extreme variability that occurs within marine habitats confounds the ability to easily evaluate habitat impacts on a regional basis. Obviously, observed impacts at coastal or nearshore sites should not be extrapolated to offshore fishing areas because of the major differences in water depth, sediment type, energy levels, and biological communities (Prena et al. 1999). Marine communities that have adapted to highly dynamic environmental conditions (e.g., estuaries) may not be affected as greatly as those communities that are adapted to stable environmental conditions (e.g., deep water communities). While recognizing the pitfalls that are associated with applying the results of gear impact studies from other geographical areas, due to the lack of sufficient and specific information within the Southeast Region it is necessary to review and carefully interpret all available literature in hopes of improving regional knowledge and understanding of fishery-related habitat impacts.

In addition to the environmental variability that occurs within the regions, the various types of fishing gear and how each is utilized on various habitat types affect the resulting potential impacts. For example, trawls vary in size and weight, as well as their impacts to the seabed. Additionally, the intensity of fishing activities needs to be considered. Whereas a single incident may have a negligible impact on the marine environment, the cumulative effect may be much more severe. Within intensively fished grounds, the background levels of natural disturbance may have been exceeded, leading to long-term changes in the local benthic community (Jennings and Kaiser 1998). Collie (1998) suggested that, to a large extent, it is the cumulative impact of bottom fishing, rather than the characteristics of a particular gear, that affects benthic communities. Unfortunately, a limitation to many fishing-related impact studies is that they do not measure the long term effects of chronic fishing disturbance. Furthermore, one of the most difficult aspects of estimating the extent of fishing impacts on habitat is the lack of high-resolution data on the distribution of fishing effort (Auster and Langton 1999).

The effects of fishing can be divided into short-term and long-term impacts. Short-term impacts (e.g., sediment resuspension) are usually directly observable and measurable while long-term impacts (e.g., effects on biodiversity) may be indirect and more difficult to quantify. Even more difficult to assess would be the cascading effects that fishery-related impacts may have on the marine environment. Additionally, various gears may indirectly impact EFH. Bycatch disposal and ghost fishing are two of the more well-documented indirect impacts to EFH. While recognizing that these are serious issues that pertain to habitat, this review does not attempt to discuss these due to the secondary nature of the impacts.

The majority of existing gear impact studies focus on mobile gear such as trawls and dredges. On a regional scale, mobile gear such as trawls impact more of the benthos than any other gear. However, other fishing practices may have a more significant ecological effect in a particular area due to the nature of the habitat and fishery. Yet there are few studies that investigate other gear types, especially static gear. Rogers et al. (1998) stated that there are few accounts of the physical contact of static gear having measurable effects on benthic biota, as the area of sea bed affected by each gear is almost insignificant compared to the widespread effects of mobile gear. Regardless, static gear may negatively affect EFH and, therefore, must be considered.

The exact relationship that particular impacts have on the associated community and productivity is not fully understood. While it is clear that fishing activities impact or alter EFH, the result of those impacts or the degree of habitat alteration that still allow for sustainable fishing is unknown (Dayton et al. 1995; Auster et al. 1996; Watling and Norse 1998). Hall (1994) noted that not all impacts are negative. A negative effect at one level may sometimes be viewed as a positive effect at a higher level of biological organization – particular species may be removed in small-scale disturbances yet overall community diversity at the regional scale may rise because disturbance allows more species to coexist.

6.2.1 Fishing Gear Regulations under Council FMPs

The following is a list of gear currently in use (or regulated) in fisheries managed under the South Atlantic Council fishery management plans. In general, if gear is not listed it is prohibited or not commonly used in the fishery:

<u>Snapper Grouper Fishery</u>
Vertical hook-and-line gear, including hand-held rod and manual or electric reel or “bandit gear” with manual, electric or hydraulic reel (recreational and commercial).

Spear fishing gear without rebreathers (recreational and commercial).

Powerheads, except where expressly prohibited in Special Management Zones (SMZs). In addition, the use of explosive charges, including powerheads, is prohibited in the EEZ off South Carolina (recreational and commercial).

Bottom longlines (commercial). Prohibited south of a line running east of St. Lucie Inlet, Florida (27° 10’ N. lat.) and in depths less than 50 fathoms north of that line. May not be used to fish for wreckfish.

Sea bass pots (commercial). May not be used or possessed in multiple configurations. Pot size, wire mesh size and construction restrictions. May not be used in the EEZ south of a line running due east of the NASA Vehicle Assembly Building, Cape Canaveral, Florida (28° 35.1’ N. lat.).

Special Management Zones (created under the Snapper Grouper FMP). Sea bass pots are prohibited in all Special Management Zones. Fishing may only be conducted with hand-held hook-and-line gear (including manual, electric, or hydraulic rod and reel) and spearfishing gear in specified Special Management Zones; however, in other specified Special Management Zones a hydraulic or electric reel that is permanently affixed to a vessel ("bandit gear") and/or spear fishing gear (or only powerheads) are prohibited.

<u>Shrimp</u>
Penaeid shrimp trawls (commercial). The Shrimp Fishery Management Plan allows North and South Carolina, Georgia and east Florida to request a closure in federal waters adjacent to closed state waters for brown, pink or white shrimp following severe cold weather that results in an 80% or greater reduction in the population of white shrimp (whiting, royal red and rock shrimp fisheries are exempt from a federal closure for white shrimp). During a federal closure, a buffer zone is established extending seaward from shore to 25 nautical miles, inside of which no trawling is allowed with a net having less than 4" stretch mesh. Vessels trawling inside this buffer zone cannot have a shrimp net aboard (i.e., a net with less than 4" stretch mesh) in the closed portion of the federal zone. Transit of the closed federal zone with less than 4" stretch mesh aboard while in possession of penaeid (white, brown and pink) species will be allowed provided that the nets are in an unfishable condition, which is defined as stowed below deck. Specified areas are closed to trawling for rock shrimp.

Rock shrimp trawls (commercial). The minimum mesh size for the cod end of a rock shrimp trawl net in the South Atlantic EEZ off Georgia and Florida is 1-7/8 inches (4.8 cm), stretched mesh. This minimum mesh size is required in at least the last 40 meshes forward of the cod end drawstring (tie off strings), and smaller mesh bag liners are not allowed. A vessel that has a trawl net on board that does not meet these requirements may not possess a rock shrimp in or from the South Atlantic EEZ off Georgia and Florida.

Bycatch Reduction Devices (BRDs). On a penaeid shrimp trawler in the South Atlantic EEZ, each trawl net that is rigged for fishing and has a mesh size less than 2.5", as measured between the centers of opposite knots when pulled taut, and each try net that is rigged for fishing and has a headrope length longer than 16.0 ft. must have a certified BRD installed. The following BRDs are certified for use by penaeid shrimp trawlers in the South Atlantic EEZ: extended funnel, expanded mesh and fisheye.

As of January 12, 2007, on a vessel that fishes for or possesses rock shrimp in the South Atlantic EEZ, each trawl net or try net that is rigged for fishing must have a certified BRD installed.

Turtle Excluder Devices (TEDs). TEDs are required for the penaeid and rock shrimp fisheries.

<u>Red Drum</u>
No harvest or possession is allowed in or from the EEZ (no gear specified).

<u>Golden Crab</u>

Crab traps (commercial). May not be fished in water depths less than 900 feet in the northern zone and 700 feet in the middle and southern zones. Rope is the only allowable material for mainlines and buoy line. Max. trap size equals 64 cubic feet in volume in the Northern zone and 48 cubic feet in volume in the Mid and Southern zones. Traps must have at least 2 escape gaps or rings and an escape panel. Traps must be identified with a permit number.

Coral, Coral Reefs, and Live/Hard Bottom Habitat
Hand harvest only for allowable species (recreational and commercial). A toxic chemical may not be used or possessed in a coral area in the EEZ. A power-assisted tool may not be used to take prohibited coral, allowable octocoral or live rock.

Oculina Bank Habitat Area of Particular Concern: Fishing with bottom longlines, bottom trawls, dredges, pots or traps is prohibited. Fishing vessels may not anchor, use an anchor and chain, or use a grapple and chain.

Coastal Migratory Pelagics
Hook and line gear, usually rod and reel or bandit gear, hand lines, flat lines etc. (recreational and commercial).

Run-around gillnets or sink nets (commercial). A gillnet must have a float line less than 1,000 yards in length to fish for coastal migratory pelagic species. Gillnets must be at least 4-3/4 inch stretch mesh.

Purse seines for other coastal migratory species (commercial) with an incidental catch allowance for Spanish mackerel (10%) and king mackerel (1%).

For Atlantic king mackerel (commercial) north of the Cape Lookout, NC Light (34° 37.3' N. lat.) all gear is authorized except for drift gillnets and long gillnets. South of the Cape Lookout Light the following gear is authorized: **automatic reel, bandit gear, handline, rod & reel.**

For Spanish mackerel (commercial) **automatic reel, bandit gear, handline, rod & reel, cast net, run around gill net and stab net**. Minimum size of 3.5" stretch mesh required for all run around gill nets.

Spiny Lobster
Traps, hand harvest, dip nets and bully nets (recreational and commercial). No poisons or explosives are allowed. No spear, hooks or piercing devices are allowed.
A degradable panel is required on non-wooden traps. Traps may not be tended at night. Buoy and trap identification is required.

Dolphin and Wahoo
Pelagic longline, hook and line gear including manual, electric, or hydraulic rod and reels, bandit gear, handline and spearfishing gear (including powerheads). Surface and pelagic longline gear for dolphin and wahoo is prohibited within any "time area closure" in the Atlantic EEZ which is closed to the use of pelagic gear for highly migratory pelagic species (HMS) (commercial).

Sargassum
Nets used to harvest Sargassum be constructed of 4” stretch mesh or larger fitted to a frame no larger than 4 x 6 feet.

6.2.2 Gear Descriptions

6.2.2.1 Mobile Gear

(excerpted from Barnette 2001)

Crab Scrape

A crab scrape is composed of a net bag attached to a rigid frame with short teeth (Figure 1). This gear, used exclusively in state waters, is dragged in the shallow water of bays and estuaries to catch crabs. There are no studies available that document potential damage to habitat. However, due to their design, their use in SAV would likely result in the potential uprooting of some plants, as well as leaf shearing (Barnette, personal observations). However, crab scrapes are not typically employed in vegetated areas due to the amount of plant litter that would fill the net. Penetration of the benthos by the teeth would result in sediment resuspension.

Frame Trawl

Roller frame trawls are primarily utilized to harvest bait shrimp in the State of Florida. They consist of a frame that holds open a net and supports slotted rollers that grip the bottom and turn freely. This motion prevents the scouring and scraping impacts primarily associated with otter trawls. Because participants in the fishery usually operate in shallow water, 9.14 m (30 ft) or less, frame trawls are typically limited to state waters.

A study by Futch and Beaumariage (1965) found that while frame trawls gathered large amounts of unattached algae and deciduous *Thalassia testudinium* leaves, no SAV with roots attached were found in the trawl catch.

Trawls with larger rollers (20.3cm; 8 in diameter) reduced the amount of bycatch material, with most drags uprooting SAV. Damage to SAV beds was noted on several occasions when the boats ran aground. The study concluded that side frame trawls do negligible damage to SAV beds. This conclusion was supported by Meyer et al. (1991; 1999), who found no significant trawl impacts on shoot density, structure, or biomass with increased trawling on turtlegrass (*Thalassia testudinium*). However, these studies did not evaluate the effects of repetitive trawling.

Woodburn et al. (1957) noted that the roller on the bottom of the trawl does cause the leaves ripe for shedding to break off, though this would not negatively impact the plant itself. Higman (1952) concluded that frame trawling is not sufficient to denude vegetated areas permanently or to damage the ecology of such locations. Additionally, Tabb and Kenny (1967), while not explicitly investigating habitat impacts, believed that roller frame trawls do no significant damage to habitat. In contrast to studies that assessed impacts to SAV, Tilmant (1979) found a high incidence of damage to stony corals in a study that investigated frame trawl impacts to hard bottom habitat in Biscayne Bay. Frame trawls turned over or crushed 80% of *Porites porites* and

Solenastrea hyades and damaged over 50% of sponges and 38% of gorgonians in the trawl path. Macroalgae, including *Halimeda* and *Sargassum*, were heavily damaged. The primary impact on *Sargassum* was that it was torn loose from the bottom resulting in an early release to the free floating state. Tilmant (1979) found it doubtful that this action was harmful to *Sargassum* unless it occurred during early column formation. It was concluded that frame trawls have a significant impact on certain benthic organisms (Tilmant 1979).

Furthermore, within dense SAV communities, removal of epibenthic algae, tunicates, sponges, and other primary producers may also be significant. Futch and Beaumariage (1965) recommended that the diameter of the rollers be no less than 15.2cm (6in) and that the teeth of the rakes on the trawls should not extend below the roller. Furthermore, they recommend that boats employed in the frame trawl fishery that operate in shallow water should be of tunneled construction to prevent damage to SAV from propeller scarring. Tabb (1958) recommended that strainer bars should be rigid and aimed into the roller so that regardless of how far forward the net frame tips, the bars cannot dig into the bottom. The results from Tilmant (1979) indicated that extensive damage occurs to hardbottom habitat from frame trawls.

A logical recommendation that can be extrapolated from this study is the prohibition of frame trawling in areas where hardbottom habitat exists. Frame trawls, while causing negligible damage to SAV, are not compatible with hardbottom areas due to the damage it causes to complex vertical habitat (e.g., sponges, corals, gorgonians).

Prohibition on the use of bottom trawls

The use of trawl gear to harvest fish in the directed snapper grouper fishery south of Cape Hatteras, North Carolina (35°15' N. Latitude) and north of Cape Canaveral, Florida (Vehicle Assembly Building, 28°35.1' N. Latitude) is prohibited (SAFMC 1987). A vessel with trawl gear and more than 200 lbs of fish in the snapper grouper fishery on board will be defined as a directed fishery. The amendment also establishes a rebuttable presumption that a vessel with fish in the snapper grouper fishery on board harvested its catch of such fish in the Exclusive Economic Zone.

The Council based the trawl prohibition on habitat destruction and the desire to prevent overfishing of vermilion snapper. Fishes present in live bottom areas are described by Grimes et al. (1982) and include 113 species representing 43 families of predominantly tropical and subtropical fishes. Vermilion snapper were more abundant on the shelf edge than on the open shelf (Grimes et al. 1982). Miller and Richards (1980) described the distribution of live bottom habitat in the South Atlantic Bight and reported the most productive area of the shelf for commercial reef fish as being in the open shelf zone between 33 and 40 meters. Parker et al. (1983) reported on a survey of the areas from Cape Canaveral, Florida to Cape Fear, North Carolina and from Cape Fear to Cape Hatteras, North Carolina. From Cape Hatteras to Cape Fear 14,486 square km between 27 and 101 m were surveyed and contained 2,040 square km (14%) of reef habitat of which only 204 square km (10%) had one meter or more relief (distance from the highest point of the live bottom to the ocean floor). In the area from Cape Fear to Cape Canaveral, 24,826 square km between 27 and 101 m were surveyed and contained 7,403 square km (30%) of reef habitat of which 1,743 square km (7%) had one meter or more relief. The Oregon II cruise report (Anon. 1978) supports the scattered nature of live bottom in the South

Atlantic from Cape Canaveral, Florida to Cape Hatteras, North Carolina. The Fishery Management Plan reported that in terms of the entire shelf area, current data suggest that from three to 30% of the shelf is suitable bottom for snapper grouper species (SAFMC 1983a).

The report on effects of a research trawl on live bottom (Van Dolah et al. 1987) documents that habitat damage does occur from the use of trawl gear even in the case of one pass through an area in a controlled study. The abstract is as follows:

"The effects of a research trawl on several sponge and coral species was assessed in a shallow-water, hard-bottom area located southeast of Savannah, Georgia. The study entailed a census of the numerically dominant species in replicate 25-square meter quadrants located along five transects established across a trawling alley. The density of undamaged sponges and corals was assessed in trawled and non-trawled (control) portions of each transect immediately before, immediately after, and 12 months after a 40/54 roller-rigged trawl was dragged through the alley once. Some damage to individuals of all target species was observed immediately after trawling, but only the density of barrel sponges (*Cliona* spp.) was significantly reduced. The extent of damage to the other sponges (*Ircinia campana*, *Haliclona oculata*), octocorals (*Leptogorgia virgulata*, *Lophogorgia hebes*, *Titanideum frauenfeldii*) and hard corals (*Oculina varicosa*) varied depending on the species, but changes in density were not statistically significant. Twelve months after trawling, the abundance of specimens counted in the trawled quadrants had increased to pre-trawl densities or greater, and damage to the sponges and corals could no longer be detected due to healing and growth. Trawl damage observed in this study was less severe than the damage reported for a similar habitat in a previous study. Differences between the two studies are attributed to (1) differences in the roller-rig design of the trawls used, and (2) differences in the number of times the same bottom was trawled."

The authors point out that in a study by Tilmant (1979) looking at the effects of commercial bait shrimping with roller-frame trawls in a shallow-water area of Biscayne Bay, Florida damage was much more severe: "Tilmant observed severe damage (specimens crushed or torn loose) to more than 80% of the stony corals, 50% of the sponges and 38% of the soft corals along the trawl path." It should be noted however, that this frame trawl consists of a solid, rectangular frame to which a net is attached and is used to fish grass bed areas; it was not designed to "roll over" live bottom and would be expected to cause significant damage to corals, etc.

Importantly, habitat damage described by Van Dolah et al. (1987) resulted from one tow of trawl gear through the study area. That study was designed to evaluate the effects of a research trawl that does not typically cross the same bottom area more than once. Commercial trawling does not operate in this manner. Under commercial fishing conditions, a live bottom area would be fished over and over until the catches from such an area become unprofitable. Under such conditions, habitat damage would be expected to be much greater than is indicated from the above study.

The *Oregon II* cruise report (Anon. 1978) indicated that drags with a trawl yielded a total catch of 476 lbs which included 424 lbs of finfish and 46 lbs of sponges and corals (10% of the total catch). This area was reported to have been on a mud bottom but turned out to be a low profile live bottom of sand ridges, clumps of sponges and scattered corals. Further indication of habitat damage is reported by Wenner (1983):

“The 3/4 Yankee trawl net effectively covers a much wider area of the bottom than the measured sweep (8.7 m) due to the configuration of the otter doors, ground cables, and bottom leg lines. Although this arrangement cannot increase the actual spread of the net beyond the headrope length, the passage of these cables over the substrate creates a disturbance that serves to herd fish in the path of the net (Baranov 1969). This net does, however, damage the sponge-coral habitat by shearing off sponges, soft corals, bryozoans, and other attached invertebrates. The 56 trawl tows made in the sponge-coral habitat for this study collected 2,351 kg of attached invertebrates (including sponges, soft corals, tunicates, bryozoans, and hydroids) yielding an average 42 kg/tow. This is only the amount of bottom material actually removed from the habitat. An estimate of the total amount of bottom destroyed by the doors, ground cables, and leg lines cannot be ascertained from the current study.

Personal observations and interviews with commercial fishermen attest to the productivity of the sponge-coral habitat. Most studies indicate the importance of habitat availability and space in determining the abundance and diversity of reef fishes (Emery 1978). With this in mind, and given the knowledge that 1) the use of the 3/4 Yankee trawl net reduces the amount of attached invertebrate growth (the amount damaged by doors and ground cables is presently not quantifiable); 2) the places where the invertebrates had been attached may be sanded over and rendered unsuitable for recolonization; and 3) the removal of these attached invertebrates reduces refugees for decapods, polychaetes, etc., that are food items for *Centropristis striata* and other benthic feeders, one must conclude that the continued use of this trawl net reduces the amount of productive fish habitat. For these reasons, in addition to the ineffectiveness of the gear in sampling commercially important species, alternate nondestructive methods, such as direct observations or the use of mark-recapture techniques with trap catches, should be employed in assessment surveys of the commercially important species of this habitat.”

Results of trawl survey work in Australia provide some insight into what can happen to catches in an area after the continued use of commercial trawl gear. Young and Sainsbury (1985) report that "At moderate to low levels of fishing effort, the main effect of fishing on the relative abundance of bottom shelf fishes is by alteration of the relative frequency and spatial distribution of habitat types. In particular this refers to the conversion of areas with dense epibenthos (sponge, corals, hydroids, gorgonians) to areas with sparse epibenthos. (It may be noted that even at the relatively low intensity of trawling of the past few years the fishing effort exerted on the main trawl grounds is sufficient to sweep 50 to 100 per cent of the area of those grounds per year.)." These results are from trawling conducted in 1982 as compared to trawl catches in 1966 from the same locations and at the same time of year. The catch composition shifted from species associated with sponges, soft corals, etc. (during 1966) to those associated with open sandy bottom (during 1982).

A similar type of scenario for the South Atlantic was suggested by Bob Low (pers. comm.): “Parker et al. (1983) estimated that, in the area they surveyed between Cape Fear and Cape Canaveral, there were 7,403 square km of reef habitat. Of this, 1,743 square km had an average profile exceeding 1 m. Assuming that such ground could not be trawled, this leaves about 5,660 square km (1,398,000 acres) of trawlable reef habitat. The average boat might pull a net with a footrope of 120 feet, giving an effective sweep of the roller gear of about 72 feet maximum. A typical tow over open bottom is perhaps 3 hours at 2 knots. The area swept by the roller gear per tow is then about 20 acres/hour or 60 acres/tow. Assume that 20 boats participate for 4 months (January-April) each year. [Note: The actual number of vessels during 1987 was seven.] The average vessel makes 3 trips/month, with 3 days of fishing each trip. The average (24 hr) fishing day includes perhaps 4 tows. A typical trip therefore consists of 12 tows or 36 hr of fishing. The 20 boats make an aggregate of 240 trips. This equates to 2,880 tows, covering around 172,800 total acres. If each tow was over a previously unswept area, the total area covered by the roller gear would then amount to about 12% of the trawlable reef habitat estimated by Parker et al. (1983). Under one set of assumptions, the area affected by the doors, bridles, and warps would add to this. Under a second set, repetitive trawling over identical areas would reduce the total area impacted. Van Dolah et al. (1987) noted a substantial renewability within a year. There are likely to be 8 months of recovery time between trawling seasons. Doesn't that allow for significant restoration in many of the trawled areas?"

The above scenario indicated that about 12% of available habitat between Cape Fear and Cape Canaveral would be impacted annually by trawling, whereas in the Australian work the area impacted was between 50 and 100%. The Council has concluded that the level of damage to the live-bottom habitat in the South Atlantic is significant and that our available knowledge is not sufficient to risk impacting the long-term abundance of snapper and groupers by reducing their habitat. The results shown by Van Dolah et al. (1987) indicated that regeneration of tissue sufficient to have rounded off the tops of partially severed sponges and to have closed wounds on other sponges occurs within a year but that additional growth is limited as indicated by some of the sponges being obviously shorter than before the trawling damage. This supports the Council's concern because in a four month trawling season there would be a net loss of habitat (i.e., more damage than regrowth) with the effects being cumulative over time. By destroying habitat we destroy the productivity of the resource being harvested and we are in essence drawing on the principal, not just taking the interest so that next year the same amount of trawling will represent more than 12% of the habitat and the year after even more. Given this information, the South Atlantic Fishery Management Council concluded that over the long-term there would be a net loss of existing habitat, which is counter to the Council's habitat policy and the Magnuson-Stevens Act.

Indirect evidence of habitat damage is provided in Christian et al. (1985) where they report on attempts to use crab nets rigged with light chain and plastic mud rollers. These nets proved to be inadequate for offshore fish trawling on broken bottom because the light molded plastic mud rollers were not durable and did not prevent net damage. They further reported that captains who tried crab nets soon switched to nets with heavy netting, properly rigged sweep systems and steel vee-doors for trawling over rough bottom. Further indication of habitat damage was presented in Section II of Snapper Grouper Amendment 1 with the numerous references to gear damage, gear loss and the need to use rollers and modified doors to be able to trawl in rough and broken areas.

An additional reference concerning potential habitat damage is provided by Moore and Bullis (1960) when they reported on the discovery of a deep water reef in the Gulf of Mexico. The MV *Oregon* was cruising over the continental slope about 40 nautical miles due east of the

Mississippi Delta and observed an unusual tracing on the depth recorder. They sampled this bottom area using a shrimp trawl and reported the following: "A drag, made over the area with a shrimp trawl, contained a large mass of coral, other invertebrates, and fish. The netting of the trawl was torn and most of its contents were lost, but about three hundred lbs of coral remained in the bag. A sample was brought back to the laboratory where it was identified by Moore as *Lophelia prolifera*."

Invertebrates associated with sponges and corals occur in disproportionately high densities which suggest that they may use sponges and corals as a food source or a refuge from predation (Wendt et al. 1985). These invertebrates in turn serve as a food source for various snapper and grouper species. In addition, corals are very slow growing with some such as *Oculina* sp. only growing between 11 and 16 mm per year (Reed 1981). Damage to these areas can negatively affect the food and shelter available to snappers and groupers. Further, Grimes et al. (1982) note the importance of the live bottom and shelf edge habitats in serving as reservoirs for recruits in shallow areas (less than 30 m).

The best estimate of the number of boats operating in the fishery during the winter of 1986/87 was four boats (one South Carolina boat fishing in South Carolina and three North Carolina boats fishing in South Carolina, Georgia and Florida). The number of vessels increased to seven during the winter of 1987/88. These vessels fished during the slow period for shrimp which is normally January to March/April. Even though the actual number of boats is small, the amount of habitat damage is significant when one realizes that these boats fish directly on the limited live bottom habitat in these areas. Productive snapper grouper habitat on the continental shelf is limited and trawl gear is fished repeatedly in these areas over this three to four month period. Most, if not all, fishermen use Loran which allows them to return to the exact spot and trawl a particular rock out-cropping repeatedly. The data previously described from Australia points out the changes to bottom habitat and catches resulting from such a fishery.

Vermilion snapper in the early 1980s were experiencing growth overfishing (see SAFMC 1983a p. 44-58 for a more detailed discussion). Yield per recruit (or yield per individual) analysis indicated that a 12 inch minimum size will increase yield per recruit from 132 g to 177 g which is equivalent to a 34% increase in yield if recruitment is constant. Confidential data available to the South Atlantic Council indicated that the minimum mesh size of 4 inches is not being adhered to and as a result the Council's prior action establishing the mesh restriction has not been effective in releasing small vermilion (less than 12 inches). The trawl prohibition will result in an increase in yield for vermilion snapper. Catch data from South Carolina (Bob Low, pers. comm.) show a slight negative correlation between trawl landings and hook & line landings ($r = -0.13$). A good fishery independent index of abundance would allow us to examine the affect of trawl catches on abundance of vermilion snapper. Given the available information, the South Atlantic Fishery Management Council concluded that the trawl prohibition would increase yield; however, our ability to measure this increase is lacking.

The potential existed for more vessels to enter the fishery particularly if the calico scallop, shrimp and sea scallop fisheries have not been productive or are not active during this time period. The actual number of vessels during 1987/88 was seven, greater than the number expected. This further supported the Council's concern that effort could have increased rapidly.

Impacts on affected vessels from prohibiting use of trawl gear in the snapper grouper fishery were not significant. Input from public hearings, committee and Council meetings indicated that income from fish trawling made up a small portion of total income. No trawl fishermen came forward with information during the public hearing process indicating that impacts would be significant. Fishermen used this fishing method primarily as a fill-in activity and had the ability to utilize other gear (e.g., electric & hydraulic reels, black sea bass traps, longlines, etc.) to fish snappers and groupers. These general conclusions are supported by the following in Christian et al. (1985):

"The major seafood industry in the South Atlantic Bight is based on shrimp, and this dependence on one crop has made the industry financially precarious....Therefore, fishermen have looked to other activities such as bottom trawling for finfishes to supplement their income. This is not the single salvation for the whole industry. Although fish trawling can offer an alternative which may aid some shrimpers in maintaining year-round income, suitable trawling bottom in this area is limited, and target species of such a fishery (snapper, grouper, and porgies) are relatively long-lived, slow-growing, and can sustain only limited fishing pressure."

Hydraulic Escalator Dredge

Hydraulic escalator dredges have been utilized since the 1940s to harvest shellfish such as clams and oysters and are designed expressly for efficient commercial harvest (Coen 1995). The dredge consists of a water pump supplying a manifold with numerous water jets mounted in front of a conveyer belt that dislodges buried organisms from the sediment (Figure 3). Hydraulic escalator dredges are currently only employed in a limited shellfish fishery in South Carolina state waters. Hydraulic escalator dredges may penetrate the benthos approximately 45.7cm (18in), thus disturbance to the sediment may be substantial (Coen 1995). Increased turbidity, burial/smothering, release of contaminants, increased nutrients, and removal of infauna were offered as potential effects from dredging activities (Coen 1995). Turbidity was found to be elevated only in the immediate vicinity of the harvester operation and downcurrent of the study area to a distance of between 1.5-1.75km. Turbidity values returned to baseline levels within a few hours (Maier et al. 1998). Manning (1957) stated that hydraulic clam dredging can result in severe damage to oysters within a distance of 7.6m (25ft) downcurrent from the site of dredging. Enough sediment was displaced and redeposited to a distance of at least 15.2m (50ft), but not more than 22.9m (75ft) downcurrent, to cause possible damage to oyster spat. Beyond about 22.9m (75ft) there was no visible or measurable change in the experimental area. Sediment plumes caused by dredge activity were found by Ruffin (1995) to range from less than 1 to 64 hectares. Although sediment plumes increased turbidity and light attenuation at all depths, plumes in shallow water (less than 1.0 m) caused greater increase in turbidity and light attenuation over background than did plumes in deeper waters. Plume decay is based largely on sediment size, with sand particles settling quickly while the silt/clay particles remain in suspension longer. Sites were monitored for storm disturbance to compare against dredge impacts. Storm events increased turbidity and light attenuation com pare d to calm days but not to the extremes obtained in sediment plumes.

Storm events affect a large area at a low intensity while dredging intensely affects a more localized area. SAV subjected to decreased light penetration will inhibit reproduction, reduce propagule abundance, and structurally weaken SAV due to the need of plants growing higher into the water column (Ruffin 1995). Ruffin (1995) concluded that clam dredging increased light attenuation to the point of inhibiting SAV growth. As may be expected, hydraulic clam dredges are highly destructive t o SAV within the immediate area of intensive dredging (Manning 1957; Godcharles 1971). Due to the capability of the water jets to penetrate the substrate to a depth of 45.7cm (18in), virtually all attached vegetation in its path is uprooted (Godcharles 1971). As the use of this gear is limited to a fishery in South Carolina where SAV does not exist, discussion of SAV impacts are included only to provide information on potential impacts should this gear type be considered in the future for other geographic area s where SAV may be found. Although there may be physical impacts associated with escalator dredge activity, the chemical effects apparently are not as dramatic. Dissolved oxygen, pH, and dissolved hydrogen sulfide were measured throughout the harvesting process at varying distances. No consistent patterns of depression or release were noted. Only in the direct plume of the harvester did they measure even a temporary reduction in dissolved oxygen and pH (Coen 1995). While it is recognized that there is infaunal and epifaunal species mortality associated with escalator dredge activity, based on all evidence, these community impacts appear to be short-term (Godcharles 1971; Peterson et al. 1987a; Coen 1995). Coen (1995) noted that the escalator possibly provides a tilling effect of the bottom that has been observed to be beneficial to subtidal oyster and clam populations. Typically, shellfish dredging operations have typically not been considered to have deleterious results, since its effects are perceived to be negligible compared to natural environmental variation (Godwin 1973). Coen (1995) concluded that based on all direct and indirect evidence, the short-term effects of subtidal escalator harvesters are minimal, with no long-term chronic effects, even under worst case scenarios. Observed effects were often indistinguishable from ambient levels or natural variability.

Recovery of the benthos may vary greatly depending on sediment composition. Shallower trenches with shorter residency times are typical of coarse sediments (i.e., sand), whereas trenches generated in muddy, finer sediments are typically deeper, often persisting for greater than 18 months (Coen 1995). Godcharles (1971) observed that trenches had filled in between 1 to 10 months, depending on bottom type. In regard to SAV, no trace of *Thalassia testudinium* recovery was evident after more than 1 year, though *Caulerpa prolifera* began to re-establish itself in dredge areas within 86 days (Godcharles 1971).

Otter Trawl

Perhaps the most widely recognized and criticized type of gear employed in the southeast region is the otter trawl. Utilized in both state and Federal waters of the Gulf of Mexico and South Atlantic, otter trawls pursue invertebrate species such as shrimp and calico scallops, as well as finfish species such as flounder and butterfish. As the most extensively utilized towed bottom-fishing gear (Watling and Norse 1998), trawls have been identified as the most wide-spread form of disturbance to marine systems below depths affected by storms (Watling and Norse 1998; Friedlander et al. 1999).

Jones (1992) broadly classified the way a trawl can affect the seabed as: scraping and ploughing; sediment resuspension; and physical habitat destruction, and removal or scattering of non-target benthos. The following discussion attempts to group documented impacts into either physical-chemical (e.g., sediment resuspension, water quality) or biological impact categories. In many instances documented habitat impacts overlap these categories.

Physical-Chemical Repercussions

The degree to which bottom trawls disturb the sediment surface depends on the sediment type and the relationship between gear type, gear weight, and trawling speed (ICES 1991). Various parts of trawl gear may impact the bottom including the doors, tickler chains, footropes, rollers, trawl shoes, and the belly of the net. While the components of trawl gear are similar, trawl design may vary greatly. Potential impacts may be shared by all otter trawls, but differences in the weight of trawl doors, footrope design, and operation (tow times), will result in a broad spectrum of impact severity. Furthermore, the number and weight of tickler chains vary the degree of disturbance. Margetts and Bridger (1971) concluded that the cumulative effect of tickler chains is likely to emulsify the sediment to a depth proportional to the number of chains. Additionally, the cumulative effect of intense otter trawling is as important as gear weight and design in impacting the benthos (Ball et al. 2000). Although the effect of one passage of a fishing (trawl) net may be relatively minor, the cumulative effect and intensity of trawling may generate long-term changes in benthic communities (Collie et al. 1997). Trawl gear disturbs the benthos as it is dragged along the bottom. Otter trawl doors, mounted ahead and on each side of the net, spread the mouth of the net laterally across the sea floor. The spreading action of the doors results from the angle at which they are mounted, which creates hydrodynamic forces to push them apart and, in concert with the trawl door's weight, also to push them toward the sea bed (Carr and Milliken 1998). The doors, due to their design and function, are responsible for a large proportion of the potential damage inflicted by a trawl. The footrope runs along the bottom of the net mouth and may be lined with lead weight and rollers. On relatively flat bottom, it is expected that the footrope would not have a major effect on the seabed and its fauna (ICES 1995). However, in areas of complex benthic habitat the footrope would likely have more impact with the benthos.

The South Atlantic Draft Calico Scallop FMP noted that during the early years of the calico scallop fishery, large quantities of benthic material were removed by trawlers. Reports were received during numerous meetings about entire "rocks" being removed. One individual provided a print-out from a depth sounder which indicated a large amount of bottom relief in a particular area prior to the calico scallop fishery. Similar bottom plots after the calico scallop fishery operated in that area indicated a relatively flat bottom (SAFMC 1998b). Additionally, while the footrope generally causes little physical substrate alteration aside from smoothing of bedforms and minor compression on relatively flat bottoms (Brylinsky et al. 1994), these minor compressions can lead to sediment "packing" after repeated trawling activity on the same general areas (Schwinghammer et al. 1996; Lindeboom and de Groot 1998). Further compression can result from the dragging of a loaded net (cod end) along the bottom. The remaining path of the trawl is influenced by the ground warps which, while not in direct contact with the seabed, can create turbulence that resuspends sediment (Prena et al. 1999).

Trawl gear, particularly the trawl doors, penetrates the upper layer of the sediments which liquefies the affected sedimentary layers and suspends sediment in the overlying water column. This sediment "cloud" generated by the interaction of the trawl gear with the benthos and the turbulence created in its wake contributes to fish capture (Main and Sangster 1979; 1981). The appearance of the sediment cloud, but not its size, is governed by the type of seabed. Brief observations on different seabed types show that soft, light-colored mud produces the most opaque and reflective type of cloud and the fine mud remains in suspension much longer than coarse sand. Studies of sediment disturbance by trawls vary greatly, though it can be concluded that benthic habitat areas composed of fine sediments (e.g., clay, mud) are affected to a greater degree than those with coarse sediments (e.g., sand). In sandy sediments, otter boards cannot penetrate deeply due to the mechanical resistance of the sediment, and the seabed in sandy areas is more rapidly restored by waves and currents (DeAlteris et al. 1999). Short-term alterations to sediment size distribution result from the various rates of redeposition of suspended sediments; as noted before, coarse grains (i.e., sand) settle out rapidly while fine grains (i.e., silt) settle out relatively slowly. In general, resuspended sediments settle out of the water column at a rate inversely proportional to sediment size (Margetts and Bridger 1971). Transport of fine-grained sediments away from trawled area s due to this slow settling period may result in permanent changes to the sediment grain size of a trawled area. Again, this effect will be more pronounced in mud/silt habitats than in habitat areas consisting of heavier sand. For example, suspended sediment concentrations of 100-500mgl-1 were recorded 100m astern of shrimp trawls in Corpus Christi Bay, Texas (Schubel et al. 1979), an estuary dominated by muddy sediments. The same study estimated that the total amount of sediment disturbed annually as a result of shrimp trawling was 25-209,000,000m^3, which is 10-100 times greater than the amount dredged during the same period for maintenance of shipping channels in the same area.

ICES (1973) concluded that the physical effects of trawling in tidal waters cannot be permanent. However, it is possible that frequently repeated trawling of one ground with a mixed sediment type bottom in strongly tidal waters might ultimately alter the nature of the bottom towards being predominantly coarse sand because the finer particles are carried away to settle elsewhere. In deeper waters, impacts may be more profound and longer lasting. Engel and Kvitek (1998) investigated two adjacent areas in 180m of water to determine the differences between a heavily trawled site and a lightly trawled site. The data indicated that intensive trawling significantly decreased habitat heterogeneity. Rocks and mound s were less common and sediments and shell fragments were more common in the highly trawled area. Rocks and mounds were more abundant in the lightly trawled area, as well as the amount of flocculent matter and detritus. They theorized that less trawling most likely results in an area with more topographical relief and allows for the accumulation of debris, whereas consistent trawling removes rocks, smoothes over mounds, and resuspends and removes debris. Likewise, Kenchington (1995) found that sand ripples were flattened and stones were displaced after a trawl passage. Churchill (1989) modeled sediment resuspension by trawling and found that this may be a primary source of suspended sediment over the outer shelf where storm-related bottom stresses are weak.

Otter trawl doors were found to have a maximum cutting depth of 50 - 300mm (Drew and Larsen 1994) and, according to Schubel et al. (1979), the footropes of shrimp trawlers in Texas disturbed approximately the upper 50mm of the sediment. Schwinghamer et al. (1996) observed that while the trawl doors may leave scours or depressions, trawling activity reduces the overall surface roughness. Ripples, detrital aggregations, and surface traces of bioturbation are smoothed over by the mechanical action of the trawl and the suspension and subsequent deposition of the surface sediment. In general, the passage of an otter trawl was found to have a minor physical and visual impact on the soft sedimentary sea bed, represented by a flattening of the normally mounded sediment surface and some disturbance of the sessile epifauna (Lindeboom and de Groot 1998). The potential to suspend sediments varies greatly, in large part due to the type of sediment a trawl is working on. Regardless, the suspension of sediments, whether fine silt or coarse sand, impacts the chemical and physical attributes of water quality. The resuspension of sediments may influence the uptake or release of contaminants and, depending on the frequency of disturbance, the nature of the contaminant(s). Clearly, such effects may be more significant where contaminant burdens are relatively high, (e.g., near areas affected by major industrialization,) (ICES 1995). Repetitive trawling on the same ground may enhance nutrient release from sediments and that estimates of average trawling effort for large areas may be unsuitable for estimating these effects (ICES 1995). This has important implications on nutrient cycling in areas that are regularly trawled. Pilskaln et al. (1998) found that impacts include burial of fresh organic matter and exposure of anaerobic sediments; large nutrient delivery to the water column, possibly impacting primary production; increase in nitrate flux out of the sediments; and reduced denitrification (conversion of remineralized nitrogen into N2 gas). All of these may have desirable or undesirable ecosystem impacts. An increase in nitrate fluxes to the water column may alter primary production (phytoplankton), potentially benefiting fisheries, or stimulating deleterious phytoplankton growth that results in harmful algal blooms (Pilskaln et al. 1998).

Increased water turbidity as a result of trawling activity has the potential to compress the width of the euphotic zone, wherein light levels are sufficient to support photosynthesis (North Carolina Division of Marine Fisheries 1999). The magnitude of this effect depends on sediment size, duration and periodicity of the trawling event, gear type, season, and site-specific hydrographic and bathymetric features (Paine 1979; Kinnish 1992).

Dredging studies would indicate that the effect of turbidity is greatly dependent on local conditions. Windom (1975) found that sediment resuspension caused by dredging operations significantly reduced phytoplankton growth in a naturally clear estuary (south Florida) but not in a naturally turbid estuary (Chesapeake Bay). Additionally, increased turbidity resulting from trawling activities may reduce primary production of benthic microalgae. This may have serious consequences as benthic microalgae support a variety of consumers and can be a significant portion of total primary production (Cahoon and Cooke 1992; Cahoon and Tronzo 1992; Cahoon et al. 1990; 1993). Increased turbidity also has may reduce the foraging success of visual predators (Minello et al. 1987) and contribute to the mortality of organisms by impeding the normal functioning of feeding and respiratory structures (Sherk et al. 1975). Sediment resuspension may increase the amount of organic matter resulting from enhanced primary production and may stimulate heterotrophic microbial production. If the amount of resuspended organic material is copious, sustained proliferation of heterotrophic microflora will reduce the dissolved oxygen content within the water, and widespread hypoxia or anoxia could ensue to the detriment of benthic and pelagic fauna (West et al. 1994). Conversely, oxygen penetration into the sediment might be enhanced through trawling activity, resulting in shifts in mineralization patterns and redox-dependent chemical processes. Among other consequences, a change from anaerobic to aerobic conditions facilitates the degradation of hydrocarbons. As Kaiser (2000) pointed out, bottom trawls are designed to stay in close contact with the seabed and an inevitable consequence of their design is the penetration and resuspension of the seabed to some extent. While it is possible to reduce the direct physical forces exerted on the seabed by modifying fishing practices, the benefits are questionable and catches would most certainly suffer. Despite attempts to improve gear design, as long as bottom dwelling species are harvested using towed gear, there will be inevitable sediment resuspension.

Biological Repercussions

The physical disturbance of sediment, such as the ones previously discussed, can also result in a loss of biological organization and reduce species richness (Hall 1994). In general, the heavier the gear and the deeper its penetration of the sediment, the greater the damage to the fauna. Impacts also will vary depending on type of habitat the gear is working. Gibbs et al. (1980) determined that shrimp trawling occurring within a sandy estuary had no detectable effect on the macrobenthos. After repeated trawls the sea bottom appeared only slightly marked by the trawl's passage. However, Eleuterius (1987) noted that scarring due to shrimp trawls in Mississippi SAV was common, especially in deeper water. Trawling activities left tracks and ripped up the margins of the beds, and great masses of seagrass were often observed floating on the surface following the opening of shrimp season. Furthermore, Wenner (1983) noted that the use of an otter trawl on hardbottom habitat may inflict considerable damage. The net damages the sponge-coral habitat by shearing off sponges, soft corals, bryozoans, and other attached invertebrates. Therefore, it is not necessarily that trawl gear is doing a constant level of damage, but rather particular habitats are more vulnerable to impacts than others.

Numerous studies cite specific, direct biological impacts to habitat such as the reduction of algal and SAV biomass (Tabb 1958; Fonseca et al. 1984; Bargmann et al. 1985; Peterson et al. 1987a; Sánchez-Lizaso et al. 1990; Guillén et al. 1994; Ardizzone et al. 2000). Gelatinous zooplankton and jellyfish, which provide habitat to juvenile and other fish species, are greatly impacted as they pass through the mesh of mobile gear (Auster and Langton 1999). Fishing activity may reduce the size and number of zooplankton aggregations and disperse associated fishes. Furthermore, there is a directed trawl fishery for cannonball jellyfish in the Gulf of Mexico.

While this fishery removes jellyfish which may provide habitat for juvenile fish, otter trawls utilized in this fishery do not interact with the benthos. Trawls in the Gulf of Mexico and South Atlantic have been noted to impact coral habitat, damaging and destroying various colonies (Moore and Bullis 1960; Gomez et al. 1987; Bohnsack, personal observation). Loss of sponges and associated cnidarian benthos has been documented to lead to a reduction in fish catch (Sainsbury 1988; Hutchings 1990). Sponges are particularly sensitive to disturbance because they recruit periodically and are slow growing in deeper waters (Auster and Langton 1999). Bradstock and Gordon (1983) observed that trawling virtually destroyed large areas dominated by encrusting coralline growths (bryozoans), reducing colony size and density. Probert et al. (1997) documented the bycatch of benthic species that occurs in a deep-water trawl fishery and noted the vulnerability of pinnacle communities and deepwater coral banks such as the Oculina habitat area of eastern Florida. Van Dolah et al. (1983; 1987) conducted experimental trawl surveys over hard bottom habitat consisting of coral and sponge off the coast of Georgia. A single pass of an otter trawl on this habitat damaged all counted species (Van Dolah et al. 1983; 1987).

However, only the density of barrel sponges was significantly decreased by trawling activities. It should be noted that these studies did not investigate the cumulative impacts of trawls. The repetitive effects of trawling over the same area can be expected to have more severe consequences to benthic habitat. While Moran and Stephenson (2000) estimated that a demersal otter trawl reduced benthos (greater than 20cm in maximum dimensions) density by 15.5% in a single pass, Cappo et al. (1998) estimated that complete denuding of the sea bottom structure occurs after 10-13 trawl passes over the same area. Of equal importance are the observations of Moran and Stephenson (2000), who noted variations among trawl studies, possibly due to differences of employed ground ropes. These variations are a warning against generalizations about the impact of otter trawls on attached benthos. As many epifaunal and infaunal organisms create structures which provide habitat for other species, summaries of these studies and their findings are included. For example, many infauna species and other bioturbators have an important role in maintaining the structure and oxygenation of muddy sediment habitats. Consequently, any adverse effects on these organisms would presumably lead to changes in habitat complexity and community structure (Jennings and Kaiser 1998). Furthermore, the loss of biogenic epifaunal species (epibenthic habitat) increases the predation risk for juveniles of other species, thereby lowering subsequent recruitment to adult stocks (Bradstock and Gordon 1983; Walters and Juanes 1993; Jennings and Kaiser 1998). Therefore, reduction in biomass of epifaunal species may be considered a reduction or degradation of habitat in certain instances and trawling has been documented to decrease mean individual biomass of epibenthic species (Sainsbury et al. 1993; Prena et al. 1999). While it may be hard to quantify the impact this loss presents to habitat-dependent organisms, it should be noted nonetheless. In a long-term study of Corpus Christi Bay, Texas, Flint and Younk (1983) noted that the continual minor and random disturbance, both in time and space, of channel sediments by large tanker traffic and shrimp trawling probably was sufficient to keep these communities in a state of constant disruption. This allowed the opportunists to persist more successfully than other species. The disturbed channel sites of the study, though viable, consistently had lower densities, lower numbers of species and corresponding low diversities contrasted to the lesser impacted shoal sampling sites (Flint and Younk 1983). Engel and Kvitek (1998) investigated two adjacent areas in 180 m of water to determine the differences between a heavily trawled site and a lightly trawled site.

They concluded that high-intensity trawling apparently reduces habitat complexity and biodiversity while simultaneously increasing opportunistic infauna and the prey of some commercial fish. The data indicated that intensive trawling significantly decreased habitat heterogeneity. All epifaunal invertebrates counted were less abundant in the highly trawled area. Bergman and Santbrink (2000) estimated direct mortality on various species of benthic megafauna from a single pass of an otter trawl (sole fishery) at between 0-52% for silty sediments and between 0-30% for sandy sediments. In general, small-sized species tend to show lower direct mortalities, when compared with larger sized species and smaller individuals of megafaunal species tend to show lower mortalities than larger-sized ones. Krost and Rumohr (1990) noted damage directly resulting from otter trawl doors. Benthic organisms were found to be reduced in number by 40 to 75% in otter board tracks, as compared to control sites. Biomass was also generally reduced. However, they found almost no differences in epibenthic species such as crustaceans. In shallow areas with densely packed sediments, inhabitants of the upper sediment layer were found to suffer most by the trawling impact.

In contrast to the above studies, there are several studies that document no significant habitat impact. Van Dolah et al. (1991) found no long-term effects of trawling on an estuarine benthic community; five months of shrimp trawling in areas previously closed to fishing were found to have no pronounced effect on the abundance, diversity, or composition of the soft bottom community when compared to nearby fished areas. They concluded that seasonal reductions in the abundance and numbers of species sampled had a much greater effect than fishing disturbance. In a power analysis of their sampling strategy, Jennings and Kaiser (1998) noted that Van Dolah et al. (1991) only considered changes in the abundance of individuals and the number of species. This assumes that the response of the infauna to trawling disturbance was unidirectional, whereas a consideration of changes in partial dominance might have been more sensitive to subtle changes in the fauna. Yet, Jennings and Kaiser (1998) stated that the results of Van Dolah et al. (1991) were plausible and that light shrimp trawls probably do not cause significant disturbance to communities in poorly sorted sediments in shallow water. Sanchez et al. (2000) determined that sporadic episodes of trawling in muddy habitats may cause relatively few changes in community composition. They found similar infaunal community changes in both fished and unfished control areas through time. Sanchez et al. (2000) also noted that the decrease in the abundance of certain species in the unfished control areas may indicate that the natural variability at the experimental site exceeds the effect s of fishing disturbance. Regardless, Ball et al. (2000) commented that epifauna are generally scarce in muddy sediment habitats, and detection of fishing effects on such species has therefore been limited.

While the passage of a trawl may damage or destroy macroinfauna, Gilkinson et al. (1998) suggested that smaller infauna are resuspended or displaced by a pressure wave preceding otter trawl doors and are redeposited to the sides of the gear path. Due to a buffer effect caused by a displacement field of sediment (sand), bivalves incur a low level of damage (5%) by the passing of a trawl door. In contrast to coarse sediment communities where the infauna are found within the top 10 cm, organisms in soft mud communities can burrow up to two meters deep (Atkinson and Nash 1990). Due to their depth, it is likely that these organisms are less likely impacted by passing trawls (Jennings and Kaiser 1998), though it should be noted that the energetic costs of repeated burrow reconstruction may have long-term implications for the survivorship of individuals.

Studies documenting impacts to habitat from successive trawling are not prevalent. However, a few studies suggest that shifts in species abundance and diversity are a result of the cumulative effects of trawling. Over a longer time scale (i.e., 50 years), Ball et al. (2000) suggested that fishing disturbance may ultimately lead to an altered, but stable, community comprising a reduced number of species, and hence, diversity. Sainsbury et al. (1993; 1997) noted that composition of a multispecies fish community in Australia was at least partially habitat-dependent and that historical changes in relative abundance and species composition in this region were at least in part a result of the damage inflicted on the epibenthic habitat by the demersal trawling gear. In summary, trawling has the potential to reduce or degrade structural components and habitat complexity by removing or damaging epifauna; smoothing bedforms which reduces bottom heterogeneity; and removing structure producing organisms. Trawling may change the distribution and size of sedimentary particles; increase water column turbidity; suppress growth of primary producers; and alter nutrient cycling. The magnitude of trawling disturbance is highly variable. The ecological effect of trawling depends upon site-specific characteristics of the local ecosystem such as bottom type, water depth, community type, gear type, as well as the intensity and duration of trawling and natural disturbances. It should also be noted that there is not a direct relationship between the overall amount of trawling effort and the extent of subsequent impacts or the amount of fauna removed because trawling is aggregated and most effort occurs over seabed that has been trawled previously (Pitcher et al. 2000). Yet, several studies indicate that trawls have the potential to seriously impact sensitive habitat areas such as SAV, hardbottom, and coral reefs. In regard to hard bottom and coral reefs, it should be recognized that trawlers do no t typically operate in these areas due to the potential dam age their gear may incur.

While trawl nets have been documented to impact coral reefs, typically resulting in lost gear (Bohnsack, personal observation), these incidents are usually accidental. Partially in response to accusations of trawl activity on hard bottom habitat, a recent research effort to investigate potential impacts on the Florida Middle Ground Habitat Area of Particular Concern concluded that there was no evidence of trawl impacts or other significant fishery related impacts to the bottom (Mallinson, unpublished report). However, low-profile, patchy hard bottom or sponge habitat areas are more likely impacted from trawls due to the gear's ability to work over these habitat types without damaging the gear. Regardless, while it may be concluded that trawls have a minor overall physical impact when employed on sandy and muddy substrates, the available information does not provide sufficient detail to determine the overall or long-term effect of trawling on regional ecosystems.

Recovery of substrate depends on sediment type, depth, and natural influences such as currents and bioturbation. Schoellhamer (1996) investigated sediment resuspension within Tampa Bay, a shallow estuary with fine non-cohesive material (muds absent), and found that sediment concentrations returned to pre-trawl conditions approximately 8 hours after disturbance. The cumulative effects of several trawlers operating were not investigated. DeAlteris et al. (1999) found that scars similar to those that occur from otter trawl boards disappear relatively quickly in a shallow sand environment, while those occurring in a deeper mud habitat took as long as two months to disappear. DeAlteris et al. (1999) also found that natural disturbances to mud substrate in 14 m of water are rarely capable of disturbing the seabed. Therefore, recovery of fishery-related impacts in deeper water may be protracted due to the lack of natural events that help deposit sediments and fill trawl scars. Ball et al. (2000) determined that intensive demersal trawling over muddy seabeds leads to apparent long –term alteration of the seabed. Trawl tracks in muddy sediments may last up to 18 months; however, in areas of strong tidal or wave action, they are likely to disappear rapidly. Also, in areas where levels of bioturbation are high, and regular turnover of sediment produces large numbers of mounds on the seabed, trawl tracks will be filled relatively quickly (Ball et al. 2000). Habitats in deeper water tend to recover at a slower rate. Berms and furrows generated by trawl doors generally disappeared within one year in sandy habitats in depths of approximately 120-146 m (Schwinghamer et al. 1998; Prena et al. 1999). More dramatic is the estimate of 50-75 years to fill a typical trawl mark (~15 cm scour depth) in deep water (greater than 175m) by Friedlander et al. (1999). The greater the water movement, the faster the scars will be filled in (Jones 1992). Churchill (1989) and Krost et al. (1990) reported an increase in the frequency of tracks attributed to trawl doors in deeper water, presumably where water movement and natural impacts are less pronounced.

In general, few studies document recovery rates of habitat. Those that do investigate recovery usually only do so after a single treatment which does not reflect the reality of fishing impacts which are ongoing and cumulative. For example, Van Dolah et al. (1983; 1987) noted that hard bottom habitat in his trawl study recovered within one year. However, the experiment did not investigate the cumulative and repetitive effects of trawling at commercial intensities. As noted by an ICES (1995) study, due to the cumulative effects of trawling, focus on the scale of individual trawl impacts may be inadequate for estimating the importance of impacts on benthic communities. ICES (1994) stated that deep water coral banks (e.g., *Oculina varicosa*), due to their fragility, long life spans, and infrequent recruitment, may be nearly exterminated by a single passage of a trawl and are unlikely to recover "within a foreseeable future." Likewise, SAV would also have a protracted recovery time in comparison to sediments. SAV recovery may vary by species and can be greater than two years if the rhizomes of the plant are removed (Homziak et al. 1982). Regardless, the majority of studies concur that shallow communities have proved to be resilient due to their adaptation to highly variable environmental conditions and thus, recovery is usually swift. Kaiser et al. (1996a) found epifaunal communities in 35m of water that were experimentally trawled were indistinguishable from control sites after six months.

In areas of low current or great tidal exchange (e.g., deep ocean), where the benthos is not adapted to high sediment loads, the adverse effects of sediment resuspension by gear could persist for decades (Jones 1992). Recovery of small epibenthic organisms may be relatively rapid, but recovery of larger epibenthic organisms would be expected to be much slower. Though they did not discuss depth as a controlling factor, Sainsbury et al. (1993; 1997) indicated that there would be a considerable time lag after trawling ceases before recovery of large epibenthic organisms is substantial. Boesch and Rosenberg (1981) predicted that recovery times for macrobenthos of temperate regions would be less than five years for shallow waters (including estuaries) and less than ten years for coastal areas of moderate depth.

The majority of management recommendations indicate that marine reserves or gear zoning may be the most effective at reducing habitat impacts. However, other specific recommendations can be extracted from several studies. Tabb (1958) recommended that otter trawls not be permitted to operate in the bait shrimp fishery due to potential impact to SAV communities. Van Dolah et al. (1987) suggested that trawls with doors attached directly to the nets would greatly reduce the bottom area damaged by trawling activities. The use of artificial reefs to protect the seabed, in particular along the perimeter of SAV habitat areas, from trawling has also been offered (Guillén et al. 1994; Ardizzone et al. 2000). The use of semi-pelagic trawls would avoid the majority of habitat impacts that demersal trawls are associated with. However, while the use of semi-pelagic nets does not significantly impact the benthos, catch efficiency may be greatly reduced.

Furthermore, enforcement on the use of semi-pelagic nets remains difficult (Moran and Stephenson 2000). Carr and Milliken (1998) offered more straightforward recommendations: target certain species and modify gear appropriately; encourage the use of lighter sweeps; reduce the sea bottom available to trawlers that fish very irregular terrain; and opt for stationary gear over mobile gear. It is suggested that where fishing effort is constrained within particular fishing grounds, and where data on fishing effort are available, studies that compare similar sites along a gradient of effort have produced the types of information on effort impact that will be required for effective habitat management (Collie et al. 1997; Auster and Langton 1999). Additionally, the use of an indicator species (e.g., quahogs) that provides a historical record of fishing disturbance events could greatly enhance the interpretation of perceived changes ascertained from samples of present-day benthic communities (Macdonald et al. 1996; Kaiser 1998). Finally, the use of tracking devices (VMS) would provide a means for identifying the most heavily fished areas and those, if any, that are presently unfished (Macdonald et al. 1996; Kaiser 1998).

Comprehensive mapping of benthic habitats may provide the necessary information to determine what areas are at risk from fishery-related impacts. Utilized in conjunction with information that details fishing effort and area, gear zoning that limits the vulnerability of sensitive habitats while minimizing economic impacts to fishery participants should be considered.

Oyster Dredge

An oyster dredge consists of a metal rectangular frame to which a bag-shaped net of metal rings is attached. The frame's lower end is called the raking bar, and is often equipped with metal teeth used to dig up the bottom. The frame is connected to a towing cable and dragged along the seabed. Oyster dredges are widely utilized in state waters along the Gulf of Mexico, as well as the South Atlantic. Mechanical harvesting of oysters using dredges extracts both living oysters and the attached shell matrix and has been blamed for a significant proportion of the removal and degradation of oyster reef habitat (Rothschild et al. 1994; Dayton et al. 1995; Lenihan and Peterson 1998). Lenihan and Peterson (1998) observed that less than one season of oyster dredging reduced the height of restored oyster reefs by ~30%. Reduction in the height of natural oyster reefs is expected to be less than that of restored reefs because the shell matrix of natural reefs is more effectively cemented together by the progressive accumulation of settling benthic organisms, while restored reefs are initially loose piles of shell material. Regardless, it is likely that the height of natural reefs is also reduced by dredging because a large portion of extracted material from natural reefs by dredges is shell matrix. Lenihan and Peterson (1998) stated that it was probable that reduction in reef heights in a Neuse River, North Carolina estuary was due to decades of fishery-related disturbances caused by oyster dredging. At an annual removal rate of 30%, restored reefs would be completely destroyed after less than 4 years of harvesting. Furthermore, they determined that the height reduction of oyster reefs through fishery disturbance impacted the quality of habitat due to the seasonal bottom-water hypoxia/anoxia which caused a pattern of oyster mortality and influenced the abundance and distribution of fish and invertebrate species that utilize this temperate reef habitat (Lenihan and Peterson 1998). Their results illustrated that tall experimental reefs – those mimicking natural, ungraded reefs – were more dependable habitat for oysters and other reef organisms than short reefs – those mimicking harvest-degraded reefs – because tall reefs provided refuge above hypoxic/anoxic bottom waters. Chestnut (1955) also documented that intensive dredging over a period of years resulted in the removal of the productive layer of shell and oyster, leaving widely scattered oysters and little substrate for future crop of oysters.

Glude and Landers (1953) noted that dredges mixed the sandy-mud layer and the underlying clay. Fished areas were found to be softer and have less odor of decomposition than the unfished control site. Glude and Landers (1953) also found a decrease in benthic fauna in the fished sites versus the unfished control sites. Conversely, a study conducted by Langan (1998) which looked at the impacts oyster dredging had on benthic habitat, as well as sediment resuspension resulting from dredging activity, concluded with different results. He noted that the size-frequency of oysters from the control site was biased towards older and larger specimen s with poor recruitment. Oysters from the dredged site illustrated good recent recruitment, while larger specimens were not as abundant as the control site. No significant differences between the two areas were found in number, species richness, or diversity of epifaunal and infaunal invertebrates, indicating that dredge harvesting had no detectable effect on the benthic community. Sediment suspension resulting from dredging activity appeared to be localized. It should be noted that the study failed to evaluate fishing activity (number of participants, effort) on the dredged site.

Due to overfishing and disease, oysters may now be more economically valuable for the habitat they provide for other valued species than they are for the oyster fishery (Lenihan and Peterson 1998). Rothschild et al. (1994) suggested the establishment of broodstock sanctuaries that includes the designation of “no-fishing” restrictions in specific areas. Lenihan and Micheli (2000) also recommended the closure of some oyster reefs to harvest. Maintaining high densities of oysters on some intertidal reefs may help to preserve future oyster harvests and broodstock. Furthermore, protecting some reefs will also preserve the ecological functions that oyster reef provide such as improving water quality and providing essential recruitment, refuge, and foraging habitat for numerous marine species.

Scallop Dredge (Inshore)

Scallop dredges are similar to crab scrapes, though scallop dredges utilized in the southeast generally do not have teeth located on the bottom bar. Scallop dredges are predominately used on SAV beds where bay scallops can be efficiently harvested, and thus, are primarily limited to state waters. Popular bay scallop fisheries exist both off Florida and North Carolina. This gear, while similar, is not the same type of dredge utilized offshore to harvest calico scallops (*Argopecten gibbus*) or Atlantic sea scallops (*Placopecten magellanicus*).

Though scallop dredges do not have teeth that would easily uproot SAV, studies have noted a reduction of algal and SAV biomass from their use (Fonseca et al. 1984; Bargmann et al. 1985). The reduction of SAV (*Zostera marina*) biomass was linearly related to the number of times a particular area was dredged, and the effects of dredging were proportionately greater on soft bottom than hard bottom (Fonseca et al. 1984). The Fonseca et al. (1984) study utilized an empty dredge that was 60% of the legal limit for a commercial dredge, and was not employed in conjunction with a boat as the commercial fishery does. Hand dredging was done to eliminate propeller scour which commonly occurs in shallow SAV beds. In commercial scalloping, the added dredge and scallop weight, as well as the propeller wash, could be expected to have a greater imp act (Fonseca et al. 1984). In general, more damage from scallop dredging occurred to SAV in soft substrates (i.e., mud) than hard substrates (i.e., sand). In softer sediments, plants were uprooted and damage to underground plant tissues, including meristems, occurred. In harder sediments, damage was found to be generally greater for above ground parts; underground meristems were left intact and able to begin to repair shoots or produce new ones after impacts had ceased (Fonseca et al. 1984).

Fonseca et al. (1984) determined that in a lightly harvested SAV area, with less than 25 % biomass removal, recovery occurred within a year. In areas where harvesting resulted in the removal of 65% of SAV biomass, recovery was delayed for two years. After four years, preharvesting biomass levels were still not obtained. These estimates were based on termination of fishery-related impacts. Continued fishing activity would likely lead to prolonged recovery and continued degradation. Homziak et al. (1982) estimated that SAV recovery can be greater than two years if the rhizomes of the plant are removed.

Due to the importance of SAV beds as a nursery area to other species, loss of eelgrass meadows should be avoided. Fonseca et al. (1984) suggested that harvest area rotation may minimize habitat impact.

Scallop Dredge (Offshore)

Scallop dredges (Figure 7) utilized to harvest calico or sea scallops consist of a metal frame that supports tickler chains and a metal ring bag that collects the shellfish. Though not widely utilized in the southeast, the gear has been included in this review due to their inclusion as an approved gear in the South Atlantic. The majority of studies on scallop dredge impacts originate from areas with extensive scallop fisheries such as the northwest and northeast Atlantic.

Due to the potential for the gear to have considerable weight and the fact that it is dragged along the bottom, habitat impacts are expected to occur. Drew and Larsen (1994) estimated that a scallop dredge maximum cutting depth would be 40 - 150mm. Kaiser et al. (1996a) found that scallop dredging greatly reduced the abundance of most species, causing significant changes in the community. It was noted that a large proportion of some animals (such as echinoderms) were not captured or passed through the mesh of the gear. The scallop dredge catches contained a low proportion of non-target species which indicates that the belly rings allow the bycatch to escape. However, the study did not investigate the extent of damage/injury to organisms that were not captured. Likewise, Collie et al. (1997) found areas on Georges Bank that were impacted by scallop dredges to have lower species diversity, lower biomass of fauna, and dominated by hard-shelled bivalves, echinoderms, and scavenging decapods. Areas less impacted by dredges had higher diversity indices. However, it should be noted that portions of Georges Bank consist of cobble habitat which is encrusted with a diverse array of epibenthic species.

Perhaps more applicable to the areas in the southeast where calico scallops are harvested off North Carolina and Florida, would be a study conducted by Butcher et al. (1981), who determined that scallop dredges had little or no environmental effect when they were used on large-grained, firm sand bottom that was shaped in roughly parallel ridges. The area in this study was also noted to be a fairly uniform, low species diversity community. Turbidity caused by the turbulence of the dredge quickly dissipated due to the nature of the substrate. Additionally, Jolley (1972) found no detrimental dredging effects on sand substrates. Yet, there is a potential for dredges to impact coral adjacent to scallop beds, especially the scallop grounds which occur in close proximity to the Oculina Bank off eastern Florida. Should a scallop dredge impact *Oculina* coral, there would be severe results, similar to the conclusion s reached by ICES (1994) for trawls. This study determined that deep water coral banks such as those composed of *Oculina varicosa*, due to their fragility, long-life spans, slow growth, and infrequent recruitment, may be nearly exterminated by a single passage of a trawl. Recovery of this habitat area, “within a foreseeable future,” is unlikely (ICES 1994).

Skimmer Trawl

Skimmer trawls are positioned along the side of a boat and pushed through the water to harvest shrimp. Two nets are typically used, one on each side of the boat. Skimmer trawls are supported by a tubular metal frame that skims over the bottom on a weighted metal shoe or skid. Tickler chains are also utilized along the base of the net. Because of the construction attributes of this gear type, skimmer trawls are generally restricted to water 3.05m (10 ft) or less which would limit them to state waters.

Skimmer trawls work on mud bottoms in water generally 3.05m (10ft) or less. The weighted shoe and tickler chains impact the bottom, resulting in sediment resuspension. Skimmer trawls may cause bottom damage due to improperly tuned or poorly designed gear (skids and bullets) or prop damage in shallow areas (Steele 1994). Furthermore, because skimmer trawls are used in shallow water, they may have a detrimental impact on critical nursery areas such as the marsh/water interface, SAV, or other sensitive submerged habitats. However, skimmer trawls are expected to impact the bottom less than otter trawls due to the absence of doors (Nelson 1993; Steele 1993). Coale et al. (1994) believed that the skimmer trawl would not have any greater effects on SAV than the otter trawl. They found it doubtful that the inside weight and outer shoe of the skimmer trawl would cause greater detrimental effects to the benthos than the heavy doors of an otter trawl. Based on underwater observations, Coale et al. (1994) suggested that the weight and shoe combination may be less-damaging than otter trawls. However, habitat such as sponges and SAV are cut off by tickler chains and lead lines whereas otter trawl doors can dig in and tear up the bottom. Given the difference in the amount of area covered by each on normal tows, Kennedy, Jr. (1993) found it doubtful that there would be much difference in the amount of habitat loss between skimmer trawls and otter trawls.

Kennedy, Jr. (1993) recommended that the use of skimmer trawls in Florida should be restricted to those areas currently approved for otter trawls. Due to the associated impacts to SAV, a prudent recommendation would be to limit skimmer trawl use to non-vegetated substrates.

6.2.2.2 Static Gear

Channel Net

Channel nets are fixed to pilings, docks, or shore installation and utilize current flow to capture shrimp, therefore, channel nets are limited to use within state waters. Though impacts of channel nets were not discussed specifically, it may be inferred from Higman (1952) that channel nets have negligible impact on habitat due to catch composition and the lack of interaction with the benthos.

Gillnet and Trammel Net

Gillnets (Figure 9) consist of a wall of netting set in a straight line, equipped with weights at the bottom and floats at the top, and is usually anchored at each end. As fish swim through the virtually invisible monofilament netting, they become entangled when their gills are caught in the mesh, hence the name. Gillnets may be fixed to the bottom (sink net) or set midwater or near the surface to fish for pelagic species. A trammel net is made up of two or more panels suspended from a float line and attached to a single lead line. The outer panel(s) are of a larger mesh size than the inner panel. Fish swim through the outer panel and hit the inner panel which carries it through the other outer panel, creating a bag and trapping the fish. Smaller and larger fish become wedged, gilled, or tangled. Gillnet s are widely used in numerous fisheries, both in state waters and in Federal waters. Trammel nets are primarily used in state waters, though they are an authorized gear in the Caribbean for both the spiny lobster and shallow water reef fish fisheries.

The majority of the studies that have investigated impacts of fixed gillnets have determined that they have a minimal effect on the benthos (Carr 1988; ICES 1991; ICES 1995; Kaiser et al. 1996b). An ASMFC (2000) report determined that impacts to SAV from gillnets would be minimal. Likewise, West et al. (1994) stated that there was no evidence that sink net (gillnet) activities contributed importantly to bottom habitat disturbance. However, Carr (1988) noted that ghost gillnet s in the Gulf of Maine could become entangled in rough bottom. He observed one net that had its leadline and floatline twisted around each other and tightly stretched between boulders. Furthermore, Williamson (1998) noted that gillnets can snag and break benthic structures. Gomez et al. (1987) noted that gill nets set near reefs occasionally results in accidental snaring often resulting in damage to coral. Bottom set gillnets have led to habitat destruction in different regions (Jennings and Polunin 1996). Bottom gillnets set over coral may cause negative impacts as the weighted lines at the base of the net often become entangled with branching and foliaceous corals. As the nets are retrieved, the corals are broken (Öhman et al. 1993). This observation has also been noted in a study by Munro et al. (1987), which documented that reefs are frequently damaged by the hauling of set (gill) nets, and the problem has been exacerbated by the use of mechanical net haulers or power blocks. Aside from the potential impacts cited on coral reef communities, the available studies indicate that habitat degradation from gillnets is minor.

Several studies note that lost gillnets are quickly incorporated by marine species. Cooper et al. (1988) found ghost gillnets in the Gulf of Maine covered with a heavy filamentous growth, exceeding 75% coverage on some nets. Anemones, stalked ascidians and sponges were attached to and growing to the net float lines (Carr et al. 1985; Cooper et al. 1988). Erzini et al. (1997) found that lost trammel nets and gill nets in shallow water (15-18m) on rocky habitat (analogous to coral reefs and hard bottom habitat) were colonized by various species, primarily macrophytes, which after three months completely blocked the meshes of some parts of the nets. Some netting would contact reef habitat, becoming heavily overgrown and eventually blended into the background. After a year, most of the netting was destroyed; those remnants that remained were completely colonized by biota (Erzini et al. 1997). Erzini et al. (1997) also noted that the nets eventually became incorporated into the reefs, acting as a base for many colonizing plants and animals. The colonized nets then provided a complex habitat which was attractive to many organisms. For example, large schools of juvenile fish were often observed in the vicinity of these heavily colonized nets, which may provide a safe haven from predators. Johnson (1990) and Gerrodette et al. (1987) noted that as gillnets tend to collapse and “roll up” relatively quickly, they may form a better substrate for marine growths and thereby attract fish and other predators which may get entangled, ultimately causing the net to sink. Therefore, one may assume that gillnets may be more of a ghostfishing problem and entanglement hazard to marine life than as an impact to habitat.

Catch by entanglement nets during 1988 was 1,398 lbs from North Carolina through Georgia (less than 1% of the combined state catch) and 253,739 lbs from the Florida East Coast (6% Florida East Coast catches). Much of the Florida landings are from a directed stab net fishery for gray snapper that operates in the EEZ. The Gulf Council and the State of Florida have prohibited entanglement nets. Florida regulations read as follows: "No person shall harvest in or from state waters any snapper of the family of Lutjanidae or any member of the genera *Epinephelus* or *Mycteroperca* by or with the use of any gear other than those types of gears specified in Subsection 1, provided however that snapper and grouper harvested as an incidental bycatch of other species lawfully harvested with other types of gears shall not be deemed to be unlawfully harvested in violation of this section, if the quantity of snapper/grouper so harvested does not exceed the bag and possession limits as specified elsewhere." The South Atlantic Council's actions track the Florida regulations in intent with respect to limiting possession to the bag limit and for species without a bag limit, no possession is allowed. Florida prohibited entanglement nets because it is an inappropriate gear to use on live bottom. Some of the reef fish are not necessarily found on the live bottom, however, many are and fishermen use stab nets to catch gray snapper on the live bottom areas.

The Council has concluded that entanglement nets are not an appropriate gear for the snapper grouper fishery and the prohibition will prevent use and/or expansion from North Carolina through Florida's East Coast. Entanglement nets targeting species other than those included in the management unit are limited to the bag limit if the species is under a bag limit, and if no bag limit is applicable, then no retention is allowed.

SAFMC Prohibition on the Use of Entanglement Nets

Snapper Grouper Amendment 4 prohibits the use of entanglement nets including, but not limited to, gill nets and trammel nets, for the harvest of species in the snapper grouper management unit (SAFMC 1991a). The simultaneous possession of entanglement nets and species in the management unit is prohibited.

Hoop Net

A hoop net is a cone-shaped or flat net which may or may not have throats and flues stretched over a series of rings or hoops for support. The net is set by securing the cod or tapered end to a post or anchored to the bottom. The net is played out with the current until fully extended, and then is allowed to settle to the bottom. The net is marked with a buoy for easy retrieval and identification purposes. The duration of time that a hoop net is set depends on the same factors that influence the duration of the set of a gill net and should be determined in a similar fashion. To harvest, the hoop net is raised at the cod end and the fish are removed.

While there are no studies that document the effect of hoop nets on habitat, due to its use primarily on flat bottoms the gear probably has less of an impact than traps.

Longline

Longlines use baited hooks on offshoots (gangions or leaders) of a single main line to catch fish at various levels depending on the targeted species. The line can be anchored at the bottom (Figure 12) in areas too rough for trawling or to target reef associated species, or set adrift, suspended by floats (Figure 13) to target swordfish and sharks. Longlines are widely utilized in numerous fisheries throughout the southeast region.

When a vessel is retrieving a bottom longline it may be dragged across the bottom for some distance. The substrate penetration, if there is any, would not be expected to exceed the breadth of the fishhook, which is rarely more than 50mm (Drew and Larsen 1994). More importantly is the potential effect of the bottom longline itself, especially when the gear is employed in the vicinity of complex vertical habitat such as sponges, gorgonians, and corals.

Bottom longlines in the snapper grouper fishery

The Council prohibited the use of bottom longline gear for snapper grouper in the South Atlantic EEZ within 50 fathoms (SAFMC 1994). Catch by bottom longlines during 1988 was 470,306 lbs from North Carolina through Georgia (6% of the combined state catches) and 576,310 lbs from the Florida East Coast (13% Florida East Coast catch). The Council was concerned about the use of bottom longline gear targeting species in the snapper grouper management unit in live bottom areas. Habitat damage and intense competition among users are problems that arise when this gear is used within 50 fathoms where significant live bottom occurs and where competition with hook and line vessels occurs. The Council concluded that this gear is appropriate for use in the deep-water snowy grouper/tilefish fishery where much of the bottom is mud with sparse live bottom areas. Allowing use of this gear deeper than 50 fathoms would preserve the traditional fishery which takes place in deeper water out to 50 fathoms. Based on information from South Carolina, up until 1983 the snapper grouper fishery was limited to vertical hook and line or bandit reels. Bottom longlines were introduced in the Gulf of Mexico after hook and line gear became less effective due to decreases in resource abundance; use of the gear grew rapidly. Up until this point there has been no gear prohibition on bottom longlines. After the golden tilefish and snowy grouper fisheries were developed, bottom longlines became the predominant gear, again as resource abundance declined. For species like snowy grouper and tilefish, it was not very efficient to use vertical hook and lines as the resource abundance declined from unfished levels. As the tilefish and snowy grouper stocks off South Carolina declined, the number of people using longlines decreased. Off South Carolina virtually all of the golden tilefish occurred well outside the 50-fathom mark and there was more than enough gear to adequately harvest these resources in the mid-depth zone. Vertical lines are much more environmentally acceptable and less damaging than bottom longlines.

This regulation essentially segments the mid-shelf and the deep-water complex to the bottom longlines. This measure was supported during the public hearing process and the Council concluded that prohibiting use of longline gear within 50 fathoms will prevent the problems of habitat damage and intense competition while at the same time allow fishermen using this gear to continue fishing in deeper water. This action effectively limits longlines to targeting the deep water component of the snapper grouper fishery and keeps the use of longlines outside of the rough bottom habitat.

The Council very briefly considered moving the line in to the 40 fathom contour but was concerned that there are substantial Oculina coral banks along this depth zone. It was further noted that the 50 fathoms was a compromise from the 100 fathom contour (which was mentioned) and that the 50 fathom contour effectively separates the inshore and deep water snapper grouper complexes.

Impacts on habitat

Observations of halibut longline gear off Alaska included in a North Pacific Fishery Management Council Environmental Impact Statement (NPFMC 1992) provide some insight into the potential interactions longline gear may have with the benthos. During the retrieval process of longline gear, the line was noted to sweep the bottom for considerable distances before lifting off the bottom. It snagged on whatever objects were in its path, including rocks and corals. Smaller rocks were upended and hard corals were broken, though soft corals appeared unaffected by the passing line. Invertebrates and other light weight objects were dislodged and passed over or under the line. Fish were observed to move the groundline numerous feet along the bottom and up into the water column during escape runs, disturbing objects in their path. This line motion has been noted for distances of 15.2m (50ft) or more on either side of the hooked fish. Based on these observations, it is logical to assume that longline gear would have a minor impact to sandy or muddy habitat areas. However, due to the vertical relief that hardbottom and coral reef habitats provide, it would be expected that longline gear may become entangled, resulting in potential impacts to habitat. Due to a lack of interaction with the benthos, pelagic long lines would have a negligible habitat impact.

SAFMC Prohibition on the Use of Bottom Longlines

The Council prohibits bottom longlining in the wreckfish fishery in the entire South Atlantic EEZ (SAFMC 1991a). A bottom longline is a stationary, buoyed, and anchored groundline with hooks attached. Regulations prohibit simultaneous possession of wreckfish and all the necessary components for bottom longlining.

The Council was concerned about wastage of fish, gear loss, gear conflict, habitat damage, and negative economic effects (both short and long run) attributable to the use of bottom longline gear in the wreckfish fishery. The bottom habitat on the wreckfish fishing grounds, which comprise an area of the Blake Plateau of approximately 50-75 square nautical miles, is characterized by a rocky ridge system having a vertical relief greater than 50 meters and a slope greater than 15° (SAFMC 1993). The depth range in this area is 450-600 meters; the substrates in areas of the Blake Plateau exhibiting significant relief are generally characterized as composed of manganese phosphate pavements, phosphorite slabs and coral banks (Pratt and McFarlin 1966; Stetson et al. 1969). This high relief, in conjunction with the strong tidal effects, makes gear loss probable (as reported by fishermen who have already tried longlines in the wreckfish fishery) which results in the loss of all fish on the gear as well as those which get hooked subsequently. Testimony from fishermen indicated gear loss on wreckfish longline sets was as great as 100% of the gear taken out on a single trip. According to accounts from fishermen, extensive lengths of lost longline gear have been observed on their fathometers. Fishermen can apparently see fish hooked on parted longline gear but are unable to recover the parted gear and its catch. Wreckfish fishermen use circle hooks that virtually prevent fish from working the hook free. The Council recognized that there was also some ghost fishing potential from lost vertical gear but believes that the extent of potential loss with vertical gear is much smaller by virtue of the fewer number of hooks used and the greater control over the gear.

Although the area is 50-75 square nautical miles, virtually all wreckfish fishing takes place along limited, high relief ledge areas within this area because wreckfish are found along the ledges and are not evenly distributed over the wider area. The sub-areas that produce wreckfish are typically 300 yards wide and 1-4 nautical miles long. Thus far, fishermen fishing vertical drop gear have been able to work in relatively close proximity without any major conflicts. If bottom longlines had been allowed to be used in this area, vessels would have not only lost gear due to the rough bottom, but this lost gear would create a hazard for those using vertical lines which would result in loss of that gear. This problem would have become progressively worse over time as more gear was lost, the more hangs were created for both longline and vertical gear, creating even more gear loss. This condition could have continued until much of the ground is unfishable. The wire cable that is used will remain a hazard for many years as the rate of decay is slow. While extensive hangs may ultimately provide protection for the resource due to much of the fishing grounds being unfishable, it may well result in the loss of the fishery. The use of longlines will result in gear losses to vertical hook and line fishermen that far exceed their losses prior to the introduction of longlines. This will serve to reduce benefits to those fishing with the traditional vertical gear.

The potential for gear entanglement and gear conflict also raised the issue of vessel safety. It was the Council's opinion that this situation would have lead to conflicts that jeopardize the safety of the vessels and fishermen participating in the wreckfish fishery.

Longline cable on the bottom has the potential to break some of the ledges, overhangs and associated organisms, and otherwise damage the habitat on which the wreckfish depend. Habitat damage caused by the longlines would violate the SAFMC habitat policy and should be avoided.

The wreckfish fishery has employed efficient vertical gear since its inception, and the addition of longlines would have eroded benefits to the majority of fishermen and adversely impact the resource and habitat. If longlines had been allowed, then all or at least many wreckfish fishermen may have been forced to adopt the gear in order to compete resulting in more gear loss from parted longlines. The Council determined that bottom longlines were not in the best interest of the wreckfish resource, habitat, fishermen or society at large. Further, the problems outlined justified prohibiting this gear/fishing method in the wreckfish fishery.

Pound net

A pound net consists of a fence constructed of netting that runs perpendicular to shore which directs fish to swim voluntarily into successive enclosures known as the heart, pound, or pocket. Pound nets are exclusively utilized in state waters.

An ASMFC (2000) report determined that impacts to SAV from pound nets are expected to be minimal, unless the net is constructed directly on SAV. West et al. (1994) also stated that pound nets do not contribute to benthic disturbance. Due to the limited amount of space a pound net may impact, it is expected that pound nets have minimal impact on habitat.

Trap and Pot

Traps and pots are rigid devices, often designed specifically for one species, used to entrap finfish or invertebrates. Depending on the type of fishing a trap is used for, most traps are generally baited and equipped with one or more funnel openings, they are left unattended for some time before retrieval. Traps and pots are weighted to rest on the bottom, marked with buoys at the surface, and are sometimes attached to numerous other traps to one long line called a trot line. Traps and pots are widely used on a variety of habitats in both state and Federal waters to commercially harvest species such as lobster, blue crabs, golden crabs, stone crabs and black sea bass. Wire-mesh fish traps are one of the principal fishing gears used in coral reef areas in the Caribbean (Appledorn 2000).

SAFMC Prohibition on the use of fish traps

It should be noted that many of the studies used in forming this document refer to fish trap fisheries outside of the continental US. These fisheries are different from crustacean trap fisheries operating on the South Atlantic coast in that the traps are built to selectively capture crabs and lobster and avoid bycatch of untargeted finfish. There are few studies to date regarding the bycatch rate of finfish but anecdotal information from fishermen and fisheries managers point out that spiny lobster traps do not capture significant amounts of snapper, grouper and other ornamental reef fish.

The Council prohibited the use of fish traps in the South Atlantic EEZ; however, black sea bass traps may be used north of Cape Canaveral (Vehicle Assembly Building, 28° 35.1' N Latitude). Fish traps were banned in federal waters off the South Atlantic states in 1992 and banned in the Gulf of Mexico west of Cape San Blas (located at about the middle of the Florida Panhandle) in 1997.

In general, pots can cost anywhere between $30-$50 USD to construct. It does take some skill in determining an appropriate location for fishing trap gear, and efficiency is based on how many traps a fishermen can service in one working day. Traps will soak an average of 1-2 weeks before they are checked. While traps can catch a wide variety of marine organisms, fishermen place traps in specific areas to avoid bycatch of untargeted species. One downfall to trap fishing is that the gear can be lost in storm events, so to avoid “ghost fishing” most traps have degradable panels and escape rings that rot off allowing fish to exit the trap. While trap fishing gear has created user-group conflicts in the past, managers are in the process of choosing particular fishing zones which will help the general public become more aware of trap fishing areas.

Due to their use to harvest species associated with coral and hard bottom habitat, traps and pots have been identified to impact and degrade habitat. Gomez et al. (1987) noted the incidental breakage of corals on which traps may fall or settle constitute the destructive effects of this gear. Within the Virgin Islands State Park, Garrison (1998) found 86% of the fish traps were set on organisms (live coral, soft coral, SAV) living on the sea floor. Damage to the live substrate has far-reaching negative effects on the marine ecosystem because the available amount of shelter and food often decreases as damage increases. Another study conducted by Garrison (1997) had similar results, as 82% of traps rested directly on live substrate, with 17% resting on stony corals.

It is important to note that the aforementioned statistics (Garrison, 1987-1998) do not reflect the way trap based crustacean fisheries operate within the continental United States. Studies from the Florida Fish and Wildlife Conservation Commission (Tom Matthews, personal communication) confirm that only 2% of spiny lobster traps are fished on top of stony coral reef habitats.

Hunt and Matthews (1999) found that lobster and stone crab traps reduce the abundance of gorgonian colonies from rope entanglement. Furthermore, seagrass smothering occurs from trap placement on SAV beds, resulting in SAV "halos." ." Studies also confirm that traps set for no longer than a two week period do not pose an adverse threat to seagrass ecology as the seagrass subsequently recovers. Van der Knapp (1993) noted that fish traps set on staghorn coral easily damaged the coral. It appeared that in all observed cases of injury due to traps, the staghorn coral regenerated completely, although the time for regeneration varied from branch to branch. The greatest impact noted from the setting of traps was observed when the point of the trap's frame ran into coral formations. Several different species of coral were observed to suffer damage from fish traps. Observations of at least one damaged coral specimen noted that algae growth prevented regeneration in the damaged portion of the coral. Additionally, complete deterioration of a vase sponge was observed after it had been severely damaged by a trap. Traps are not placed randomly, rather they are fished in specific areas multiple times before fishing activity moves to other grounds. Therefore, the damage caused by wire fish traps in this study has a concentrated cumulative effect in particular areas rather than being uniform over all coral reef habitat

Appledorn et al. (2000) commented that fish traps may physically damage live organisms, such as corals, gorgonians, and sponges, which provide structure and in some cases, nutrition for reef fish and invertebrates. Damage may include flattening of habitats, particularly by breaking branching corals and gorgonians; injury may lead to reduced growth rates or death, either directly or through subsequent algal overgrowth or disease infection. During initial hauling, a trap may be dragged over more substrate until it lifts off the bottom. Traps set in trotlines can cause further damage from the trotline being dragged across the bottom, potentially shearing off at their base those organisms most important in providing topographic complexity.

Traps that are lost or set unbuoyed are often recovered by dragging a grappling hook across the bottom. This practice can result in dragging induced damage from all components (grappling hook, trap, trotline). The area swept by trotlines upon recovery is orders of magnitude greater than the cumulative area of the traps themselves. Appledorn et al. (2000) documented that single-buoyed fish traps off La Parguera, Puerto Rico, have an impact footprint of approximately 1 m^2 on hard bottom or reef. Of the traps investigated in the study, 44% were set on hard bottom or reef, resulting in 23% damage to coral colonies (70 cm^2 average), 34% damage to gorgonian colonies (56 cm^2 average), and 30% damage to sponges, though sponges were less frequently impacted due to their patchy distribution. Hauling these wire fish traps resulted in 30% of the traps inflicting additional damage to the substrate. In a similar study focusing on fish trap impacts conducted off St. Thomas, U.S.V.I., by Quandt (1999), 40% of all traps investigated were found to be resting on reef substrate. On average, 4.98% of all hard corals and 47.17% of all gorgonians were damaged; tissue damage averaged 20.03% to each gorgonian. Secondary impacts, such as trap hauling and movement due to natural disturbances were not investigated.

However, the effects of pulling a string of two or more wire fish traps would most likely be much greater than one trap alone.

Eno et al. (1996) found pots that landed on, or were hauled through beds of bryozoans caused physical damage to the brittle colonies. It was noted that several species of sea pens bent in response to the pressure wave created by a descending pot and were lying flat on the seabed. When the pot was removed, the sea pens were able to reestablish themselves in the sediment. A species o f sea fan also was found to be flexible and specimens were not severely damaged when pots were hauled over them. This suggests that in some instances the direct contact of certain gears may not be the primary cause of mortality, rather the frequency and intensity may be more important. Additionally, Sutherland et al. (1983) cited little apparent damage to reef habitats inflicted from fish traps off Florida. The study found four derelict traps sitting atop high profile reefs with four other traps observed within a live-bottom area. There was no visual evidence that traps on the high profile reef killed or injured corals or sponges. One uprooted gorgonian was observed atop a ghost trap in a live bottom area. However, these observations were made on randomly located derelict traps. Thus, the primary impacts that may occur during deployment and recovery could not be evaluated.

Trap loss

Gear failure, theft, and improper placement are several of the many reasons why traps are lost both inshore and offshore. Gear failure can occur because of pot warp (line) parting, buoys separating from the pot warp, or buoys breaking up. Normal wear and tear, powerboat propellers, and sea turtles or sea gulls biting the buoys or pot warp can cause gear failure. Theft is also a major cause of lost traps in many areas. Losses also occur because of setting the traps too deep or on too steep a slope. Storm surge and wave action can cause loss of traps, particularly in shallow inshore waters during hurricane and foul weather events. Traps without buoys are less susceptible to storm damage, but may be moved from a site by currents or wave action and become irretrievable. In coralline areas, the buoy lines may become entangled on coral, chafe, and break. Offshore, losses are primarily caused by large vessels cutting or dragging gear, gear failure, and storms. Strong currents submerging buoys or sweeping traps away from the locations where they were set and traps becoming entangled with other fishing gear and anchors have also been cited as causes of trap loss.

The percentage of traps lost varies considerably among studies by both area and depth fished. Wolf and Chislett (1974) reported fish trap losses of 10-20% per trip in exploratory efforts in deep water shelf edges in the Virgin Islands. They attributed these losses to pots tumbling down steep slopes. Craig (1976) reported a fish trap loss rate of about 20% for a period of six months with some loss due to theft while trap fishing off Boca Raton, Florida. In Broward County, Florida, the same study reported that fish trap fishermen reported an average of 20.3% annual loss due mainly to strong currents, entanglement and theft. Dade County, Florida trap fishermen reported losing 1-5 traps per trip, with an annual loss of 100%. Losses were due to theft or loss of buoys. Trap theft was such a problem that traps were brought back to port at the end of each fishing day in Dade (Sutherland and Harper 1983).

Sutherland and Harper reported that Monroe County, Florida trap fishermen had estimated average annual trap losses of 63%. The losses were mainly from currents and severance of buoys by large ships in deep water and from vandalism inshore. Trap loss in the spiny lobster fishery was not a problem in Collier County, Florida with an annual loss of only 5% due to the fact that fishermen brought back traps to the dock after each trip (Taylor and McMichael 1983). About 85% of traps used off Key Biscayne, Florida were lost with most losses attributed to theft (Sutherland et al. 1987). Fish trap loss from theft and severed fouling lines was reported as a major problem in the Virgin Islands (Swingle et al. 1970; Olsen et al. 1974; Sylvester 1972).

In Jamaica, Munro and Thompson (1973) had such a theft problem in their study that the use of buoyed traps had to be abandoned. Losses due to theft, storms, and vessels cannot easily be controlled, but fish trap fishermen can inspect gear frequently for wear and tear and use more durable materials.

Fish traps that fishermen cannot locate and retrieve or that are abandoned but are still capable of catching fish, are often referred to as ghost traps. Ghost traps have long been a subject of concern, but opinions have changed considerably over time. Since Olsen et al. (1978) made their observations that if traps were lost, juvenile and forage species mortality could decimate a fishing ground, they suggested that considerable mortality could take place over the 1-2 years before the wire mesh corroded away, and indicated corrosion time would be longer and mortality would be greater for small sizes of mesh. A study by Harper and McClelland (1983) estimated the average fishing life of eight traps observed off Key Biscayne to be from 5.5 to 157 days before becoming unable to capture fish. They also found that 19.2% of the fish that entered the trap died (Harper and McClelland 1983). While the decay and catch rates of ghost traps are not well documented, at least some evidence indicates that lost traps quickly become damaged and ineffective (Sutherland et al. 1978). Most reports of injury and mortality from lost ghost traps are anecdotal but underwater video presented to the South Atlantic Fishery Management Council on June 11, 1990 documented dead and injured fish in ghost traps in the Florida Keys. The video was presented by Capt. Fernand Braun (a charter fishing guide) in an effort to persuade the Council to ban fish traps.

Derelict traps are lost or abandoned traps that are incapable of catching fish due to structural damage or deterioration. Derelict traps may have small holes or breaks and gaps between ceiling and floor panels and walls, or entire panels degraded or missing (Smolowitz 1978). Traps become derelict in a number of ways. Predator damage, corrosion, escape windows opening, and materials fastened to escape devices decomposing have all been documented.

Munro et al. (1971) speculated that lost fish traps that have accumulated large numbers of fish may be attacked and rendered ineffective by large predators such as nurse sharks (*Ginglymostoma cirratum*). Harper and McClelland (1983) found funnel openings enlarged with the prongs bent back and speculated that the damage was by large predators such as cubera snapper (*Lutjanus cyanopterus*), great barracuda (*Sphyraena barracuda*), yellow jacks (*Caranx bartholomae*), and lemon sharks (*Negaprion brevirostris*) attempting to escape and that mortality of these fish was high. Craig (1976) found that escapement through trap holes caused by predators became a problem if traps were not hauled after five or six days. Fish are rarely caught in traps with holes or breaks in the mesh and even small holes or breaks in the wire mesh apparently render them ineffective (Craig 1976; Sutherland and Harper 1983; Ward 1983).

Sutherland et al. (1983) found juvenile fish numerous in and around derelict fish traps. The derelict traps and other manmade objects appeared to serve as artificial reefs on barren sand sea floor areas (Sutherland et al. 1983; Harper and McClelland 1983). Sutherland et al. (1983) observed that fish were absent or rare near traps on or adjacent to reefs.

Impacts on habitat

The Council concluded that the issue of wire fish traps was a critical issue to the State of Florida and in the long term to the entire South Atlantic as well. Florida deliberated the issue of fish traps for many years and the Florida State Legislature prohibited the use of wire fish traps in 1980. The snapper grouper stocks are more overfished off Florida than they are anywhere else in the South Atlantic.

The Council concluded that fish traps are non-selective by size and by species (e.g., red grouper recruit to the hook and line fishery at around 19" and to the trap fishery at around 11"). Bohnsack et al. (1989) notes that modifications to mesh size will alter the size of fish caught. This study concluded that total value, species caught, number of individuals and mean total weight per haul declined with meshes larger or smaller than 1.5" hexagonal mesh. The mesh sizes required to correlate with the 20" minimum sizes would be so large as to result in de facto prohibition on use of fish traps.

Based on studies regarding fish traps between 1980-1990, the SAFM Council has concluded that wire fish traps capture a significant amount of bycatch. Information contained in Bohnsack et al. (1989) documents the bycatch of these species. Unfortunately, a variety of ornamental reef fish were not recorded separately in the commercial landings data until recently, thus the commercial landings data are not available to quantify the extent to which catches of these species have increased. We also expect that there has been a decline in the amount of ornamental reef fish caught as bycatch since wire fish traps were banned from federal waters (and state waters in Florida).

Since March 1, 1991 the State of Florida has prohibited the harvest of tropical fish: "The purpose and intent of this Chapter is to protect and conserve Florida's tropical marine life resources and to ensure the continued health and abundance of these species. . The affect of selective removal of herbivores on the health of coral reefs was discussed by LaPointe (1989). These species were harvested by fish traps more frequently than by hook and line gear. Again, due to the fact that commercial statistics did not record these fish by species, data was unavailable to document the level of harvest by fish traps or by hook and line.

The further intent of this Chapter is to ensure that the harvesters in this fishery use non-lethal methods of harvest and that the fish, invertebrates and plants so harvested be maintained alive for the maximum possible conservation and economic benefits." Allowing fish traps in federal waters would make Florida's regulations difficult, if not impossible, to enforce and would not address Problem #5 which is, that "the existence of inconsistent state and federal regulation makes it difficult to coordinate, implement and enforce management measures and may lead to overfishing. Inconsistent management measures create public confusion and hinder voluntary compliance."

The way in which fish traps were used made enforcement extremely difficult. All other kinds of fishing gear are eventually brought back to the dock where they can be examined by state marine patrol officers or other law enforcement personnel. Once traps are placed in the water, they were seldom are brought back to the dock. Testimony documents the various kinds of violations recorded in the Key West area (e.g., biodegradable panel requirement violations). The loss of traps was high ranging from 20% to 63% and in certain sectors trap loss may be as high as 100%.

The SAFMC Law Enforcement Committee and Advisory Panel were established to advise the Council on enforceability of various management approaches. They noted that the existing system is difficult to enforce and is incompatible with Florida state law, that the 100-foot contour limitation is difficult to enforce and that poaching is a big law enforcement problem in the fish trap fishery. These two bodies recommended to the Council that a total prohibition on use of fish traps in the South Atlantic EEZ was the most enforceable of all alternatives considered.

The enforcement issue was summarized by Kelley (1990): “Enforcement is the largest problem of all. There are widespread abuses of the regulations governing the use of fish traps. There seems to be no effective way to enforce regulations in a fishery, such as fish trapping fishing, where gear can't be observed readily by enforcement officials. The largest present day problems in the Florida Keys and southeast Florida are the extensive trap poaching and the use of illegally constructed or deployed traps.”

The Council recognized that gear that is not brought back to shore at the end of a fishing trip makes enforcement more difficult. The Council considered other, less drastic measures that would allow traps to be used but concluded that the at-sea enforcement required to effectively monitor and ensure compliance with existing regulations does not and will not exist. Therefore, the Council was persuaded that nothing short of a total ban on fish traps would be enforceable.

There is evidence that fish trapping causes habitat damage where fish traps are set in trawls on live bottom and where grappling hooks are dragged across live bottom to retrieve them. Testimony and video records of damaged *Oculina* reefs off Palm Beach County, provided to the Council at the February 1991 meeting, depicted significant and measurable damage to coral reef and live bottom communities. These activities leave an imprint of the trap upon the bottom communities and trenches caused by grappling hooks dragged over the bottom for the purpose of locating and recovering traps. Lost traps not only continue to fish, as it has been pointed out in the ghost trap discussion, but may contribute considerable secondary habitat damage by becoming mobilized at times of storm activity and impacting delicate bottom communities.

The affect of selective removal of herbivores on the health of coral reefs was discussed by LaPointe (1989). These species were harvested by fish traps more frequently than by hook and line gear. Again, due to the fact that commercial statistics did not record these fish by species, data was unavailable to document the level of harvest by fish traps or by hook and line.

Prohibiting fish traps was determined to be consistent with Florida's Coastal Zone Management Plan. Also, internationally, a number of countries (e.g., Bermuda) have tried to manage fish trap gear only to end up prohibiting their use. Bermuda has managed their snapper grouper fishery for a number of years and imposed a limited entry system with trap limitation. In addition, modifications to mesh size were also attempted. The Bermudian Government concluded that regulation the fish trap fishery was not effective and recently imposed a total ban on use of fish traps. The Council concluded that a total prohibition on the use of fish traps was the most effective alternative to address the stated problems and to achieve the plan's stated objectives.

6.2.2.3 Other Gear

Allowable Chemical

Collectors of live tropical reef fish commonly employ anesthetics such as quinaldine. Quinaldine (2-methy lquinoline, $C_{10}H_9N$) is the cheapest and most available of several substituted quinolines (Goldstein 1973). As a result of using this compound near corals where tropical species shelter, there may be residual effects which was discussed in a study by Japp and Wheaton (1975). Short-term impacts of quinaldine include increased flocculent mucus production, retraction of polyps and failure to re-expand with a five minute observation period, and tissue discoloration in certain species. At both study sites, octocorals were found to suffer no long-term impacts. However, a minority of Scleractinians displayed minor damage, including mild discoloration and small patches of dead tissue, three months after quinaldine treatment. Two of these specimens degraded to poor condition or displayed areas of dead tissue more than six months after initial treatment. Overall, Japp and Wheaton (1975) determined that quinaldine exposure resulted in minimal damage to corals.

Barrier Net

Barrier nets are used in conjunction with small tropical nets or slurp guns to collect tropical aquarium species. The net is deployed to surround a coral head or outcropping and may or may not have a pocket or bag that fish are "herded" into for capture. Barrier nets may be utilized by tropical fish collectors in both state and Federal waters.

The American Marine Life Dealers Association conducted a survey (Tullock and Resor 1996) that focused on tropical collection practices. The survey defined a sustainable fishing practice as one that a) does not cause physical damage to the reef environment; b) does not impair the captured specimen's longevity in a properly maintained aquarium environment; and c) does not damage non-target species such as coral polyps, other invertebrates, or non-aquarium fish. The survey concluded that barrier nets were a sustainable fishing practice. However, a study conducted by Öhman et al. (1993) summarized that moxy nets, a type of barrier net that is used in other regions to collect ornamental fish species, may break corals during their use. However, it is likely that damage inflicted by barrier nets would be infrequent and incidental in nature, and therefore, the gear would have a negligible effect on habitat.

Castnet

Used to capture baitfish and shrimp, castnets (Figure 18) are circular nets with a weighted skirt that is thrown over a schooling target. Castnets are primarily used in shallow areas such as estuaries, though they may be used to catch baitfish offshore in Federal waters. Castnets have the potential to dislodge organisms or become entangled if utilized over heavily encrusted substrates. Observations by the author have noted numerous castnets entangled amongst sponges and other growth around rough bottom. However, a study conducted by DeSylva (1954) determined that castnets have no detrimental effect on habitat.

Clam Kicking

Clam kicking is a mechanical form of clam harvest primarily practiced in the state waters of North Carolina. The practice involves the modification of boat engines in such a way as to direct the propeller wash downwards instead of backwards. The propeller wash is sufficiently powerful in shallow water to suspend bottom sediments and clams into a plume in the water column, which allows clams to be collected in a trawl net towed behind the boat (Peterson et al. 1987a).

Several studies have noted that the practice of clam kicking reduces algal and SAV biomass (Fonseca et al. 1984; Bargmann et al. 1985; Peterson et al. 1987a). Reduction of SAV biomass was noted to increase with harvest intensity. Intense clam kicking treatments reduced SAV biomass by approximately 65% (Peterson et al. 1987a). Because of the importance of SAV to coastal fisheries and estuarine productivity, Peterson et al. (1987a) noted that intense clam kicking could have long-lasting and serious impacts on many commercially important fisheries. However, clam harvesting had no detectable effect on the abundance of small benthic invertebrates and outside of SAV habitat, clam kicking does not appear to have any serious negative impacts on parameters of ecological value (Peterson et al. 1987a).

SAV recovery can be greater than two years if the rhizomes of the plant are removed (Homziak et al. 1982; Peterson et al. 1987a). Peterson et al. (1987a) observed that SAV had yet to recover after four years of an intense clam kicking treatment. Although Peterson et al. (1987a) designated their heavier clam kicking treatment as “intense,” they conceded that it probably falls well short of the effort that commercial clammers would apply to a productive SAV bed. Limiting the intensity of clam fishing in SAV habitat would probably be beneficial. Peterson et al. (1987a) offered that a restriction of mechanical clam harvesters to unvegetated bottoms may be a suitable mechanism to minimize habitat damage.

Clam Rake, Scallop Rake, Sponge Rake and Oyster Tong

Rakes are used to harvest shellfish and sponges from shallow areas such as bays and estuaries. Oyster tongs, similar to two rakes fastened together and facing each other like scissors, are used by fishermen from the deck of a boat. As these gears are limited by water depth, they are exclusively utilized in state waters.

Lenihan and Micheli (2000) reported that the harvest of shellfish utilizing clam rakes and oyster tongs significantly reduce oyster populations on intertidal oyster reefs. Both types of shellfish harvesting, applied separately or together, reduced the densities of live oysters by 50-80% compared with the densities of unharvested oyster reefs. While oysters are removed, Rothschild et al. (1994) concluded that hand tongs probably have a minor effect on the actual oyster bar structure. Peterson et al. (1987b) compared the impacts of two types of clam rakes on SAV biomass. The bull rake removed over 89% of shoots and 83% of roots and rhizomes in a completely raked area while the pea digger removed 55% of shoots and 37% of roots and rhizomes. Loss or impact on SAV by bull rake was estimated to be double the impact of the smaller pea digger rake. Peterson et al. (1987a) found raking with a pea digger rake reduced SAV biomass by approximately 25%. An earlier study conducted by Glude and Landers (1953) noted that bull rakes and clam tongs mixed the sandy-mud layer and the underlying clay. Fished areas were also softer and had less odor of decomposition than the unfished control site. A decrease in benthic fauna was noted in the fished sites versus the unfished control sites.

Sponges are an important fishery in the Florida Keys and along the west coast of Florida (NOAA 1996). Sponges are dominant organisms in deepwater passes and along hard bottom habitat communities. Sponges create vertical habitat which provides shelter and forage opportunities for other invertebrates and tropical fish species. The fishery in the Keys typically employs a four-pronged iron rake attached to the end of a 5–7 m pole, which hooks the sponges from the bottom. While no studies document the extent of habitat damage from this gear type, it may be concluded that the harvest of sponges directly reduces the amount of available habitat, and thus may present a negative localized impact.

Peterson et al. (1987a) found that SAV biomass recovered to equal and even exceeded expected values within one year. Lenihan and Micheli (2000) recommended the closure of some oyster reefs to shellfish harvest. Maintaining high densities of oysters on some intertidal reefs may help to preserve future oyster harvests and broodstock. Furthermore, protecting some reefs will also preserve the ecological functions that oyster reef provide such as improving water quality and providing essential recruitment, refuge, and foraging habitat for numerous marine species. Due to the extensive habitat that sponges provide, further ecological study on the directed harvest of these organisms should be conducted.

Dipnet and Bully Net

Widely utilized to catch baitfish, crabs, or lobster, varieties of dipnets (Figure 22) consist of a long pole with a bag of netting of varying mesh size that are lowered into the water. Dipnets may also be employed to capture tropical reef fish (Figure 23), though these utilize a short handle and very fine mesh. Additionally, landing nets or hand bully nets (Figure 24) used to capture lobster can be considered a form of dipnet. Varieties of dipnets may be used both in state and Federal waters.

DeSylva (1954) determined that dipnets have no detrimental effect on habitat. However, the use of small dipnets (i.e., tropical fish nets and lobster hand bully nets) may result in minor isolated impacts to coral species as individuals attempt to capture specimens (Barnette, personal observation).

Hand Harvest

Hand harvest describes activities that capture numerous species such as lobster, scallops, stone crabs, conch, and other invertebrates by hand. As many small biogenic structures occur on the sediment surface, even gentle handling by divers can destroy them easily. Movements by divers were observed to cause demersal zooplankters to exhibit escape responses (Auster and Langton 1999). A study that assessed recreational SCUBA activity in the US Caribbean (Garcia-Moliner et al. 2000) concluded that approximately 2% of the total recreational divers in the USVI and 1.9% of the total recreational divers in Puerto Rico were lobstering. Potential impact of approximately 13,532 units occurred in the USVI and 14,946 units occurred in Puerto Rico. In this study, impact units consisted of two hands and two feet (4 units per diver) and impact was broadly defined as ranging from touching coral with hands to the resuspension of sediment by fins. No assessment of habitat degradation or long-term impacts was discussed. Divers pursuing lobster along coral or hard bottom communities have been observed to impact gorgonians and other encrusting organisms (Barnette, unpublished observations).

Harpoon

Harpoons, thrown from the decks of a vessel, are utilized to target swordfish and tuna. As this gear is employed to harvest pelagic species, there is no contact with the benthos and, thus, no impact to habitat.

Haul Seine and Beach Seine

A haul seine is an active fishing system that traps fish by encircling them with a long fence-like wall of webbing. It is made of strong netting hung from a float line on the surface and held near the bottom by a lead line. They are fished either along the shoreline (beach seine) where they are deployed in a semi-circle to trap fish between shore and net or, more typically, fish are encircled away from shore, worked into an even smaller pocket of net and lifted onto a boat for culling (Sadzinski et al. 1996). The use of this gear is limited to state waters. Sadzinski et al. (1996) found no detectable effects from haul seining on SAV. However, possible damage from haul seining to sexual reproduction, such as flower shearing, was not examined. There are possible long-term or cumulative impacts at established haul-out sites, resulting in loss of SAV biomass (Orth personal communication). As the seine is generally used in flat benthic areas to prevent the net becoming damaged, in most cases the impact from seines would be expected to be minor and temporary.

Hook and Line, Handline, Bandit Gear, Buoy Gear and Rod and Reel

These gear types are widely utilized by commercial and recreational fishermen over a variety of estuarine, nearshore, and marine habitats. Hook and line may be employed over reef habitat or trolled in pursuit of pelagic species in both state and Federal waters.

Few studies have focused on physical habitat impacts from these gear types. Impacts may include entanglement and minor degradation of benthic species from line abrasion and the use of weights (sinkers). Schleyer and Tomalin (2000) noted that discarded or lost fishing line appeared to entangle readily on branching and digitate corals and was accompanied by progressive algal growth. This subsequent fouling eventually overgrows and kills the coral, becoming an amorphous lump once accreted by coralline algae (Schleyer and Tomalin 2000). Lines entangled amongst fragile coral may break delicate gorgonians and similar species. Due to the widespread use of weights over coral reef or hardbottom habitat and the concentration of effort over these habitat areas from recreational and commercial fishermen, the cumulative effect may lead to significant impacts resulting from the use of these gear types.

Patent Tong

Similar to hand tongs, hydraulic patent tong s (Figure 26) are much larger and are assisted with hydraulic lift, allowing them to purchase more benthic area in pursuit of oysters. Patent tongs are utilized in the oyster fisheries that occur in state waters. Rothschild et al. (1994) found that hydraulic-powered patent tongs are the most destructive gear to oyster reef structure because of their capability to penetrate and disassociate the oyster reef. The capability arises from the gear weight and hydraulic power. Patent tongs operate much like an industrial crane with each bite having the ability to remove a section of the oyster bar amounting to $0.25 m^3$.

Due to overfishing and disease, oysters may now be more economically valuable for the habitat they provide for other valued species than they are for the oyster fishery (Lenihan and Peterson 1998). Rothschild et al. (1994) suggested the establishment of broodstock sanctuaries that includes the designation of "no-fishing" restrictions in specific areas. Lenihan and Micheli (2000) also recommended the closure of some oyster reefs to harvest. Maintaining high densities of oysters on some intertidal reefs may help to preserve future oyster harvests and broodstock. Furthermore, protecting some reefs will also preserve the ecological functions that oyster reef provide such as improving water quality and providing essential recruitment, refuge, and foraging habitat for numerous marine species.

Purse Seine and Lampara Net

Purse seines are walls of netting used to encircle entire schools of fish at or near the surface. Spotter planes are often used to locate the schools, which are subsequently surrounded by the netting and trapped by the use of a pursing or drawstring cable threaded through the bottom of the net. When the cable has pulled the netting tight, enclosing the fish in the net, the net is retrieved to congregate the fish. The catch is then either pumped onboard or hauled onboard with a crane-operated dip net in a process called brailing. Purse seines are utilized to harvest menhaden in the Gulf and South Atlantic. Similarly, the lampara net has a large central bunt, or bagging portion, and short wings. The buoyed float line is longer than the weighted lead line so that as the lines are hauled the wings of the net come together at the bottom first, trapping the fish. As the net is brought in, the school of fish is worked into the bunt and captured. In the Florida Keys a modified lampara net is used to harvest baitfish near the top of the water column. The wing is used to skim the water surface as the net is drawn in and fish are herded into the pursing section to be harvested with a dip net. Purse seines in the Gulf menhaden fishery frequently interact with the bottom, resulting in sediment resuspension. Schoellhammer (1996) estimated that sediments resuspended by purse seining activities would last only a period of hours.

Pushnet

Employed to harvest shrimp in shallow water, pushnets (Figure 30) consist of netting supported by a frame that is mounted on to a pole, which is then pushed across the bottom. Pushnets are generally utilized on SAV beds where shrimp can be harvested in abundant numbers. DeSylva (1954) determined that push nets have no detrimental effect on habitat.

Slurp Gun

A slurp gun is a self-contained, handheld device that captures tropical fish by rapidly drawing seawater containing such fish into a closed chamber. Slurp guns are typically employed on hardbottom and coral reef habitat in both state and Federal waters. It is possible that tropical collectors may impact coral or other benthic invertebrates in pursuit of tropical species that are harvested on hardbottom or coral habitat areas. However, due to the limited force applied by a diver in an errant fin kick or hand placement, the likely effects to habitat would be minor.

Snare

Recreational divers pursuing spiny lobster often use a long, thin pole that has a loop of coated wire on the end called a snare. The loop is placed around a lobster that may be residing in a tight overhang or other inaccessible location, and then tightened by a pull toggle at the base of the pole in order to capture and extract the lobster.

While there are no studies that evaluate this gear type, it is probable that use of this gear may minimize impacts to habitat in comparison to divers that use no additional gear (hand harvest). Due to the more surgical precision with the snare, divers likely impact the surrounding habitat to a lesser extent than if capturing by hand only due to the required leverage needed by the divers to capture a lobster by hand.

Spear and Powerhead

Divers use pneumatic or rubber band guns or slings to hurl a spear shaft to harvest a wide array of fish species. Reef species such as grouper and snapper, as well as pelagic species such as dolphin and mackerel, are targeted by divers. Commercial divers sometimes employ a shotgun shell known as a powerhead at the shaft tip, which efficiently delivers a lethal charge to their quarry. This method is commonly used to harvest large species such as amberjack.

Gomez et al. (1987) concluded that spearfishing on reef habitat may result in some coral breakage, but damage is probably negligible. A study that assessed recreational SCUBA activity in the US Caribbean (Garcia-Moliner et al. 2000) concluded that approximately 0.7% of the total recreational divers in the USVI and 28% of the total recreational divers in Puerto Rico are spearfishing. Potential impact would be approximately 4,736 units in the USVI and 220,264 units in Puerto Rico. In this study, impact units consisted of two hands and two feet (4 units per diver) and impact was broadly defined as ranging from touching coral with hands to the resuspension of sediment by fins. No assessment of habitat degradation or long-term impacts was discussed. It may be assumed that divers pursuing pelagic species have no effect on habitat due to the absence of any interaction with the benthos.

6.3 Cumulative impacts of fishing and non-fishing activities

This section analyzes cumulative impacts, which are defined by the Council on Environmental Quality (CEQ) as "impacts on the environment that result from the incremental impact of an action when added to other past, present, and reasonably foreseeable future actions, regardless of who undertakes such actions." Increasing evidence suggests that the most severe environmental effects may not result from the direct impacts of a particular action, but rather from cumulative environmental effects. The incremental loss of important habitat can irreversibly alter the structure and function of the nearshore marine ecosystem and ultimately affect human activities (Jackson 1997). Further, regional problems are highly vulnerable to small decision effects – the tyranny of small decisions, as evidenced in the Florida Everglades (Odum 1982).

The overall cumulative impact of human-induced activities and natural events remains poorly documented, understood, and in dire need of more study. Nationally, one report noted that "federal agencies have struggled with preparing cumulative effect analyses since the CEQ issued its National Environmental Policy Act (NEPA) regulations in 1978." (CEQ 1997).

It is evident that the effect of human activity on aquatic systems has been substantial in locations where access and economically profitable modification could be readily accommodated. Dahl (1990) reports that in the 1780's there were about 20.3 million acres of wetlands in Florida, about 6.8 million acres in Georgia, about 6.4 million acres in South Carolina, and about 11.1 million acres in North Carolina. By the 1980's Florida's wetlands had been reduced to 11.0 million acres, Georgia's to 5.3 million acres, South Carolina's to 4.7 million acres, and North Carolina's to 5.7 million acres. Overall about 36.3% of all wetlands in states under SAFMC purview have been eliminated. On a state-by-state basis this includes 46% of Florida's wetlands, 23% of Georgia's wetlands, 27% of South Carolina's wetlands, and 49% of North Carolina's wetlands. A 2001 National Research Council report found that, as a result, by the 1980s the area of wetlands in the contiguous United States had decreased to approximately 53% of its extent one hundred years earlier (NRC 2001).

According to the FWS Status and Trends of Wetlands in the Conterminous United States 1998 to 2004 there was an estimated net gain in wetlands of 191,750 acres, however the report did not draw conclusion regarding the quality of the nation's wetlands and counted over 700,000 acres of open water ponds as wetlands. Intertidal wetlands declined by an estimated 28,416 acres, with the greatest percent change attributed to marine intertidal wetlands. The overriding factor in the decline of estuarine and marine wetlands was the loss of emergent saltmarsh to open saltwater systems due to manmade activities such as dredging, water control, and commercial and recreational boat traffic. There was an estimated 800 acre gain of estuarine shrub wetlands, however most of this gain came from areas formerly classified as estuarine emergent wetland. Estuarine vegetated wetlands have continued to decline over time as losses to the estuarine emergent category have overshadowed the small gains to estuarine shrub wetlands (Dahl 2006). As an indication of the scope of developmental pressure, hence one aspect cumulative effect on EFH (coastal and tributary wetlands), NOAA Fisheries Service data show receipt of more than 20,778 individual development proposals (COE permit applications, federal projects, etc.) in North Carolina, South Carolina, Georgia, and Florida between 1981 and 1996 (See Tables 26, 27, 28, & 29). A subsample of 4,000 of these development proposals involved over 13,856 acres of various wetland habitats. Between 1996 and 2006, NOAA Fisheries Service reviewed an additional 20,896 applications to impact areas known to support EFH.

In addition to the substantial loss of wetlands in the southeastern United States, Nocholls et al. (1999) determined that by the 2080s, sea-level rise could cause the loss of up to 22% of the world's coastal wetlands. When combined with other losses due to direct human action, up to 70% of the world's coastal wetlands could be lost by the 2080s, although there is considerable uncertainty. Therefore, sea-level rise would reinforce other adverse trends of wetland loss.

While it is believed that most regulated activities are implemented as planned, Mager and Thayer (1986) report that limited monitoring indicate that about 20% of the projects they examined did not comply with provisions of the associated permits. Notably, most of the differences observed related more to design of structures and not the area of habitat affected. As shown in the following tables, individually and cumulatively significant impacts to EFH can be moderated through the COE regulatory program; however, significant wetland perturbations persist. This situation is largely perpetuated by (1) regulatory provisions that exempt regulation of certain wetland types and activities and (2) by severe staffing limitations within regulatory and environmental review agencies. In the absence of substantial correction in these two areas, significant wetland areas will continue to be adversely altered or eliminated, and regulatory and review agency effectiveness will be limited.

In addition to the direct cumulative effect incurred by developmental type activities, EFH is also jeopardized by persistent increases in certain chemical discharges. In that case incremental change in habitats, hydrology, and chemical inputs produced, over time, an enormous and extremely harmful result whose negative economic and social implications may far exceed any benefits related to the causative factors. Unfortunately, the effect of adding ever greater volumes and varieties of chemicals to surface waters is often insidious and resulting declines in the abundance and quality of affected and harvested resources may be slow and difficult to identify. As illustrated by Scott et al (1997), the effects may be realized at rudimentary trophic and ecological association levels in key portions (including EFH) of estuarine environments.

The rate and magnitude of anthropomorphic change on EFH, whether cumulative, synergistic, or individually large, is influenced by natural parameters such as temperature, wind, currents, rainfall, salinity, etc. Consequently, the level of threat posed by a particular activity or group of activities may vary considerably from location to location. This situation may be most acute in locations that are subject to extreme weather and oceanic conditions such as hurricanes and large waves, or where the effects of periodic or global change are most prevalent.

Nutrient over-enrichment has become a large cumulative problem for southeastern EFH. Excessive nutrients may be directly toxic. Even relatively low nitrate-nitrogen levels (as low as 3.5 uM NO3-N) have been found to cause impacts on both growth and survival in eelgrass (*Z. marina*) during spring and fall growing seasons (Burkholder et al. 1992). In contrast, Cuban shoal grass (*Halodule wrightii*) and widgeon grass (*Ruppia maritima*) were stimulated by nutrient enrichment (Burkholder et al. 1994). Eelgrass provides important brackish water habitat element for finfish, crustaceans and molluscs in North Carolina (Thayer et al. 1984). Nitrate toxicity to eelgrass in the field has yet to be documented, although nitrate concentrations in the range found to have an impact in mesocosm experiments certainly occurs in many estuarine settings.

The effects of nutrient enrichment and stimulation of toxic dinoflagellates and other algae, especially *Pfiesteria piscidida*, have been widely reported by the news media. The high abundance of small heterotrophic algae in southeastern estuaries was well known among plankton researchers during the 1980s and earlier; however, the toxic nature of *Pfiesteria* was not reported until the late 1980s (Burkholder et al. 1992, 1993, 1995; Noga et al. 1993). Analyses suggest that a large suite of *Pfiesteria*-like small heterotrophic dinoflagellates exist in most southeastern estuaries (P. Tester, personal communication). These organisms include toxic forms, like *Pfiesteria*, and may be responsible for a significant number of fish kills associated with eutrophic estuaries (Burkholder et al. 1992). Fish kills in North Carolina and Maryland have been attributed, at least in part, to these organisms (Burkholder et al. 1995), and analyses suggest that toxic dinoflagellates (and related organisms) are on the rise at a global scale (Paerl 1988; Smayda 1989; Paerl et al. 1995a).

The stimulation of toxic organism population growth by nutrient enrichment may be related to factors outside the South Atlantic region. The most notable recent case was the transport of the toxic dinoflagellate *Ptychodiscus brevis* in 1989 by the Gulf Stream and associated eddies into Onslow Bay, North Carolina. Among other impacts offshore and inshore, this seriously impacted scallop production in Bogue Sound, North Carolina (Tester et al. 1989).

Enrichment of estuarine algal and bacterioplanktonic communities by excessive nutrients is probably the most often cited example of estuarine degradation globally (Nixon 1995; NRC 1994; Ryther and Dunstan 1971). In general, the ecological pathway involves enhanced algal or bacterial production and metabolism followed by excessive oxygen uptake and subsequent deoxygenation. Anoxia and hypoxia have been identified as the fundamental problems facing Chesapeake Bay, the Gulf of Mexico, the Tar-Pamlico and Neuse River Estuaries, and other locations throughout the world (Paerl 1988).

Associated processes may be complex. For example, nutrient uptake and excessive autotroph production may result in deposition of organic material into benthic sediments, where increased sediment oxygen demand may occur at some later time. In stratified estuaries, the process may even be exacerbated by the re-release of nutrients as sediment oxygen demand is exerted in bottom, anoxic waters. The ecological effects of modification of production patterns also includes hypercapnia (elevated levels of carbon dioxide), which exerts powerful effects on some organisms (Burnett 1997).

Algal blooms in southeastern waters represent a major threat to EFH. Important algal blooms have been documented in Albemarle Sound, the Chowan River, the Tar-Pamlico River, the Neuse River Estuary, the New River Estuary, Bogue Sound, the St. Johns River, and Indian River (NOAA 1996). Algal levels can be extremely high in grossly enriched waters. A one-day survey of the Pamlico Estuary in 1988 found chlorophyll a (an algal pigment) in excess of 200 ug/l, compared to a North Carolina Water Quality Standard of 40 ug/l (15A NCAC 2B.0200). Another type of algal community stimulation occurs when airborne nitrogen from all sources, including agriculture, is deposited through wet and dry deposition into distant oceanic waters. This phenomenon was largely unrecognized until recently (Paerl 1985, 1993). Consequences of this type of deposition, where the majority of “new” primary production comes from this source, can be quite significant, both on patterns in primary and secondary production and in the taxonomic makeup of that production, including the toxic forms cited above.

Among the most serious problems caused by algal blooms and other effects of over enrichment is the removal of oxygen from the water. The extent of deoxygenation in southeastern estuaries has been well documented (Rader et al. 1987; Stanley 1985). A more recent survey of the South Atlantic region found periodic hypoxic conditions in 13 of the 21 estuaries surveyed, with bottom-water anoxia in 11 locations. Only one instance of anoxia was found along the Sea Island Coast of South Carolina and Georgia, and this was linked to stratified conditions in the Savannah River. Major anoxic events were documented in the Neuse River, the Tar-Pamlico River Estuary, the Indian River and St. Helena Sound (NOAA 1996). Although seasonal low-oxygen events may be natural in southeastern stratified estuaries, expansion in the size or persistence of deoxygenated areas has been identified for some of the above listed waters (Breitburg 1990; Rabalais et al. 1996).

Effects of deoxygenation on resident and post-larval fish, crustacean, and mollusc communities can be significant. The enormous fish kills that have plagued the Tar-Pamlico and Neuse River Estuaries have received abundant popular press since the late 1980's, and have recently been systematically analyzed (Pietrafesa and Miller 1997). This study identified 246 kills in the Pamlico during the period 1985-1995, and 73 in the Neuse, including many over 1,000,000 fish. Fish kills have also been documented in the St. John River, Florida and Charleston Harbor, South Carolina (Burkholder et al. 1995).
Another possible manifestation of nutrient over enrichment is the occurrence of chitonoclastic shell disease in blue crabs. This is believed by some to be related to water pollution (either stress incurred after exposure to anoxic conditions or cadmium). Little is known absolutely (Noga et al. 1990). In addition, fish diseases have been implicated throughout polluted estuaries, but the link to pollution remains uncertain (Noga et al. 1989).

The impact of fish kills from nutrient over enrichment is difficult to assess in terms of their effect on stocks of commercially important fish. Many of the fish killed are juveniles and Atlantic menhaden appear especially vulnerable. If these stocks are density independent, then kills translate directly into reduced adult population sizes. Vaughan (1986) found that in Atlantic menhaden, catastrophic kills, where 10% mortality events occur periodically, coupled to the accumulating 1% annual losses from permanent habitat loss, could cause a loss of 60% of the fishery within 30 years.

Impacts of atmospheric deposition of nutrients on inshore EFH is well documented, as cited above (and in Fisher and Oppenheimer 1991). Some studies suggest that nutrient enrichment from atmospheric and more traditional surface water sources can also modify planktonic and epibenthic algal communities to the detriment of fish. Changes in the phytoplankton community lead to changes in the grazer community, including the reduction or elimination of preferred prey items for planktivorous fish and fish larvae. One example is the plankton community of Western Albemarle Sound, North Carolina, where nanoplankton (the small-celled algae that are the principal food source for crustacean zooplankters) are replaced in part in some years by blue-green algae of low food value, with a concomitant elimination of the zooplankters preferred by some anadromous fish larvae and juveniles (Rulifson et al. 1986).

Besides fish, plankton, and algae, vascular marine plants also are adversely affected by excessive nutrients and their consequences. Eutrophication may cause the reduction in coverage of SAV due to shading associated with water column turbidity and the growth of epiphytic filamentous algae. Although significant die-offs of SAV have occurred in some locations in the southeast, including the Pamlico River Estuary, the direct causes of algal growth stimulation has not been established (Davis et al. 1985). NOAA’s 1996 survey of impacts on SAV found declines in 5 of 21 estuaries of the southeast, including Albemarle/Pamlico Sounds, but increases in Biscayne Bay and Charleston Harbor (NOAA 1996).

A major problem with regard to assessing cumulative effects is that the majority of the methods developed to evaluate cumulative effects were developed in a terrestrial context and the applicability to marine resources and EFH is not clear. However, new analytical approaches may advance management evaluations of cumulative environmental effects. Ecological risk assessment procedures provide a useful frame for comprehensively structured analyses of anthropogenic effects (EPA 1992). These procedures involve the systematic evaluation of stressors and effects using flexible methods that foster detailed evaluations of effects (Harwell et al. 1995). The application of risk assessment principles to environmental assessments could result in more comprehensive scientific products that also carry more administrative weight. In addition, systematic applications of decision support systems can offer logically consistent methods to evaluate multiple policy alternatives. Decision support systems aid the objective identification of appropriate decision combinations according to multiple priorities and they support group-based policy evaluations (Saaty 1990; Keyes and Palmer 1993; Schmoldt et al. 1994). Combined utilization of these approaches may identify previously underemphasized factors and objective policy alternatives (Lindeman 1997b). Ultimately, they may foster more logical and explicit decision-making regarding cumulative effects issues.

A cumulative assessment of population-scale fishing effects in the Florida Keys documents that 13 of 16 grouper species, 7 of 13 snappers, and 2 of 5 grunts are recruitment overfished (Ault et al. 1998). The cumulative result of technologically enhanced fishing effort has been the accelerated removal of those top predators with most economic value. Therefore, intensive effort is now being expended to obtain species that are lower on the food chain (Pauley et al. 1998). This has serious implications; as the lower levels of the food chain decline, the chances of revival at the top of the food chain are diminished even further (Williams 1998). Top-down ecosystem degradation can result in a variety of unfavorable species abundance shifts (Goeden 1982) and, potentially, outright ecosystem collapse (Pauley et al. 1998). Further cumulative assessments of managed species in the South Atlantic may reveal long-term declines similar to those now identified in the Keys. Under such circumstances, traditional management measures (e.g., size and harvest limits), may not be adequate to rebuild sustainable fisheries for the most desirable species.