to the ends of the respective shoals, but shoreward of the Gulf stream; The Point, The Ten-Fathom Ledge, and Big Rock (North Carolina); The Charleston Bump and Hurl Rocks (South Carolina); The Point off Jupiter Inlet (Florida); *Phragmatopoma* (worm reefs) reefs off the central east coast of Florida; nearshore hard bottom south of Cape Canaveral; The Hump off Islamorada, Florida; The Marathon Hump off Marathon, Florida; The "Wall" off of the Florida Keys; Pelagic *Sargassum*; and Atlantic coast estuaries with high numbers of Spanish mackerel and cobia based on abundance data from the ELMR Program. Estuaries meeting this criteria for Spanish mackerel include Bogue Sound and New River, North Carolina; Bogue Sound, North Carolina (Adults May-September salinity >30 ppt); and New River, North Carolina (Adults May-October salinity >30 ppt). For Cobia they include Broad River, South Carolina; and Broad River, South Carolina (Adults & juveniles May-July salinity >25ppt).

These areas include spawning grounds and habitats where eggs and larvae develop. In addition, the estuarine habitats also provide prey species along migration pathways.

3.3.5   Golden Crab
3.3.5.1 Description of the Species and Distribution

The golden crab, *Chaceon fenneri*, is a large gold or buff colored species inhabiting the continental slope of Bermuda (Luckhurst, 1986; Manning and Holthuis, 1986) and the southeastern United States from off Chesapeake Bay (Schroeder, 1959), south through the Straits of Florida and into the eastern Gulf of Mexico (Manning and Holthuis, 1984, 1986; Otwell et al., 1984; Wenner et al., 1987, Erdman 1990).
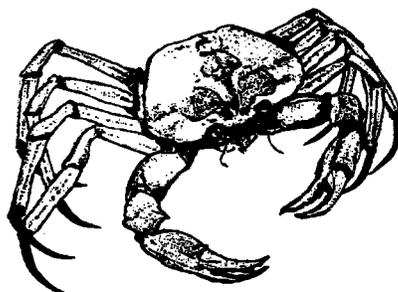
Reported depth distributions of *C. fenneri* range from 205 m off the Dry Tortugas (Manning and Holthuis, 1984) to 1007 m off Bermuda (Manning and Holthuis, 1986). Size of males examined range from 34 to 139 mm carapace length (CL) and females range from 39 to 118 mm CL. Ovigerous females have been reported during September, October and November, and range in size from 91 to 118 mm CL (Manning and Holthuis, 1984, 1986)."

Larval Distribution & Recruitment

The following text is from Lockhart et al. (1990):

"The distribution patterns of *Chaceon fenneri* and possibly *C. quinquedens* in the eastern Gulf of Mexico suggest a causal role for the Loop Current System (Maul 1977) in basic life history adaptations. Female distribution within these species' geographic ranges and the timing of larval release supports this hypothesis. Ours was the first study to discover female golden crabs in any significant numbers and was also the first to find a major population of female red crabs in the Gulf of Mexico. Both of these concentrations of females were seemingly shifted counter-current to the Loop Current circulation. We hypothesize that this counter-current shift is linked to larval release and transport, and serves to maximize recruitment into the parent population by minimizing risk of larval flushing.

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Similar counter-current shifts of other female decapods have been reported or hypothesized. In the Gulf of Mexico, spawning female blue crabs (*Callinectes sapidus*) have been hypothesized to undergo a late summer spawning migration in the northeastern Gulf of Mexico that is counter to the Loop Current system (Oesterling and Adams 1979). Female western rock lobsters (*Panulirus cygnus*) are hypothesized to undergo migration to favor recruitment back into the parent population (Phillips et al. 1979). Kelly et al. (1982) proposed that only those red crab larvae (*Chaceon quinquedens*) released up-current in the species' range will recruit back into the parent population. Melville-Smith (1987a, 1987b, 1987c) in a tagging study of red crabs (*C. maritae*) off the coast of southwest Africa, showed that the only segment of the population exhibiting significant directional movement were adult females: 32% of recaptures had moved greater than 100 km and the greatest distance traveled was 380 km over 5 yr. This directional movement was later shown to be counter to the prevailing surface currents (Melville-Smith 1990). Thus, within decapods in general, and the genus in particular, adult females are capable of, and appear to undergo, long-distance directional movement in their lifetimes.

A similar migration of adult female golden crabs, counter-current to Loop Current circulation in the Gulf of Mexico, would produce the geographic population structure observed off the southeastern United States. Females would be most common farthest up-current whereas males would be most common intermediate in the species geographic range. Wenner et al. (1987) reported a 15:1 (M:F) sex ratio in the South Atlantic Bight and in this study, we had an overall sex ratio of 1:4 — both consistent with hypothesized net female movements to accommodate larval retention and offset the risk of larval flushing.

In fact, given this, two female strategies could maximize recruitment in a prevailing current. The first is for females to position themselves far enough up current so that entrainment would return larvae to the parent population (Sastry 1983). The second is to avoid larval entrainment altogether and thus avoid flushing of the larvae out of the system. Female *Chaceon fenneri*, and perhaps *C. quinquedens*, appear to use both strategies but rely mainly on the latter.

Female golden crabs release larvae offshore in depths usually shallower than 500 m. If larvae were released directly into the Loop Current-Gulf Stream System, they would be entrained for their entire developmental period. Given a developmental time of 33-40 d at 18°C (K. Stuck, Gulf Coast Research Laboratories, Ocean Springs, Mississippi, pers. comm.) and current speeds of 10-20 cm/sec (Sturges and Evans 1983), transport of the larvae would be 285 km to 690 km downstream. Thus, larvae released on the Atlantic side of Florida are in danger of being flushed out of the species' range before recruiting to the benthic stock. Likewise, larvae released directly into the current in the southeastern Gulf of Mexico would be flushed from the Gulf.

Female golden crabs release larvae from February to March (Erdman and Blake 1988; Erdman et al. 1989) and the greatest concentration of female golden crabs to date found in this study was in the northeastern Gulf of Mexico off central Florida. Only during this period and in this region (Maul 1977), can female golden crabs avoid complete entrainment and possible flushing of larvae out of the system. Partial entrainment of larvae might still occur, but its duration should be much reduced, and the risk of larval flushing minimal. This hypothesis predicts that most larvae should be found near the concentrations of females we found in the northeastern Gulf of Mexico with decreasing settlement further downstream. The abundance of juveniles should show a similar pattern.

One need not invoke similar counter-current movements for male geryonid crabs. In particular, males moving perpendicular to adult females (i.e. males moving up and down the continental slope) would have a greater encounter rate with females than males moving along the

slope with females. Given low female reproductive frequency (Erdman et al. 1989), intense male-female competition (Lindberg and Lockhart 1988), and probability of multiple broods (Hinsch 1988) from a single protracted copulation (H. M. Perry, pers. obs.), the male strategy should be to intercept relatively rare receptive females all along the species' range, not to aggregate with presumably inseminated females. This hypothesis would predict a relatively uniform abundance of males along their geographic range. In addition, the incidence of inseminated females should be high farthest upstream with an ever decreasing percentage down-stream. Our study supports the former hypothesis but we cannot address the latter.

The distributional patterns of geryonid crabs we observed are consistent with those reported from elsewhere. Furthermore, these patterns lead us to suggest that the Loop Current System has had a causal role in life history adaptations of *Chaceon fenneri* and perhaps *C. quinquedens*. In general, females are expected to release larvae during a time and in a region where risk of larval flushing is minimal (Sinclair 1988), whereas males are expected to compete intensely for rare, receptive mates."

The coastal physical oceanography in the Florida Keys was described by Yeung (1991) in a study of lobster recruitment:

"The strong, northward-flowing Florida Current is the part of the Gulf Stream system confined within the Straits of Florida. It continues from the Loop Current in the Gulf of Mexico, and proceeds beyond Cape Hatteras as the North Atlantic Gulf Stream.

The mean axis of the Florida Current is approximately 80 km offshore of Key West and 25 km off Miami (Lee et al. 1991). Mean annual cross-stream surface current speed in the Straits of Florida is approximately 100 cm/s (U.S. Naval Oceanographic Office 1965).

Brooks and Niller (1975) observed a persistent countercurrent near Key West extending from surface to the bottom, and from nearshore to approximately 20 km seaward. They believed that it was part of the cyclonic recalculation of the Florida Current between the Lower and Middle Keys.

The presence of a cold, cyclonic gyre was confirmed by physical oceanographic data collected in the SEFCAR cruises. It was named the Pourtales Gyre since it occurs over the Pourtales Terrace -- that area of the continental shelf off the Lower and Middle Keys (Lee et al. 1991). When the Florida Current moves offshore, the Pourtales Gyre forms over the Pourtales Terrace, and can last for a period of 1-4 weeks.

The Pourtales Gyre could entrain and retain locally spawned planktonic larvae for a short period. The combination of the cyclonic circulation and enhanced surface Ekman transport could also advect foreign arrivals into, and concentrate them at, the coastal boundary (Lee et al. 1991).

Vertical distribution of the larvae within the 3-dimensional circulation will subject them to complicated hydrographic gradients, which might influence their development time, and hence their dispersal potential (Kelly, Sulkin, and van Heukelem 1982; Sulkin and McKeen 1989). Thus, variability in the circulation features and water mass properties can lead to variability in larval transport and recruitment."

The Pourtales Gyre may provide a mechanism for entrainment of golden crab larvae spawned on the Florida east coast, and also as a mechanism to entrain and advect larvae from the Gulf and Caribbean (e.g., Cuba). This possibility is supported by the conclusion of Yeung (1991) suggesting that larvae of a foreign origin supply recruits to the Florida spiny lobster population:

"The foreign supply of pre-recruits arriving with the Florida Current might easily meet the same fate as the locally spawned larvae, that is, passing on with the Florida Current. The

Pourtales Gyre may play a significant role in recruitment by providing a physical mechanism to entrain and advect larvae into the coastal boundary.

The Pourtales Gyre, even if linked with the Dry Tortugas gyre or the Florida Bay circulation, may not be able to provide a pathway much more than 2 months in period. For locally spawned *Panulirus* larvae to be retained for their entire development would require several circuits -- not impossible, but unlikely"

The timing of the Pourtales Gyre provides a mechanism for local recruitment of *Scyllarus* larvae (Yeung, 1991) and may also provide a similar mechanism for golden crab larvae. Golden crab larvae from the Gulf of Mexico, Cuba, and possibly other areas of the Caribbean, probably provide larvae to the South Atlantic population. The proportion of local recruitment is unknown but could be significant.

Feeding

Feeding habits are very poorly known. Golden crabs are often categorized as scavengers that feed opportunistically on dead carcasses deposited on the bottom from overlying waters (Hines, 1990).

Movement

Wenner et al. (1987) found in the South Atlantic Bight that: " Size-related distribution of *G. fenneri* with depth, similar to that reported for red crab, may occur in the South Atlantic Bight. We found the largest crabs in the shallowest (274-366 m) and deepest (733-823 m) strata. A clear trend of size-related up-slope migrations such as Wigley et al. (1975) reported for *G. quinquedens* is not apparent, however, because of trap bias for capture of larger crabs of both sexes. Otwell et al. (1984) also noted no pattern in size of golden crab by depth for either sex. Tagging studies of red crab off southern New England provided no evidence for migration patterns and indicated instead that tagged crabs seldom moved more than 20 km from their site of release (Lux et al., 1982)."

Lindberg and Lockhart (1993) found in the Gulf of Mexico: " The golden crab *Chaceon fenneri* in the eastern Gulf of Mexico exhibits a typical bathymetric pattern of partial sex zonation and an inverse size-depth relationship, as first reported for red crabs (*C. quinquedens*: Wigley et al., 1975; *C. maritae*: Beyers and Wilke, 1980). Sex segregation, with females shallower than most males, was more evident in our results than in those of Wenner et al. (1987) from the South Atlantic Bight, primarily because our trap catch had a higher proportion of females (25.9% compared to 5.2%)."

Abundance

Golden crab abundance studies are limited. Data from the South Atlantic Bight (Wenner et al., 1987) estimated abundance from visual assessment was 1.9 crabs per hectare while traps caught between 2 and 10 kg per trap. Wenner and Barans (1990) estimated the golden crab population in small areas of 26-29 square km between 300-500 m off Charleston to be 5,000-6,000 adult crabs. In the eastern Gulf of Mexico adult standing stock was estimated to be 7.8 million golden crabs and the biomass was estimated to be 6.16 million kg (13.6 million pounds) (Lindberg et al., 1989). Experimental trapping off Georgia yielded an average catch of 7 kg per trap (Kendall, 1990).

3.3.5.2 Essential Fish Habitat and Environmental Requirements

Essential fish habitat for golden crab includes the U.S. Continental Shelf from Chesapeake Bay south through the Florida Straits (and into the Gulf of Mexico). In addition, the Gulf Stream is an essential fish habitat because it provides a mechanism to disperse golden crab larvae. The detailed description of seven essential fish habitat types (a flat foraminferan ooze habitat; distinct mounds, primarily of dead coral; ripple habitat; dunes; black pebble habitat; low outcrop; and soft-bioturbated habitat) for golden crab is provided in Wenner et al. (1987).

Based on exploratory trapping, golden crab maximum abundance occurs between 367 and 549 meters in the South Atlantic Bight. Information on sediment composition suggest that golden crab abundance is influenced by sediment type with highest catches on substrates containing a mixture of silt-clay and foraminiferan shell. Wenner et al. (1987) further notes: "Other studies have described an association of *G. quinquedens* with soft substrates. Wigley et al. (1975) noted that bottom sediments throughout the area surveyed for red crab from offshore Maryland to Corsair Canyon (Georges Bank) consisted of a soft, olive-green, silt-clay mixture. If golden crabs preferentially inhabit soft substrates, then their zone of maximum abundance may be limited within the South Atlantic Bight. Surveys by Bullis and Rathjen (1959) indicated that green mud occurred consistently at 270-450 m between St. Augustine and Cape Canaveral, FL (30°N and 28°N). This same depth range from Savannah, GA to St. Augustine was generally characterized by Bullis and Rathjen (1959) as extremely irregular bottom with some smooth limestone or "slab" rock present. Our study indicates, however, that the bottom due east between Savannah and St. Catherines Island, GA at 270-540 m consists of mud and biogenic ooze. Further north from Cape Fear, NC to Savannah, bottom topography between 270 and 450 m is highly variable with rocky outcrops, sand and mud ooze present (Low and Ulrich, 1983)."

In a subsequent study using a submersible, Wenner and Barans (1990) found the greatest abundance in rock outcrops:

Observations on density and a characterization of essential habitat for golden crab, *Chaceon fenneri*, were made from a submersible along 85 transects in depths of 389-567 m approximately 122 km southeast of Charleston, South Carolina. Additional observations on habitat were made on 16 transects that crossed isobaths between 293-517 m.

Seven essential habitat types can be identified for golden crab from observations:
•   A flat foraminiferon ooze habitat (405-567 m) was the most frequently encountered habitat. This habitat type is characterized by pteropod-foraminiferan debris mixed with larger shell fragments, a sediment surface mostly covered with a black phosphorite precipitate;

•   Distinct mounds, primarily of dead coral at depths of 503 to 555 meters and constituted 20% of the bottom surveyed on dives to count crabs. Coral mounds rose approximately 15 to 23 meters in height above the surrounding sea floor and included several that were thinly veneered with a fine sediment and dead coral fragments, as well as a number that were thickly encrusted with live branching ahermatypic corals (*Lophelia prolifera* and *Enallopsammia profunda*). Fan-shaped sponges, pennatulids and crinoids were oriented into the northerly 1.4-1.9 km- h^{-1} current. The decapod crustaceans *Bathynectes longispina*, *Heterocarpus ensifer* and *Eumunida pita*, the black-bellied rosefish, *Helicolenus dactylopterus*, and the wreckfish, *Polyprion americanus*, were frequently sighted along transects in the coral mound habitat.

•   Ripple habitat (320-539 m); dunes (389-472 m); black pebble habitat (446-564 m); low outcrop (466-512 m); and soft-bioturbated habitat (293-475 m). A total of 109 *C. fenneri* were

sighted within the 583,480 m^2 of bottom surveyed. Density (mean no. per 1,000 m^2) was significantly different among habitats, with highest values (0.7 per 1,000 m^2) noted among low rock outcrops. Lowest densities were observed in the dune habitat (<0.1 per 1,000 m^2), while densities for other habitats were similar (0.15-0.22 per 1,000 m^2)."

A similar submersible study in the eastern Gulf of Mexico (Lindberg and Lockhart, 1993) found similar results with higher abundance on hard bottom: "Within the bathymetric range of golden crabs, crab abundance may be related more to habitat type than to depth. The greatest density (36.5 crabs/ha) occurred on or near hard-bottom canyon features."

Golden crab occupy offshore oceanic waters along the Atlantic and Gulf of Mexico coasts as adults. Offshore areas used by adults are probably the least affected by habitat alterations and water quality degradation. Currently, the primary threat comes from oil and gas development and production, offshore dumping of dredged material, disposal of chemical and other wastes, and the discharge of contaminants by river systems.

3.3.5.3 Essential Fish Habitat - Habitat Areas of Particular Concern for Golden Crab

There is insufficient knowledge of the biology of golden crabs to identify spawning and nursery areas and to identify HAPCs at this time. As information becomes available, the Council will evaluate such data and identify HAPCs as appropriate through the framework.

3.3.6   Spiny Lobster
3.3.6.1 Species Distribution and Essential Fish Habitat and Environmental Requirements

Essential fish habitat for spiny lobster includes nearshore shelf/oceanic waters; shallow subtidal bottom; seagrass habitat; unconsolidated bottom (soft sediments); coral and live/hard bottom habitat; sponges; algal communities (*Laurencia*); and mangrove habitat (prop roots). In addition the Gulf Stream is an essential fish habitat because it provides a mechanism to disperse spiny lobster larvae.

Spiny lobster begin their existence in the Keys as larvae that arrive oceanic currents. As planktonic larvae they pass through 11 life stages in more than six months (FKNMS 1995). They then metamorphose into a transitional swimming stage (puerulus) (Little and the Milano, 1980; Lyons, 1980) that is found along Florida's southeast coast all year-long (Hunt et al., 1991). Pueruli travel through channels between the Keys and enter nursery areas in Florida Bay and the Gulf, where they preferentially settle into clumps of red alga *Laurencia* (Herrnkind and Butler, 1986). In seven to nine days a metamorphose into juveniles and take a solitary residence in the algal clumps for two to three months (Marx and Herrkind, 1985b; Hunt et al., 1991).

When juvenile spiny lobster reach a carapace length of 15 to 16 mm they leave the algal clumps and reside individually within rocky holes, crevices, coral, and sponges. They remain solitary until carapace length reaches approximately 25 to 35 mm, when they begin congregating in rocky dens. They remain in these nurseries for 15 months to two years (Hunt et al., 1991).

Adult lobsters move to deeper waters in the coral reef environment, where they occupy dens or holes during daylight hours. They are nocturnal feeders and predominantly prey upon molluscs and crustacea, including hermit crabs and conch.

Spiny lobster, *Panulirus argus*

Adults move to the offshore reef to spawn, and larvae are swept up to the East Coast by the Florida Current, where many are lost due to the length of pelagic pueruli stage (9 months) (Marx and Herrnkind, 1985a; Hunt et al., 1985 a; Hunt et al., 1991).
The following abstract of Yeung, (1996) summarizes recent research efforts on transport and retention of spiny lobster larvae: Transport and Retention of Lobster Phyllosoma in the Florida Keys. Abstract of a doctoral dissertation at University of Miami. December 1996.

"Physical transport can significantly affect recruitment variability of marine species with planktonic larvae. This especially pertinent to the phyllosoma larvae of spiny lobsters (Palinuridae), which have an estimated planktonic duration of 6-12 months. A large population of spiny lobster, *Panulirus argus*, inhabits the reef offshore of the Florida Keys in the Straits of Florida, constituting one of Florida's most valuable fisheries. The hydrography of this region is dominated by the strong Florida Current, which links the Loop Current in the Gulf of Mexico with the Gulf Stream in the North Atlantic. This dynamic oceanography favors the entrainment and dispersal of locally-hatched phyllosoma larvae, leading to contention about the origin of recruits for Florida's population. In this study, the problem of lobster recruitment is approached from the perspective of transport. The main objective is to find the linkage between spatial variables of larval distribution and transport processes. The main physical processes likely to influence larval advection are the meanders and frontal modulations of the Loop Current - Florida Current, coastal gyres and countercurrents, and wind-driven onshore surface transport. The hypothesis is that, due to those processes, intra-regional spatial variability in the distribution and abundance of phyllosomata exists along the Florida Keys. Spatial variability of transport is established with empirical observations of associated physical parameters, e.g. wind vectors, wind-driven surface onshore transport, frequency of coastal countercurrent reversals, the mode of the Loop Current, and the configuration of the Florida Current. The physical data are related to the pattern of larval distribution derived from five years of sampling. Interspecific comparison of larval recruitment strategies between palinurid and scyllarid (Scyllaridae) lobsters, who also inhabit the region and possess the phyllosoma larva, lends insight to the mechanisms of larval transport. Simulation modeling of larval trajectories in an advective model of current-modified ageostrophic transport in the Straits of Florida further aids the conceptualizing of processes, and testing and formulation of hypotheses regarding the interaction between larval behavior and oceanography. Clarification of this biological-physical coupling will advance our understanding of spiny lobster population dynamics and promote effective management of the fishery stocks."

3.3.6.2 Essential Fish Habitat-Habitat Areas of Particular Concern for Spiny Lobster
Areas which meet the criteria for essential fish habitat-habitat areas of particular concern (EFH-HAPCs) for spiny lobster include Florida Bay, Biscayne Bay, Card Sound, and coral/hard bottom habitat from Jupiter Inlet, Florida through the Dry Tortugas, Florida.

3.3.7   Coral, Coral Reefs, and Live/Hard Bottom Habitat
3.3.7.1 Species or Groups of Species and Their Distributions
3.3.7.1.1   Shallow-water Species
3.3.7.1.1.1   Octocorallia (sea fans, sea whips, etc.)
        The shelf waters of the southern and southeastern United States contain a considerable diversity of octocorals. Among those listed for the shelf regions of the western Atlantic by Bayer (1961), only 19 have not been reported from the management area (four species are reported which require confirmation). However, 36 species of primarily deeper-dwelling species have been added to Bayer's list since 1961, bringing the total shelf octocoral fauna of the present study area to 113 species. Of that total, 18 species appear to be endemic, and an additional three species find their principal distribution here (Table 22).
        The temperate region from North Carolina to the southeast Florida coast contains no distinctive octocoral elements. Typical species are *Leptogorgia virgulata*, *L. setacea*, *Lophogorgia hebes*, *Muricea pendula*, and *Titanideum frauenfeldii*.
        The area from Palm Beach south to the Dry Tortugas contains a tropical Atlantic fauna, which appears to be fairly homogeneous. Some faunal differences occur along the Florida reef tract in response to water temperature ranges, substrate availability, and other variables.
        Cairns (1977a) published a field guide to the more common gorgonians of the Gulf of Mexico, Caribbean, and Florida. Wheaton described the octocoral fauna off southeast Florida in 20-50 meter zones (1987), off Key Largo, in 27-57 m depths (1981), at Looe Key (1988), and at Dry Tortugas (1975,1989.)

Table 22.   Endemic elements of the octocoral fauna from the shallow-water continental shelf regions (less than 200 m or 660 ft) of the southern United States.

Telestacea Pennatulacea	Alcyonacea	Gorgonacea (Scleraxonia)
Teiesto flavula *Virgularia presbytes*	*Pseudodrifa nigra*	*Anthopodlum rubens*
T. sanguinea *Stylatula antillarum*		*Anthothela tropicalis*
T. fruticulosa *Acanthoptilum agassizii T. nelleae*		**Titanideum frauenfeldii*
	(Holaxonia)	*A. oligacis*
		Thesea cirtina
		T. plana *Swiftia casta*
		Trichogorgia viola
	Eunicea palmeri	
		Eunicea knighti *Muricea pendula* *Leptogorgia medusa* **Lophogorgia cardinalis*

* Indicates species with principal distribution within study area but also reported from Cuba.

3.3.7.1.1.2   Milleporina and Scleractinia (the fire corals, stinging corals, and stony corals)
      Sixty-eight species of stony corals are known from the continental shelves of the study area**,** 62 of which have been noted from the Florida Keys and the Dry Tortugas alone. This is a remarkably high number, considering that the most diverse locale in the Caribbean (Jamaica) lists only 66 species (Goreau and Wells, 1967; Wells and Lang, 1973). Twelve Jamaican species are absent from Florida waters and an additional seven species are known from the Florida reef tract but not Jamaica: *Madracis asperula, Oculina tenella, O. robusta, Cladocora debilis, Caryophyllia horologium, Flabellum fragile,* and *Favia gravida*. The latter species had been considered as endemic to Brazil until their identification from Florida by Jaap (1979, personal communication) and Avent, et al. (1977), respectively. Two scleractinians are endemic to the South Atlantic and are members of the Oculinidae included in Table 23.

Table 23.   Endemic elements of the scleractinian fauna from the shallow-water continental shelf regions (less than 200 m or 660 ft) of the southeastern United States (References as listed) .

Oculina varicosa Lesueur.	Rare off Florida Keys at 72 to 90 m (236 to 295 ft) (Pourtales, 1871; Verrill, 1901). Common on the continental shelf and shelf edge north of Palm Beach (Avent, et al., 1977; Reed, 1978, personal communication). Known as far north as Cape Hatteras, North Carolina from subtidal to 152 m in depth (Reed, 1980b). Also known from Bermuda in 5 to 22 m (l6 to 72 ft.) (Verrill, 1901). Ludwick and Walton (l957).
Oculina arbuscula Verrill.	Cape Hatteras, North Carolina, to Charleston, South Carolina (McCloskey, 1970). Reportedly common off Savannah, Georgia, 3 to 25 m (10 to 82 ft). Porter (1978, personal communication) reports this species from Bermuda.

      The basic pattern of stony coral distribution follows:

Corals in the 0-200 m depth that are azooxanthellate (lacking algal symbionts) are distributed throughout the tropical wetern Atlantic. Most are solitary ahermatypic corals and small colonials: *Madracis brueggemanni*, *Oculina tenella*, *Cladocora debilis.*

Corals found in deeper waters that are azooxanthellate have a temperate distribution (not found south of 30° N. Latitude). This includes solitary and some colonial species such as *Madrepora carolina* and *Madrepora oculata*.

Corals that are limited in depth to less than 70 m, are zooxanthellate, and almost exclusively colonial have a strong tropical affinity (Caribbean-Bahamas, southeast Florida, Bermuda, with extreme records in Brazil and North Carolina). This group is often referred to the shallow water reefs corals. In Florida, coral distribution is from Fowey Rocks south. Examples of this group include *Acropora palmata*, *Porites porites*, *Diplora labyrintiformis*, *Mussa angulosa*, and *Eusmilia fastigiata*.

3.3.7.1.1.3   Antipatharia (black corals)

Black corals are not well represented in the management area with the exception of *Cirripathes sp.* (probably *C. lutkeni*) which occurs rarely in the Florida Keys (Goldberg, 1979, personal communication). The species appears to be quite common below 20 m (66 ft.) on the southeast Florida coast (Goldberg, 1973a) (Table 24).

3.3.7.1.1.4   Stylasterina

Some Stylasterina have been reported in waters less than 200 m (660 ft) deep (Boschma, 1957): *Distichopora foliacea* P. from Key West at 183 m (595 ft.) and off Vaca Key (Marathon) at 152 to 244 m (500 to 720 ft.); and *Plibothrus symmetricus* P. from American Shoal at 179 m (585 ft). Each of these records probably represents unusually shallow occurrences of deeper water species.

Table 24.   Shallow-water *Antipatharia* from the continental shelves of the southern United States. .

SPECIES	LOCATION/DEPTH	REFERENCE
Cirripathes desbonni (D. & M.)	Sand Key, 81 m (267 ft) Jeffs Reef	Pourtales, 1878; Reed,
	(Vero Beach, Florida), 80 to 90 m	1979, personal communication;
	(265 to 300 ft).	Goldberg, 1979, personal communication.
Antipathes pennacea (Pallas)	Crocker Reef Florida, 28 m (93 ft).	Goldberg, 1979, personal communication.
	Alligator Light, Florida, 29 to 38 m (96 to 125 ft).	Opresko, 1974.
Antipathes lenta Pourtales	Carysfort Reef - Dry Tortugas, Florida, 45 to 67 m (149 to 221 ft).	Opresko, 1974.
Parantipathes columnaris (Duch.)	Dry Tortugas, Florida, 183 m	Cairns (l979, personal communication; Smithsonian 91 m (300 ft.). Institution records).

3.3.7.1.1.5   Protected Shallow-water Species

State and Federal laws and regulations protect corals in general.   Fourteen species have been identified as worthy of special protection (Table 25). Antonius, et al. (l978) noted that pillar coral (*Dendrogyra cylindrus*) was recommended for listing as an endangered species under the U.S. Endangered Species Act. A conference sponsored by the Atlantic Reef Committee, determined the species to be threatened in the management area but not endangered throughout its range (defined by the Endangered Species Act as worldwide for invertebrates). Jaap (unpublished) produced a summary document on systematics, distribution, stratigraphy, and ecology of the pillar coral for the meeting. The Florida Committee on Rare and Endangered

Plants and Animals (a private group that supplies information to state agencies) has listed as endangered throughout the Florida reef tract (in all unprotected areas, i.e., outside Biscayne National Park and other areas) an additional 13 species.

All of the corals listed as continental shelf fishery resources in the Fishery Conservation and Management Act of 1976 that may occur in the management area are found deeper than the 200 m (660 ft) contour.

3.3.7.1.2 Deepwater Corals

As a group, deepwater corals (found deeper than 200 m or 660 ft) are among the most poorly understood corals considered in this plan. Field and laboratory observations of deepwater species are sparse. Collecting expeditions have been fair to adequate; the best available sources of data are the coral specimens scattered at research institutions such as the Florida Department of Environmental Protection Marine Research Institute (formerly the Florida Department of Natural Resources Marine Lab), the Smithsonian Institution, the Museum of Comparative Zoology at Harvard, the University of Miami's Rosenstiel School of Marine and Atmospheric Sciences, and Texas A&M University. Cairns (l979) has comprehensively reviewed the deepwater Scleractinia but the deepwater gorgonians remain relatively unstudied. The work of Cairns (1979) on deepwater scleractinian coral zoogeography revealed seven species to be endemic (i.e., limited) to the temperate region off the eastern United States. Five of those species have a primarily warm temperate distribution (*Concentrotheca laevigata, Cyathoceras squiresi, Thecopsammia socialis, Bathypsammia tintinnabulum,* and *B. fallosocialis*), two are found in cold temperate waters (*Enallopsammia profunda* and *Dasmosmilia lymani*).

Generally, Caribbean waters have more deepwater species than adjacent waters. In the warm temperate western Atlantic, 28 species occur. Of those species, 14 are tropical and do not occur north of Cape Hatteras, seven are endemic to the temperate region north of Florida and Cuba, and seven species are more cosmopolitan. North of Cape Hatteras, 12 species have been reported, six of which also occur in warm temperate waters. Distribution maps and tables of these corals are included in Cairns (1979).

In light of the inadequate data base, separate sections discussing the other major taxonomic groupings of deepwater corals are not attempted.

3.3.7.1.2.1 Distributions

Within the management area there are at least 183 species of corals collected from deeper than 200 m (660 ft.). Although information from deepwater collections is far from complete, the areas of highest coral concentration along the Atlantic coast appear to be between the 600 and 800 m (1,960 to 2,600 ft) contours of the continental slope where deepwater banks are found. Although a complete listing of coral species associated with such structures is impossible at present, at least 23 species of coral have been collected from them.

3.3.7.1.2.2 Protected Deepwater Corals

No deepwater species have been listed as endangered or threatened by the Endangered Species Act nor are any under consideration for listing (Roe 1979, personal communication).

Corallium (precious red coral) and *Keratoisis* (bamboo coral) were listed as fishery resources in the Fishery Conservation and Management Act of 1976.

3.3.7.2 Abundance and Status
3.3.7.2.1   Shallow-water Species
        Prior to about 1985, information concerning relative abundance of shallow-water corals must be gleaned from a large number of papers, reports, and personal unpublished observations of specific coral habitats and communities. Since these studies/observations were almost always conducted at different times by different investigators using different methods, the composite data base was incomplete and inconsistent and did not provide a thorough assessment of the present condition of the coral stock. However, available data do allow an overview of the resource primarily from the original 1982 coral plan (GMFMC and SAFMC 1982). For purposes of discussing relative abundance of shallow-water corals, the management unit may be subdivided into seven regions based on general species compositions. Each of these regions is discussed individually below. As an overview of major shallow-water coral communities surveyed in the following. Section 3.2.1 and Appendix E presents the major hard bottom and coral reef areas of the south Atlantic. Since the late 1980's numerous surveys of shallow water corals have been undertaken.

Table 25.   Corals categorized as endangered by the Florida Committee on Rare and Endangered Plants and Animals (Source: Layne, 1979 pers. comm.; Simon, 1979 pers. comm.).

Common Name	Scientific Name
Elkhorn coral	*Acropora palmata* (Lamarck)
Staghorn coral	*Acropora cervicornis* (Lamarck)
Fused staghorn coral	*Acropora prolifera* (Lamarck)
Pillar coral	*Dendrogyra cylindrus* (Ehrenberg)
Large flower coral	*Mussa angulosa* (Rallas)
Flower coral	*Eusmilia fastigiata* (Pallas)
Lettuce coral	*Agaricia agaricites* (Linnaeus)
Starlet coral	*Siderastrea siderea* (Ellis and Solander)
Brain coral	*Diploria clivosa* (Ellis and Solander)
Brain coral	*Diploria labyrinthiformis* (Linnaeus)
Brain coral	*Diploia strigosa* (Dana)
Small star coral	*Montastraea annularis* (Ellis and Solander)
Large star coral	*Montastraea cavernosa* (Linneaus)
Brain coral	*Meandrina meandrites* (Linneaus)

* Although this Committee (FCREPA) is a private group of scientists and conservationists, the lists they prepare do contribute to efforts by the Florida Game and Fresh Water Fish Commission (GFWFC) in their own Endangered Species Program. However, since the GFWFC addresses only vertebrate animals, the FCREPA list constitutes the only state listing of marine invertebrates, including corals. These species are not necessarily rare or endangered at this time.

        The most recent edition of rare and endangered biota of Florida is M. Deyrup and R. Franz (eds.), 1994. Rare and endangered biota of Florida, Vol. IV Invertebrates. University Press of Florida, Gainsville, 798pp.

3.3.7.2.1.1   North Carolina to Cape Canaveral
        NOAA's Office of Coastal Zone Management (l979d) cited reports that three to 30 percent of the shelf region is covered by live bottom habitats. The coral fauna along the edge of the continental shelf from Cape Hatteras, North Carolina, to Cape Canaveral, Florida, remains incomplete. Studies by Menzies, et al. (l966) and Macintyre and Milliman (l970) indicate that Pleistocene algal accumulations account for the ledges, small terraces, and slight rises of the continental margin off North and South Carolina, while oolitic deposits predominate in the more southerly sector. *O. varicosa* is present on the inner and mid-shelf (3 to 40 m) as small discrete

colonies (<30 cm diameter, usually <15 cm), and on the outer shelf and upper slope to depths of 152 m either as individual colonies (l to 2 m diameter), thickets, or banks. While *O. varicosa* has been found in water as deep as 128 m (off Cape Lookout, North Carolina) and as far north as Cape Hatteras, North Carolina, the majority of the thickest growth occurs off the east coast of Florida, from Cape Canaveral to Ft. Pierce, in the area of the Oculina Bank Habitat Area of Particular Concern discussed in Section 3.2.1.1.3.2.

Corals on the outer continental shelf proper are characterized by patches of low relief hard bottom also referred to as live bottom (Struhsaker, 1969). Hard bottom communities throughout this shelf area have been reviewed by Continental Shelf Associates (1979).

These areas are inhabited by tropical and subtropical fishes, coralline algae, sponges, hydroids, and various species of other invertebrates and coral. They have been described at depths of 20 to 40 m (66 to 132 ft) from Onslow Bay, North Carolina, by MacIntyre and Pilkey (l969) and Huntsman and MacIntyre (1971). Four other species of scleractinians were noted: *Balanophyllia floridana Pourtales*; *Phyllangia americana* Milne-Edwards & Haime; *Astrangia danae* Agassiz (= *A. astreiformis* M.-E. & H.); and the eye coral, *Oculina arbuscula* Verrill. Additional scleractinian records for the North Carolina continental shelf include a number of small, mostly solitary species: *Rhizosmilia maculata* (reported as *Bathycyathus maculatus*), *Dasmosmilia lymani*; *Rhizatrochus fragilis* (reported as *Monomyces fragilis*); *Paracyathus defilipii*; and *Cladocora sp.* (Cerame-Vivas and Gray, 1966).

Reports from South Carolina and Georgia waters (Powles and Barans, 1979; Reed, 1978, personal communication, respectively) indicate that the coral fauna is largely the same as off North Carolina, except that coral patches are even more sparsely distributed (Barans, 1978, personal communication). Gray's Reef occurs in this region, approximately 33 km (18 nm) east of Sapelo Island, Georgia. This complex rises from a depth of 22 m (72 ft) to a crest at 18 m (59 ft). It is approximately 6 km (3.2 nm) long and 2 km (1 nm) wide. The geology of Gray's Reef has been studied by Hunt (1974). Although the area is not a true coral reef a number of corals and their associates are found there. Porter (1978, personal communication) noted that the biomass is dominated primarily by a large pink ascidian (probably *Eudistoma sp.*), secondly by the gorgonian *Leptogorqla sp.* (probably *L. virgulata*), and thirdly by scleractinians, *Oculina varicosa* identified by J. K. Reed and eye coral, *Oculina arbuscula*. If confirmed, this identification extends the range of *O. arbuscula* from Charleston to Savannah (McCloskey, 1970). Other species noted by Porter include stump coral (*Solenastrea hyades*), star coral (*Montastraea annularis*, uncommon), *Cladocora arbuscula, Astrangia poculata*, and *Phyllangia americana*.

Bayer (1961) stated that the shelf octocoral fauna from the East Coast of Florida north of Cape Canaveral is indistinguishable from the fauna from Georgia and the Carolinas. Reports from North Carolina (Menzies, et al., 1966; Cerame-Vlvas and Gray, 1966), South Carolina (Powles and Barans, 1979), and Georgia (Reed, 1978, personal communication) appear to confirm this conclusion for both octocorals and scleractinians.

3.3.7.2.1.2   Central Florida to South Florida (Cape Canaveral to Palm Beach)

This shelf region represents a transitional zone for coral fauna and deserves special consideration. The shelf edge contains a conspicuous band of pinnacles, benches, mounds, and troughs (here collectively referred to as hard bottoms) which are often capped by the Ivory Tree Coral, *Oculina varicosa* Lesueur. Although the species occurs at least as far north as Cape Hatteras, North Carolina (Reed, 1980b), its structural development is greatest in this region; thickets 1-2 m (3-6 ft) high are found on pinnacles with up to 25 m relief (Avent, et al., 1977;

Reed, 1980). A major portion of the shelf edge is littered with *Oculina* debris (MacIntyre and Milliman, 1970).

The *Oculina* community harbors a rich vertebrate and invertebrate fauna which includes other scleractinians (*Astrangia poculata* (Peters et al., 1988)*, Balanophyllia floridana, Cladocora debilis, Paracyanthus pulchellus*, and *Coenocyathus* species) and octocorals (*Telesto nelleae*, and *Tltanideum frauenfeldii*) (Avent, et al., 1977). Two hundred species of mollusks, 47 species of amphipod crustaceans, 21 species of echinoderms, and 50 species of decapod crustaceans have been found directly associated with *Oculina varicosa* (Reed, et al., 1982).

Although shelf-edge *Oculina* communities seem not to persist south of Jupiter, Florida, the species is found on coquinoid rock ledges scattered over the shallow shelf south to St. Lucie Inlet and Stuart, Florida (27° 10'N latitude) where *Oculina* is associated with decidedly Carolinian octocorals such as *Lophogorgia* and *Leptogorgia spp*. In spite of the Antillean ecological character of other groups which persist north to Cape Canaveral (Avent, et al., 1977; Briggs, 1974), the scleractinian and octocorallian fauna became Antillean only south of St. Lucie Inlet (in a similar fashion to the Mollusca studied by Work, 1969). The coquinoid ledges here possess the same species noted above, but mixed with tropical genera such as the *Diploria* (brain coral), *Isophyllia* (cactus coral), *Montastraea* (star coral), and the octocorals *Eunicea, Pseudopterogorgia*, and *Gorgonia* (Reed, 1979, personal communication).

3.3.7.2.1.3 Southeast Florida Coast (Palm Beach to Fowey Rocks)

South of 27° North latitude to near Miami, the continental shelf narrows to 3 to 5 km (1.6 to 2.7 nm) and the warm waters of the Florida current become the most dominant hydrographic feature (Lee and McGuire, 1972). Thus, in the vicinity of Palm Beach, Florida, Carolinian corals are replaced by a diverse hard-bottom community, tropical in character, zoogeographically similar to that of the Florida Keys, but less well developed than the majority of the Florida reef tract.

The hard-bottom community found in this region is dominated by gorgonian corals. The antipatharian black coral *Cirripathes lutkeni* is prominent below a depth of 22 m (72 ft.) but the scleractinians are less abundant at the northern end (Wheaton and Jaap, 1976) and in the vicinity of Miami (Courtenay, et al., 1975) than in the central Florida coastal region (Goldberg, 1973a,b). The underlying substrate is a Holocene elkhorn coral, *Acropora palmata*, and staghorn coral, *A. cervicornis*, relic reef which lies 15 to 30 m (50 to 100 ft.) below present sea level. The reef apparently has not been active for the last 7,000 years (Lighty, et al., 1977). Presently, the dominant hermatypes are the large star coral *Montastraea cavernosa*, the small star coral *M. annularis*, the lettuce coral *Agaricia lamarcki*, and the brain coral *Diploria clivosa*.

Nearshore habitats of this area (less than 4 km) are primarily sand plains. However, nearshore hardbottom reefs are also interspersed. These structures consist primarily of exposed *Anastasia*-formation limestone and Holocene caps of sabellariid worm reefs (*Phragmatopoma caudata*) with some small, domal corals represented. Nelson (1990) recorded 325 species of invertebrates and plants in association with similar nearshore hardbottom habitats at Sebastian Inlet, approximately 150 km north. Over 190 species of fishes are documented from such habitats in the Palm Beach area (Lindeman, 1997). At least 515 species total are now known from nearshore hardbottom habitats of the east coast of mainland Florida, a number expected to grow with more studies (Nelson, 1990). These habitats are discussed further in Section 3.2.1 Live/Hard Bottom Habitat.

The deeper zones of this community (20 to 30 m; 66 to 100 ft) are characterized by the presence of the scleraxonian gorgonian *Iciligorgia schrammi* as described by Goldberg (1973a).

Wheaton and Jaap (1976) and Courtenay, et al. (1975) have confirmed the existence of the same zonation oft Palm Beach and Miami Beach, respectively. Wheaton described the octocoral fauna of the outer slope and fore reef zone from Palm County, to Looe Key (Wheaton, 1987). Blair and Flynn (1989) observed hard bottom community structure off Miami.

3.3.7.2.1.4   Florida Keys (Fowey Rocks to the Dry Tortugas)

Coral reefs and hardbottom communities are common within the south Florida coastal ecosystem. With the exception of Bermuda and the northern Bahamas, the Florida Keys represent the northernmost limit of coral reefs in the western Atlantic. Coral reefs are constructed by complexes of corals and other plants and animals that build limestone skeletons or leave calcium carbonate debris as a result of their growth. The cumulative result is a three-dimensional irregular structure that is unique compared to the surrounding seascape. Well developed coral reefs similar to those found in the Bahamas and Caribbean occur from the Ragged Keys to Tortugas Banks: 25° 40' – 24° 30'N latitude, 80° 30' – 82° 40'W longitude (Jaap, 1984, Jaap and Hallock, 1990). High profile bank reefs parallel the island arc in a band four to six miles from shore.   Bank reefs are characterized by spur and groove formations (Shinn, 1963), elkhorn coral (*Acropora palmata*), and *Millepora complanata* (encrusting fire coral) at the reef crest. Patch reefs are found between the coast and the offshore bank reefs and typically are characterized by an irregular ring of large corals (*Montastraea annularis, M. cavernosa* (star corals), *Colpophyllia natans, Diploria labyrinthiformis*, and *D. strigosa* (brain corals). The diversity of corals is quite variable, upwards of 60 stony coral species have been documented on an individual bank reef (Jaap et al., 1989).   The diversity and abundance of octocorals tends to be greatest in patch reefs and offshore deep reefs. Coral cover is also variable and often quite low (Aronson and Murdoch, 1997).   Functionally, coral reefs enhance the abundance and variety of life, provide a living breakwater that protects the coast from storm waves, provide economic benefit from fisheries and tourism, and are important education and research resources.

Many well developed patch and outer bank reefs, such as Carysfort Reef and Key Largo Dry Rocks, occur shoreward of the 18-m (60 ft) isobath and are dominated by *Acropora palmata* (elkhorn) and *Millepora complanata* (encrusting fire coral) at the crest, followed by *A. cervicornis* (staghorn), *Montastraea annularis* (small star coral), and *M. cavernosa* (large star coral), in successively deeper zones (Shinn, 1963). Prior to the 1990's, specific information on the distribution and abundance of corals on these reefs was available in individual works at localized sites (in spite of their position as the northernmost *Acropora* reefs in the western Atlantic). The outer bank reefs of Biscayne National Park to the north have been described by Voss, et al. (l969) but quantitative data on distribution and abundance of corals on a single reef were not included. Wheaton (unpublished) surveyed reefs in Biscayne National Park from 1978 to 1981.

Looe Key Reef (12.9 km, 200° off the SW tip of Big Pine Key, 24° 37'N, 81° 24'W) is a representative outer bank reef. The reef was subdivided into reef flat, spur and groove, forereef, and deep reef habitats to characterize these habitats (Wheaton and Jaap, 1988). Inshore of the reef there is a fan-like mosaic of seagrass and sediments. Progressing from the seagrass-sediments, there is a zone of consolidated rubble that is in less than one-meter deep. It is constructed by coral skeletons that have been carried into the shoal water by storm waves. This area is called reef flat or reef crest. This is a very physically controlled zone; strong waves, winds, intense solar radiation, and extreme temperatures limit the species that can survive in this habitat. Morphologically, the corals found in this area are low relief-encrusting forms and or

species that can thrive in the strong wave turbulence (Geister, 1977). The reef crest at Looe Key is dominated by *Millepora complanata* (encrusting fire coral), *Porites astreoides* (mustard hill coral), and *Palythoa caribaeorum* (golden sea mat). Seaward of the reef crest, spurs and grooves (S & G.) extend from the shoal-water approximately 150 to 200 m. The S & G system at Looe Key is 5 to 9 m (16 to 30 ft) deep at the seaward spur terminus. *Acropora palmata* (elkhorn coral) skeletal material is the principal construction component of the spur formations. The spurs can be subdivided into shallow (<1 to 5 m), intermediate (2 to 7 m), and deep (7 to 9 m) habitats (Wheaton and Jaap, 1988). The numerically abundant corals in these habitats are:

> **Shallow:** Porites astreoides, *Millepora complanata, Agaricia agaricites*
> **Intermediate:** *Agaricia agaricites, M. complanata, P. astreoides*
> **Deep:** *Montastraea cavernosa, Plexaura flexuosa, Acropora cervicornis*

Taxonomic richness in these S & G habitats based on Wheaton and Jaap (1988) is:

HABITAT	No. of *Octocorallia* Species	No. of *Milliporina* and *Scleractinia spp.*
Shallow S&G	4 Colony density (m2): 1.18 to 1.33	4 Colony density(m2): 7.60 to 9.59
Intermediate S&G	7 to 11 Colony density (m2): 2.16 to 6.05	16 to 18 Colony density (m2):10.11 to 10.18
Deep S&G	14 to 15 Colony density (m2): 6.15 to 8.94	20 to 22 Colony density (m2): 7.65 to 9.75

Colonies of very large, living *Montastraea annularis* (small star coral), *Diploria strigosa* (brain coral), and *Colpophyllia natans* (boulder brain coral). *Montastraea cavernosa* (large star coral) become dominant at the seaward ends of the spurs. They also can be found sitting independently off of the spur formations.

The end of the spur and groove zone at Looe Key Reef is marked by a sandy plain at 10 to 12 m (33 to 40 ft), which grades into a deeper reef zone, particularly on the west side of the reef. A series of deep spurs and grooves continues to a depth of 30 to 35 m (100 to 115 ft.). Octocorals such as the rough sea plume (*Muriceopsis flavida*; eleven percent of deep reef gorgonians) are common but are replaced by *Pseudopterogorgia bipinnata* (the bipinnate sea feather) and *Iciligorgia schrammi* with increasing depth. The scleractinians of the deep reef are similar in composition to the shallower zones but contain a relatively greater abundance of branching and star forms such as *Eusmilia fastigiata* (star or flower coral), *Porites porites*, and *Madracis spp.* (ten-rayed star coral). The larger scleractinians of the deep reef are *Agaricia spp* (lettuce coral) and *Mycetophyllia spp.* (cactus coral). To seaward the reef terminates and grades into a plain of sediments.

Patch reefs are generally located between Hawk Channel and the outer reefs. Their distribution is bimodal with major concentrations between Elliott Key and lower Key Largo and between Boca Chica Key and Key West. Fewer patch reefs are distributed between Lower Key Largo and Boca Chica Key. The distribution pattern is influenced by Florida Bay; inimical and unpredictable water quality from Florida Bay impedes reef development. The upper and lower keys block Florida Bay waters from egress into the Atlantic. In the middle keys area, there are small islands and large channels between Florida Bay and the Atlantic allowing free exchange of Florida Bay Waters. Recent studies have documented that coral growth near Florida Bay

channels is retarded in contrast to corals isolated from this influence (Personal communication, Clay Cook, Harbor Branch Oceanographic Foundation).   Patch reefs are also common in the Dry Tortugas, north and south of Garden Key.

Patch reefs of the Florida Keys have received the most comprehensive treatment as far as ecology and systematics of corals in the management area are concerned. Generally, patch reefs found in the lagoon between the outer reefs and the Florida Keys may include star corals *Montastraea spp.*, fire corals *Millepora spp.*, regular finger coral *Porites porites* (*P. furcata* or *P. divaricata*), mustard hill coral *P. astreoides*, starlet coral *Siderastrea spp.*, brain coral *Diploria clivosa*, and staghorn *Acropora cervicornis*. *Acropora palmata* (elkhorn) is almost always absent. Antonius, et al. (1978) found that five species composed 50 percent of the stony corals found on the patch reefs at Looe Key; *Millepora complanata*, the star corals *Dichocoenia stellaris, Siderastrea siderea*, and *Montastraea annularis* accounted for eight to ten percent each, while staghorn coral *Acropora cervicornis* dominated with 15 percent of the total.

Throughout the Florida Keys, hardbottom communities are distributed from near-intertidal to beyond 90 m depth. These are characterized as a low relief rocky substrate with attached algae, sponges, octocorals, and in some cases, stony corals are a conspicuous component. These habitats in the inshore waters in the immediate vicinity of the Keys are dominated by hardy corals (including brain coral *Diploria clivosa*, *Favia fragum*, *Porites porites, P. astreoides, Siderastrea radians, S. siderea, rose coral Manicina areolata*, and *Cladocora arbuscula*), which appear to have a greater tolerance to silt, thermohaline changes, and unconsolidated bottom (Vaughan, 1919; Kissling, 1965). Voss and Voss (1955) have described such an environment in the vicinity of Soldier Key, the northernmost of the Florida Keys, as have Turmel and Swanson (1976) at Rodriguez Bank, near Tavernier, Florida. The dominant scleractinian in both locations is *Porites porites* (*Porites divaricata*), found in a distinct seaward band associated with the coralline alga *Goniolithon sp*. and turtle grass *Thalassia testudinum.*

Deep reef communities (80 to 120 ft) that appear as reefs that were unable to keep pace with rising sea level are relatively common seaward of many of the individual bank reefs (Carysfort, French, Molasses, Sand Key). These formations often have low relief spur and groove formations. The area referred to as, Tortugas Banks, is a similar deep reef system with channels and characteristics of the deep reefs in the Florida Keys.   Because of the low light, the coral growth is not prolific on the deep reefs.

Quantitative information dealing with distribution and abundance of gorgonians is available for several back reef areas in the Florida Keys. Opresko (1973) has analyzed gorgonian data for Boca Chita Pass, Soldier Key, and Red Reef. The first two locations lie on the seaward side of Biscayne Bay and are subject to fluctuations in salinity, temperature, and turbidity. Boca Chita Pass is the least oceanic in character and not surprisingly possesses the lowest diversity and density of gorgonians. Red Reef is a lagoonal patch reef located on Margot Fish Shoal, approximately 4 km (2 nm) east of Elliott Key and about 3 km (1.6 nm) west of the outer reef arc (Long Reef); this location displayed the greatest diversity and density of the areas studied by Opresko.

Comparative information is available for the gorgonian fauna on other lagoonal patch reefs. Bagby (1978) has studied three sites off Key Largo, Florida, chosen to provide a view of the influence of increasing oceanic conditions. The patches, hereafter referred to as Five, Seven and Nine Kilometer Reefs, are named for their respective distances from Key Largo, Florida. Nine Kilometer Reef is immediately shoreward of the outer reef arc just south of Molasses Reef. Distribution and abundance records of gorgonians from both Opresko (1973) and Bagby (1978). It is apparent that *Pseudopterogorgia americana* (slimy sea plume) and *P. acerosa* (porous *false*

Plexaura) are the most widespread species, being found at every station. In agreement with the conclusions of Opresko (1973), *P. acerosa* is most common inshore, while *P. americana* is more dominant at offshore patch reef stations. Equally widespread, but numerically less dominant, are the species *Plexaurella dichotoma* (double-forked *Plexaurella*) and *Plexaura flexuosa* (sea rod). The former is present at all stations but is abundant only at Soldier Key and Five Kilometer Reef. Two species, *Eunicea succinea* (amber Eunicea) and *Pterogorgia citrina* (yellow sea whip), are distributed in abundance at both Soldier Key and Nine Kilometer Reef, but not in intermediate areas. *Pseudoplexaura porosa* was dominant on Five Kilometer Reef and *Plexaura homomalla* (black sea rod) was of considerable importance on Red Reef, but neither was prominent elsewhere in the areas studied.

Species with patchy or widespread distributions are apparently the rule rather than the exception. Goldberg (1973a) noted that offshore patch reefs near the 9 m (30 ft) isobath off the southeast Florida coast could be dominated by either *Pseudopterogorgia americana* or *P. acerosa*. *Plexaura flexuosa* was equally abundant along with *Eunicea calyculata* (warty Eunicea) and *Muricea muricata* (spiny Muricea). Reefs at 14 to 20 m (46 to 66 ft) depths off Palm Beach are dominated by *Plexaura flexuosa* and *Pterogorgia citrina* (Wheaton, 1976). *Plexaura flexuosa* and *Pseudopterogorgia americana* dominated the shallow reefs at Long Key, Dry Tortugas (Wheaton, unpublished). Thus, any or all of these species can be found prominently on inshore or offshore reefs, in shallow water or on outer reefs at depths up to 20 m (66 ft). Their relative abundance on a given reef must therefore be interpreted with caution. Shallow patch reefs near the outer reef tract display a number of clear-water indicator species. *Gorgonia ventalina* (common sea fan), *Muriceopsis flavida* (rough sea plume), *Briareum asbestinum* (corky sea finger), and *Pseudopterogorgia bipinnata* all fall in this category, in decreasing order of consistency (Opresko, 1973; Bagby, 1978). However, only the sea fan *G. ventalina* showed any correlation between abundance and reef position. At Red Reef and Five Kilometer Reef, this species accounted for 2.7 to 4.1 percent of the total fauna. At Seven Kilometer Reef this figure increased to 6.4 percent, and at Nine Kilometer Reef it increased again to 12.8 percent.

3.3.7.2.2   Deepwater Corals

As noted in Section 5.1.2, information concerning deepwater corals is exceedingly sparse. In most instances, the information is too incomplete to make assessments as to the abundance of the stocks. With respect to the condition of the stock (i.e., mortality versus replacement rates) and overall stock stability, it is impossible, possible to make an informed assessment. In one sense of the word "condition", however, the lack of exploitation and other damaging development activities in deepwater areas (except for limited collection and damage by research dredging) infers that the stocks should be in a pristine state. Cairns (1979) documented 55 species of solitary or colonial Scleractinia referenced as "deep-water" off the east Coast of Florida including the Florida Keys. These species bathymetric ranges were from 2 to 2634 m, most were found in depths greater than 30 m.

In the Atlantic, bioherms have been reported along the margins of the Straits of Florida from Miami to the north (Squires, 1963; Neumann and Ball, 1970). One such mound observed from a submersible in 825 m (2,700 ft) depth on the Miami Escarpment was described by Neumann and Ball (1970) as "small mounds of muddy sand capped by thickets of branching, deepwater azooxanthellate-branching species of scleractinian corals." The uncollected species were possibly of the genera *Lophelia, Madrepora,* and *Dendrophyllia*. Cairns (1979, personal communication) studied collections housed at the Smithsonian Institution and suggested that

deep water banks may possibly occur commonly along the Atlantic continental slope within the coral management area—particularly around the 600 to 800 m (1,980 to 2,640 ft) depth contour. If this is true, associated deepwater corals including *Enallopsammia* (which Cairns believes to be the *Dendrophyllia* reported by earlier investigators) and *Lophelia* may be relatively abundant in many localized areas.

Also identified within the Atlantic coral management area are "bump areas" (Stetson, et al., 1962; Squires, 1963) located in a broad area about 370 km (200 nm) southeast of Charleston, South Carolina, in 720 to 970 m (2,350 to 3,200 ft) of water. Here, a 5,145 km2 (1,130 nm2) area contains thousands of "humps" (hummocks of low relief) hypothesized to represent accumulations of coral material. As in the Straits of Florida, the corals were predominantly the branching azooxanthellate corals *Lophelia prolifera* and *Enallopsammia profunda*.

In the Atlantic, solitary corals may also occur along the shelf flank, slope, and plain. Although solitary deepwater corals have occasionally been collected from a single trawl in numbers exceeding several hundred individuals, such collections are rare and fit no discernable pattern.

3.3.7.3 Ecological Relationships

Most coral assemblages are so complex that holistic approaches to community metabolism are useful primarily for the purpose of comparison with similar measurements made elsewhere. Therefore, most of the attention on coral reef systems has focused on metabolism and interactions of component parts. Lewis (1977) has reviewed the components which contribute to the well known high production rates on coral reefs. Reviews of coral reef primary production and calcification rates include: Gladfelter (1985), Kinsey, (1985), Larkum and Koop (1997), Venier and Pauly (1997).

Although summarized here, supplemental information on ecological relationships is included in Appendix G.

3.3.7.3.1   Coral Ecosystems as a Special Resource

The importance of coral ecosystems and associated habitats has been well documented by numerous studies, reviews, and symposia (e.g., Jones and Endean, 1973, 1976; Bright and Pequegnat, 1974; Taylor, 1977; Bright, Jaap and Cashman, 1981, Jaap, 1984, Jaap and Hallock, 1990, Chiappone, 1996). Many of those documents emphasize the complex structure of coral ecosystems, the importance of coral for habitat, the sedentary lifestyle and its implications, the wide geographic and bathymetric distributions, and the many behavioral, physiological, ecological, and physical associations that combine to yield an exceedingly complex biological community. The Magnuson-Stevens Act recognizes these values and lists several corals as continental shelf fishery resources subject to exclusive U.S. use beyond the EEZ.

Ecosystems which include coral (solitary corals, hard bottoms or banks, bioherms, and coral reefs) often represent unique arrays of plants and animals in an integrated ecosystem system. The key to many of these systems, if there can be one most important link, is often coral itself, since the corals provide habitat and/or food for most of the other members of the ecosystem. Connell (1973) and Grassle (1973) have studied aspects of population ecology and diversity within coral reefs (see below, Section 6.2.1). Individual biotic components have also been studied -among them, microbes (DiSalvo, 1973), algae (Cribb, 1973), holothurians (Bakus, 1973), shrimps and prawns (Bruce, 1976), echinoderms (Clark, 1976), fishes (Goldman and Talbot, 1976), and others. The resultant coral community is exceedingly complex and productive. Helfrich and Townsley (1965), Odum (1971), DiSalvo (1973), Sorokin (1973c), and

others have attempted to quantify and qualify the productivity of corals and their associated biota (e.g., microorganisms) compared to other marine and terrestrial communities.

Because of their vast species diversity, trophic complexity, and productivity, mature coral communities possess numerous mechanisms that enable them to resist normal disturbances, especially those biological in nature (Endean, 1976). As classified by Sanders (1968), coral reefs in deeper water (10 m) may be termed biologically accommodated communities with interspecific competition and predation major determinants of stability. Shallow reef areas (less than 10 m) may be more appropriately termed physically controlled. Numerous other factors also play major roles in coral health. It is many of those other factors that potentially threaten the continued viability of domestic corals.

The special nature of corals as a fishery is further highlighted by their sedentary attached (not mobile) existence, which separates them from the subjects of many other fishery plans. Protection via escape or camouflage is limited by the design of coral skeletons and polyps. Although some protection is afforded by polyp withdrawl, strict energy budgets restrict the use of such behavior. Hence, in the midst of persistent adversity, (e.g., water pollution, cold temperatures, sedimentation), corals appear precariously susceptible. The life history of the octocorallian and scleractinian corals is similar to the other invertebrate species. The fruits of coral sexual reproduction are planulae larvae; the larvae are free living (planktonic or benthic). The larvae select settlement sites through chemoreceptors, settle, and undergo metamorphosis to juvenile, sessile corals.

Part of the uniqueness of the reef corals covered by this FMP is their position at the northernmost limits of zooxanthellate corals in U.S. waters. Although *Solenastrea* (stump coral) and *Siderastrea* (starlet coral) occur off North Carolina where bottom temperatures drop to 10° C or 50°F (MacIntyre and Pilkey, 1969), zooxanthellate corals and coral reef development of a shallow-water and tropical nature is limited to south of Stuart Florida and dynamic coral reef accumulation is found south and west of Fowey Rocks.

Patch reef, hard bottom, and solitary corals occur north of Fowey Rocks and off west Florida, but not to the extent seen off the Florida Keys, northeast of Key Largo, or southwest of Big Pine Key. Most corals inhabiting our nation's continental EEZ, especially the hermatypic species which are less temperature tolerant, are at the very limit of their geographical range.

3.3.7.3.2   Value as Essential Fish Habitat

Coral's most valuable contribution to the marine environment is as habitat for numerous associated organisms. As described by Jones and Endean (1973, 1976), Antonius, et al. (1978), Starck (1968) Jaap (1984) Bohnsack et al. (1987) and Chiappone and Sluka (1996), and many other researchers, a coral assemblage within the management area may support rich populations of invertebrates (corals, sponges, tunicates, echinoderms, crabs, lobsters, gastropods, etc.), vertebrates (primarily fish, turtles, birds, and marine mammals), and plants (coralline algae, fleshy algae, eelgrass, turtle grass, etc.). Wells (1957) emphasized this habitat value in defining a coral reef as "... fauna and flora ... (that) ... provide the ecological niches essential to the existence of all other reef dwelling animals and plants." Undoubtedly coral is a primary provider of high quality refuge habitat for a multitude of attached and mobile organisms.

All demersal fish species under SAFMC management which can associate with coral habitats are contained within the snapper-grouper FMP. Seventy-three managed species within ten diverse families are under this plan (Section 2.2). Several of these families are among the most commercially and recreationally valuable fishes of the south Atlantic coast of the United States (e.g., snappers and groupers). All of these species can show some association with coral

or hardbottom habitats during their life history. Among species, these associations differ as some coral habitat use patterns are obligate while some are facultative. In addition, temporal variations in habitat use operate at broad scales ranging from interannual to seasonal to daily (nocturnal feeding migrations). The value of coral habitats can vary accordingly. Within snapper grouper species, ontogenetic changes in habitat use lead to further variation in coral habitat use. However, the coral reef ecosystem is fundamental to the occurrence and survival of all of these species by providing direct food or shelter resources to at least some life stages of all snapper-grouper species, or providing food or shelter to their prey resources (SAFMC, 1983).

Of the ten families within the snapper-grouper plan, the three most diverse and valuable are the groupers, snappers, and grunts, with 21, 14, and 11 managed species, respectively. In groupers, the entire demersal life history of almost all *Epinephelus* species, several *Mycteroperca* species, and all *Centropristis* species, takes place in direct or peripheral association with coral or hard bottom habitats. In contrast, several species of *Mycteroperca* (gag, scamp), utilize nearshore, vegetated habitats before offshore migrations to hard structures with maturation. This latter pattern (primary use of coral/hardbottom structures during later ontogenetic stages) is also seen in many species of snappers and grunts. However, some species, particularly those preferring deeper water, utilize coral/hardbottom structures throughout their life cycle while others utilize both vegetated and hard structures opportunistically.

Similar variations in use of coral habitats are present within most of the other snapper-grouper families. For example, some managed species of triggerfish and porgy utilize coral/hardbottom during their entire demersal life history, while spadefish and hogfish typically settle in vegetated, nearshore areas and use coral/hardbottom structures only during later ontogenetic stages. Other patterns are also present. Most notably, jacks are not demersal and commonly associate with coral/hardbottom habitats as free-swimming transients, not demersal residents. Nonetheless, coral habitats are primary aggregators of prey species for many species of jacks, providing habitat of essential value for the maintenance of food resources.

The habitat diversity within a coral community is usually proportional to ecosystem diversity. Complex reef systems usually provide greater types and quantities of habitat than the more unidimensional hard bottoms. The living and nonliving components of the ecosystem are also of considerable significance in assessing value as habitat. Corals and associated benthos, e.g., sponges, tunicates, and algae, contribute most of the living habitat. Dead corals, perhaps parts of relic reefs, coral limestone, or lithified coral rock contribute refuge habitat and areas where the larvae of corals and sponges can settle. Regardless of the type of substrate or source of protection, the coral community offers space for organisms ranging from microscopic invertebrates to large fish. Those animals in turn contribute to the food webs of the entire ecosystem.

Octocorals have numerous interactions with other animals, including functioning as a refuge and food for numerous other invertebrates and fish. Octocorals are a primary substrate for encrusting fire coral (Millepora).   Additionally, octocorals contribute to calcium carbonate production, adding over a ton of limestone spicules per acre/ per year to a reef habitat (Cairns, 1977).

Data from a five-year study at Biscayne National Park (BNP) support the importance of octocoral habitat. Average octocoral density was as high as 58 colonies/m^2 for eight patch reefs studied within BNP (Wheaton, unpublished). Stony coral density on the same sites averaged only 8.5 colonies/m^2 (Jaap, 1984). Tilmant, et al. (1979) reported 214 fish species from these same octocoral dominated reefs. This exceeds 134 species for Tortugas and 146 species for

Pennekamp reported by Jones and Thompson (1978). These octocoral dominated reefs are thus rich in reef fish and serve not only as refuge habitat and probably as a recruitment area.

3.3.7.3.3   Economic Values

Due to state and Federal laws prohibiting coral taking and the subsequent shift of supply to foreign sources, such as the Philippines, India, and Haiti, much of the current economic value derived from corals in the management area comes from the nonconsumptive recreational uses of living corals or collection of other reef resources.

Throughout the management area but especially in the Florida Keys, dive shops, glass bottom boats, reef fishing tours, snorkel trips, boat ramps, and/or tropical specimen collecting companies, emphasize the importance of corals to many local economies. Coastal regions depend on viable coral ecosystems therefore, extreme care must be taken to protect the long-term viability of the reef and the closely related economics of coastal counties, particularly Monroe County, Florida.

The key fact in the above discussion is the derivation of value from living corals in the natural environment rather than from any collected coral specimens. Collection of coral-associated biota constitutes another value that is related to corals. If managed appropriately, both consumptive use of associated biota and nonconsumptive uses of corals and coral reefs should not be detrimental to the environment or any user group's economic well-being. Preservation of existing fisheries that are related to corals should be of vital economic concern.

The Florida Keys are probably the mostly heavily fished area in Florida and many species are dependent on or associated with coral habitats (Bohnsack et al., 1994). Increasing fishery effort in these areas has resulted in substantial reductions in stocks of many fishery species. Sixty-three percent of the stocks (22 of 35 stocks) analyzed in Ault et al. (in press) were considered overfished with Spawning Potential Ratios below 30%.

3.3.7.3.4   Buffer Values

Coral reefs occurring along southern Florida, and indeed throughout the world, are markedly affected by patterns of water circulation. The most highly developed reefs in the management area are the Florida reefs, confined to the windward or southeastern margins of the land masses (Glynn, 1973j Shinn, 1976). Less developed coral communities and other distinguishable biotic assemblages, e.g., grass beds, frequently occur leeward of the reef barriers.

The protection offered by land from cross-platform currents (Ginsburg and Shinn, 1964) is mirrored by the buffer provided to the islands by relic and/or live coral reefs. Offshore reefs help dissipate storm energies and serve to minimize impacts of storms, wave action, and other physical stresses.

The net result of these two buffering systems is a peculiar, abiotic "symbiosis" -- islands protect corals by shielding away cold water and low salinity flows from the Florida Bay and Eastern Gulf and the corals protect land masses and nearshore communities from oceanic effects. As a result, the distribution of coral reefs parallels the distribution of islands (Shinn, et al., 1977).

Protection offered by corals may be crucial to the existence of other shallow-water, continental shelf communities. Coastal Florida, and elsewhere in the management area, is represented by a band of grasses shoreward of the coral reefs. These beds of turtle grass (*Thalassia testudinum*), manatee grass (*Syringodium filiforme*), and shoal grass (*Halodule wrightii*) represent highly productive communities (Helfrich and Townsley, 1965), on which numerous species, e.g., spiny lobster (Herrnkind, 1979, personal communication; Davis, 1979, personal communication) and commercial finfish (Weinstein and Heck, 1979), depend for

development and recruitment. Fishes and other species also use the beds as prime foraging grounds. Another coastal community protected to a lesser extent by the corals are mangroves, which along with grass beds, are crucial to nutrient flows in the coastal environment. Lastly, many less developed coral communities, categorized as solitary corals or hard bottoms, shoreward of the coral reefs are also spared from storm damage. Although not as prominent as massive coral reefs, grass beds, mangroves, and small coral assemblages are all important components of the coastal ecosystem. Without the buffer of coral reefs, those three zones would be exposed to unusually destructive forces. Also, without grass beds and mangroves to assist in filtering sediments, coastal waters would deposit particulates on corals and other bottom dwellers.

3.3.7.3.5   Sources of Energy
Stony corals and octocorals derive energy from several sources including from sunlight through their photosynthetic, symbiotic zooxanthellae (algae living in the coral tissue), from consumption of zooplankton, from bacteria (which act as biochemical recycling agents), from consumption of detritus, and perhaps even directly from dissolved organics. Antipatharian corals such as *Cirripathes* apparently rely heavily upon stinging nematocysts to feed upon animal tissues, although plant material has been noted in the gut of black corals. These energy sources are detailed in Appendix G.

3.3.7.3.6   Predators and Associations
As described in detail in Appendix G, corals are subject to the ecological pressures of predation (by fish and invertebrates), competition for space, and other interactions with associated organisms. In some instances, such as the symbiotic relationship of corals to zooxanthellae, the association is mutually beneficial. At the other end of the spectrum, however, are predatory pressures such as those applied by certain reef fishes and invertebrates that eat corals.

3.3.7.4 Biological Factors
3.3.7.4.1   Growth and Size
3.3.7.4.1.1   Octocorals (Gorgonians, Precious Corals)
The published data on gorgonian growth has been determined from work on the black sea rod (*Plexaura homomalla*). Kinzie (1974) calculated a range of growth rates of 1.0 to 40 mm (0.05 to 1.6 in) yr~1 with a mean increase in height of 20 mm (0.8 in) yr~1. In that same study, Kinzie also noted that colonial growth in terms of height need not be mirrored by growth of new branch tips. Mature *P. homomalla* colonies are 25 to 35 cm (10 to 14 in) high with multiple branches arising from a single stem; other gorgonians in the management area attain sizes averaging 18 cm (7 in) up to 2.25 m (7.4 ft.) (Cairns, 1977a). These measurements parallel data collected by Wheaton (unpublished) off Biscayne National Park.
Research on the precious black, bamboo, and pink corals has been restricted because of their occurrence in deep waters. Other than *Cirripathes lutkeni*, which lives at 20 to 174 m (66 to 535 ft), most other corals in this category occur below 200 m (660 ft).
Growth and size data for the precious corals in the management area is represented only by the work of Goldberg (1977) on *Cirripathes lutkeni*.

3.3.7.4.1.2 Stony Corals (Fire Corals, Branched Scleractinians, Brain Corals, etc.)
Growth data for stony corals is concentrated on the scleractinian species, especially the branched reef corals (*Acropora spp.*) and the head corals (*Montastraea* and others). Limited information is available on deepwater species and the hydrocorals. Growth in terms of stock size and number of colonies is not limited to new corals initiated by settling larvae; Shinn (1979, personal communication) and other have noted that many stony corals including the branched corals (*Acropora spp.*) may regenerate from small pieces remaining after damage to or destruction of a larger colony.

Much of the growth data on the branched scleractinians comes from *Acropora palmata* (elkhorn), *A. cervicornis* (staghorn), and *A. prolifera* (fused staghorn). Generally, these corals have different growth rates dependent upon temperature (*A. palmata* and *A. prolifera*), placement in the reef zone (*A. palmata*), and geographic area (*A. cervicornis*) (Gladfelter, et al., 1978). Growth rates of *Acropora* in the management area and on Caribbean reefs range from 34 to 266 mm per year for *A. cervicornis*, 47.3 to 105 mm per year for *A. palmata*, and 59.2 to 81.8 mm for *A. prolifera.* Those rates are lower if expressed solely for corals in the management area.

Gladfelter, et al. (1978) found that calcification rates (the amount of calcium carbonate deposited per unit branch perimeter) in *Acropora palmata* were independent of temperature yet dependent upon zonation; 0.85 9 per cm per year in the backreef, 1.66 in the shallow forereef, and 1.35 in the deeper forereef were typical.

The data of Shinn (1966) and Gladfelter, et al. (1978) indicate that *Acropora spp*. growth rates in terms of linear extension are higher in the warm fall months than in cooler spring months. Similarly, corals in the management area may exhibit slower growth rates than the same species in warmer climates.

Growth data for other shallow-water scleractinians (brain corals and finger corals) has been summarized by Bright, et al. (1981) and Gladfelter, et al. (1978). Generally, growth rates for these species are only ten to 20 percent that of *Acropora spp*.

Most growth rates for *Montastraea, Porites*, and *Diploria* are less than 10 mm (0.2 in) per year, excepting the work of Lewis, et al. (1968) in the Caribbean. Rates between geographic areas are more consistent than observed in *Acropora*. Also, rates recorded by Gladfelter, et al. (1978) at the backreef (2 m) and deep forereef (10 m) of Buck Island, Virgin Islands, indicated that depth did not affect growth; both portions of the reef had identical average growth rates of 7.6 mm (0.3 in per year based on colonies ranging in size from 9.63 cm2 to 138 cm2 (1.5 to 23 in2). Highest density bands of *Montastraea annularis* seem to be deposited in the warmest months of the year (Hudson, et al., 1976).

Although not quantified, several references to *Millepora* and *Manicina aereolata* growth rates have conveyed the preliminary conclusion that growth rates on suitable hard surfaces are quite high. Recently discarded bottles, rocks, and other debris may be covered by *Millepora alcicornis* or other stinging corals within several months to a year. Prior to the existing Florida coral law, several collectors have suggested rapid recolonization in the rose coral *M. aereolata* in Florida Keys waters. Limited data indicate that growth may be rapid in the first three to four years and much slower thereafter (Vaughn, 1911, 1916).

Data on growth rates of deepwater scleractinians within the management area are practically nonexistent. In general, growth rates observed in these limited reports are significantly lower than growth rates reported above for shallow-water corals in the management area.

3.3.7.4.2   Mortality Rates

Most of the information on natural or human-related mortalities of corals in the management area is in accounts of destruction related to storms, groundings, etc. These qualitative reports relay limited information on death of a coral area (e.g., "many head corals near the grounding were overturned and smashed") and occasionally certain species (e.g., "the 13°C water killed 90 percent of the staghorn corals, *Acropora cervicornis*, at Dry Tortugas," Davis, 1979, personal communication). Such conversational data represents the best available information. General aspects of coral mortality are discussed in the work of Antonius (1975, 1976, 1977, and in press).

One quantitative study was that of Antonius, et al. (1978) at Looe Key, Florida. Dive transects and inspections of the reef-building corals were transformed in to a "percent dead" number: patch reefs (ten percent); reef flat (25 percent); fore reef (ten percent); and deep reef (22 percent). The total at the Looe Key study area was 13 percent dead. These data are presented by species in the report.

Grigg (1976) calculated the annual instantaneous natural mortality rate of pink coral (*Corallium secundum*) in the Makapuu Bed off Hawaii to be 0.066 or 6.6 percent.

Natural massive mortalities of staghorn coral (*Acropora cervicornis*) at Dry Tortugas have been observed on two occasions: 1878 when nearly 100 percent of the colonies died because of unidentified "black water" (Vaughan, 1911) and in 1976 to 1977, when a winter cold front killed about 90 percent of the staghorn corals (Davis, 1979, personal communication).

The work of Jaap (1979, personal communication) at Biscayne National Park also provides some insight into coral mortalities. By measuring recruitment, Jaap quantified net changes in 4 m^2 quadrats. Negative net changes show mortality. Gain and loss in corals in fixed station quadrats must be qualified. Loss and gain in many cases is not a case of larval settlement and death. In shallow depths, storms dislodge corals and transport them to areas outside or within the sampling station. These individuals often survive the dislodgment by a process called fragmentation recruitment.

3.3.7.4.3   Abundance and Density

Calculations of the total amount of percent coverage of corals in the management area in the 1980's was estimated by extrapolating from small scattered studies. Jaap and Wheaton at Biscayne National Park, provided some percent coverage data however, their data were not representative of the entire management area. The EPA coral hardbottom monitoring project encompasses 40 sampling sites from Key Largo to Key West. This project has begun analyzing percent cover for stony corals, octocorals, sponge and macroalgae at these sites (Wheaton et al., 1996).

Qualitative statements on the distribution and abundance of corals may be made. Coral reefs are very limited in distribution, perhaps to less than one percent of the total management area; patch reefs cover slightly more area than outer bank reefs. Deepwater banks again account for less than one percent, probably less than the coral reefs. Most of the corals in the management area occur in hard bottom areas or as solitary specimens.

3.3.7.4.3.1   Octocorals

Wheaton (unpublished and 1987), Opresko (1973), and Goldberg (1973a), detailed abundance and diversity for octocorals in the southeastern Florida and Florida reef tract areas. Very limited information exists for the remainder of the management area.

At four pairs of reefs in Biscayne National Park Wheaton (unpublished) surveyed octocoral abundance and density by transect, species count, and photographic analysts. Octocoral colonies usually comprised more than half of the total coral colonies. The five most abundant species (53.9 percent of total octocorals) were *Plexaura flexuosa*, *P. homomalla*, *Gorgonia ventalina*, *Eunicea succinea*, and *Pseudopterogorgia americana*.

Mean numbers of octocoral colonies counted along a 20 m (66 ft) transect of the eight reefs were 102.81 and 155.17 (Wheaton unpublished). In 1977, as counts per quadrat, were 27.41 colonies/m^2 (range 16.00 to 46.50); in 1978, photo plot counts were 26.28 colonies/m^2 (range 9.75 to 50.00).

Opresko (1973), based on field studies at Soldier Key, Boca Chica Pass, and Red Reef, calculated mean densities of gorgonians of 11.3, 6.9, and 27.1/ m^2 respectively. Most common genera at the three areas were *Eunicea, Pterogorgia, Pseudopterogorgia, Briareum,* and *Plexaura.*

The only other density information for octocorals is from off; Palm Beach County, Florida. Goldberg (1973) reported an average density of 25.1 colonies/m2. No data were given on abundance in that area.

3.3.7.4.3.2   Stony Corals

Data on abundance and density of stony corals in the management area were presented in Jaap (unpublished). Stony corals comprised only about 21 to 22 percent of the coral biota at eight reefs in Biscayne National Park. The most common five species were *Porites astreoides*, *Millepora alcicornis*, *Porites porites*, *Montastraea annularis*, and *Siderastrea siderea*. Based on 25 m (80 ft) diver transects, stony coral abundance at the Biscayne reefs in 1977 and 1978 averaged 25.06 and 26.95 colonies, respectively.

Stony coral densities were 7.53 colonies/ m^2 in 1977 (quadrant sampling; range O to 23) and 6.16 colonies/ m^2 in 1978 (photographic analysis; range 2 to 16).

3.3.7.4.4   Diversity
3.3.7.4.4.1   Octocorals

Data on diversity was done by Wheaton (unpublished) in Biscayne National Park. Highest octocoral diversities along a single 20-m (66-ft) transect were 3.2 at Schooner Reef Control in 1977 and 3.98 at the same reef in 1978. All calculations using the H'n Shannon-Weaver species diversity index were relatively high, mostly above 3.00. Diversities of octocorals reported for Looe Key (Wheaton, 1988) ranged from 1.19 (on the reef flat) to 3.72 (back reef).

3.3.7.4.4.2   Stony Corals

Species diversity for stony corals at Biscayne National Park was comparably lower than that for octocorals (Jaap, 1979). Whereas many transects revealed octocoral diversities of over 3.00, the highest stony coral diversities (Shannon-Weaver H'n) were 2.80 at Star Reef in 1977, 3.33 at Dome Reef in 1978, and 3.06 at Schooner Reef in 1979; diversity values remained under 3.00 in all but four cases for the three years combined. Compared to other regions (see Loya, 1972; Porter, 1972; Ott, 1975), these diversities are low for stony corals. H'n ranged from 0.47 to 3.06, H'max from 1.58 to 3.46, evenness J' from 0.30 to 0.94.

3.3.7.4.5   Age

Age data on corals include scattered reports on the age of living corals and relic reefs. In the relic reefs underlying the Florida reef tract, Shinn, et al. (1977), calculated accumulation rates and ages (+ standard deviation) by Carbon-14 dating of drill cores from six reef sites identified below.

These data confirm the thickness and ages of coral rock in relic reefs. The corals present varied between sites but included *Siderastrea, Montastraea annularis, M. cavernosa, Colpophyllia*, and *Diploria. Acropora palmata*, long considered a major reef-builder in Florida, was absent in most reefs drilled.

Shinn (1979), in a coring survey at the Grecian Rocks off Key Largo, stated that the growth rates of *Montastraea sp.* indicate 1 m (3.3 ft) of upward growth in less than 150 years.

In Makapuu Bed, Hawaii, the Western Pacific Fishery Management Council (1979) calculated the "critical age" at which coral growth gains are overtaken by natural mortality losses. For the pink coral (*Corallium secundum*), that age was 31.4 years, which corresponds to an average colony weight of 237 g (8.2 oz.).

Site	Accumulation Rate (m/1,000 yrs)	Age (yrs)
1. Bal Harbor	0.38	6,300 + 120
2. Sewer Trench	0.74	4,930 + 70
3. Long Reef	0.65	5,630 + 120
4. Carysfort Reef		
- 4.0 m depth	0.86	4,570 +85
- 7.3 m depth	1.39	5,250 +95
5. Marker G Reefs		
- 3.1 m depth	0.49	6,170 +80
- 4.6 m depth	0.56	7,160 +85
- 8.2 m depth	-	37,480 + 1,300
6. Ft. Jefferson National Monument (Dry Tortugas)		
- 9.1 m depth	1.91	4,762 + 85
-13.7 m depth	2.28	6,017 +90

3.3.7.4.6   Reproduction and Recruitment

Reproductive and recruitment capabilities of corals in the management area have been studied at Biscayne National Park. Research quantified changes in marked plots between the summers of 1978 and 1979 (Jaap, 1979). Results were variable, ranging from an addition of 34 colonies at Elkhorn Plot 1-7 or five species at Elkhorn Plot 1-9 to a loss of ten colonies at Star Plot 3-7 or four species at Elkhorn Plot 1-4. Generally, recruitment did not appear to differ between control and experimental reefs. However, some plots (e.g., Elkhorn Controls 1-6 to 1-9) did have exceptionally high changes.

Mass spawning in corals has been observed by divers in late August, early September in Florida Keys and Dry Tortugas reefs.

Pink corals in Hawaiian waters apparently reach sexual maturity at a height of about 12 cm (4.7 in) or an age of 13 years (Grigg, 1976). The reproductive cycle is annual with spawning taking place in June and July.

Based on the assumption of steady state recruitment of the Makapuu Beds off Hawaii (Western Pacific Fishery Management Council, 1979), an estimate of recruitment was obtained by calculating the quantity of coral lost via mortality. In a system in equilibrium, the rates should be equal. The estimate of annual recruitment to Makapuu for pink coral was 5,227 colonies (Western Pacific Fishery Management Council, 1979). Fluctuations between year classes are probable. There is some indication that the assumption of an equilibrium state may not be valid in coral reefs.

3.3.7.4 Distribution

Data on the areal distributions of corals in the management area have become available through GIS. Previously isolated collection records pinpointed locations of certain species but conveyed little information on the area of stony coral beds. However paucity of abundance data in many regions prevents a realistic calculation of standing stock and biomass.

3.3.7.5 Probable Future Conditions

The information available on productivity and health (see Sections 3.3.7.4 and 3.2.1.1.1) enable several cursory statements to be made:

1) Coral growth rates are so slow in most species that recovery rates following large-magnitude harvest, human impact, or natural stresses are far slower than observed in most other living resources. In most respects many corals may be considered as a nonrenewable resource.

2) Human impacts that have been identified as possible limiting factors in coral health do not appear to be subsiding. Many chronic problems such as shipping bilge discharges, industrial and recreational pollution, and sewage have not subsided since the implementation of the original fishery management plan.

3) Natural stresses continue to act on portions of the management area where species occur at or near their geographical limits.

Despite the data gaps already mentioned, several recent efforts have generated preliminary data for use in indicating any future trends. Coring studies at Key Largo National Marine Sanctuary indicate that coral growth rates have increased in the past decade (Hudson, 1981). Whether or not that improvement is attributable to management practices is masked by the discovery by Hudson in the same study that cyclical coral growth may be normal.

Studies at Biscayne National Park have shown concentrated damage to coral immediately adjacent to several mooring buoys (Tilmant, 1979, personal communication). The variability in apparent impact was summarized as total counts of corals and diversities between buoyed and control plots which revealed no pattern in all 24 sampled plots. Perhaps the approach of directing users to particular areas may be detrimental to objectives of preserving corals. Conversely, limited damage in high use areas; may decrease damage to other areas and enhance overall coral management efforts. Quantifying these impacts is difficult.

One future determinant of coral health in the management areas is the status of stocks in nations that export corals to the United States, i.e., the Philippines and a few others. The possibility that coral exports from other countries may be curtailed or even stopped could redirect resource pressures to domestic stocks.

To allow a realistic assessment of future conditions, it appears mandatory that a multiyear survey of coral growth, stress factors, and management practices be initiated on a species- and area-specific basis. These data are a minimal base from which estimates of future conditions could be made and supported.

The fishery for snapper and grouper introduced various types of bottom fishing gear directed at those fish closely associated with hard bottoms and reefs. Roller trawls, bottom longlines, and fish traps are now prohibited for use in this fishery due to potential for bottom damage when fishing in close proximity to coral, coral reefs, or live/hard bottom. Some gear may also be lost when it becomes entangled in coral and continue to ghost fish. The competition among fishermen for a finite resource has increased fishing effort in all areas thus increasing the incidental damage to corals and coral reefs. Similarly the high recreational fishing level increasingly subjects coral bottoms to injury from anchoring by small boats and vessels.

Octocorals (other than reticulate sea fans) are being harvested for aquarium use off Florida without apparent damage to the stocks. Because they are a rich source of marine medical products, the possibility exists for harvest of substantial amounts for experimental or even commercial purposes. One American pharmaceutical company estimated its annual need to be ten tons per year of *Plexaura homomalla* for use in extraction of prostaglandin for medical research prior to the synthesis of the desired hormones. The stocks can most likely provide adequate material for experimental research purposes, but may not be able to sustain an extended commercial market should one develop. In either case, local depletion could occur as the result of localized harvest of large numbers of colonies.

3.3.7.6 Essential Fish Habitat for Coral, Coral Reefs and Live/Hard Bottom

Essential fish habitat for corals (stony corals, octocorals, and black corals) must incorporate habitat for over 200 species. EFH for corals include the following:

A. Essential fish habitat for hermatypic stony corals includes rough, hard, exposed, stable substrate from Palm Beach County south through the Florida reef tract in subtidal to 30 m depth, subtropical (15°-35° C), oligotrophic waters with high (30-35 $^o/_{oo}$) salinity and turbidity levels sufficiently low enough to provide algal symbionts adequate sunlight penetration for photosynthesis. Ahermatypic stony corals are not light restricted and their essential fish habitat includes defined hard substrate in subtidal to outer shelf depths throughout the management area.

B. Essential fish habitat for *Antipatharia* (black corals) includes rough, hard, exposed, stable substrate, offshore in high (30-35 $^o/_{oo}$) salinity waters in depths exceeding 18 meters (54 feet), not restricted by light penetration on the outer shelf throughout the management area.

C. Essential fish habitat for octocorals excepting the order Pennatulacea (sea pens and sea pansies) includes rough, hard, exposed, stable substrate in subtidal to outer shelf depths within a wide range of salinity and light penetration throughout the management area.

D. Essential fish habitat for Pennatulacea (sea pens and sea pansies) includes muddy, silty bottoms in subtidal to outer shelf depths within a wide range of salinity and light penetration.

3.3.7.7 Essential Fish Habitat - Habitat Areas of Particular Concern for Coral

Areas which meet the criteria for essential fish habitat-habitat areas of particular concern (EFH-HAPCs) for coral, coral reefs, and live/hard bottom include The 10-Fathom Ledge, Big

Rock, and The Point (North Carolina); Hurl Rocks and The Charleston Bump (South Carolina); Gray's Reef National Marine Sanctuary (Georgia); The *Phragmatopoma* (worm reefs) reefs off the central east coast of Florida; Oculina Banks off the east coast of Florda from Ft. Pierce to Cape Canaveral; nearshore (0-4 meters; 0-12 feet) hard bottom off the east coast of Florida from Cape Canaveral to Broward County); offshore (5-30 meter; 15-90 feet) hard bottom off the east coast of Florida from Palm Beach County to Fowey Rocks; Biscayne Bay, Florida; Biscayne National Park, Florida; and the Florida Keys National Marine Sanctuary.

3.3.8   Calico Scallops
3.3.8.1 Description and Distribution of the Species

The calico scallop, *Argopecten gibbus*, occurs most often at moderate depths of 18-73 m (59-240 ft) and restricted generally to the continental shelf of the western North Atlantic and Gulf of Mexico between about 35° N and 20° N latitude (Broom, 1976). Identification of calico scallops can be made from shell color and morphology. The upper (left) valve has red or maroon calico markings over a white or yellow base; the lower (right valve) is more lightly pigmented. The calico markings on the shell distinguish this scallop from the solid gray or brown upper valve of the bay scallop, which resembles the calico scallop in size. Calico scallop shell morphology varies with locality, but generally the species reaches 40 to 60 mm (1.6-2.4 in) in shell height (a straight line measurement of the greatest distance between the umbo and the ventral margin), with a maximum size reported to be about 80 mm (3.2 in) in shell diameter (a straight line measurement of the greatest distance between the anterior and posterior margin) (Roe et al., 1971). The shells are almost equally convex, deeply ridged, with 17 to 23 ribs on the right valve (Allen and Costello, 1972).
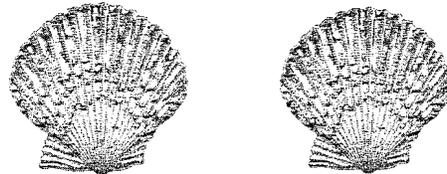
Calico scallop, *Argopecten gibbus*

The calico scallop ranges from the northern side of the Greater Antilles, throughout the Gulf of Mexico, to Bermuda and slightly north of Cape Hatteras (possibly Delaware Bay) in waters varying from 2 m (6.6 ft) at Bermuda to 370 m (1,214 ft) on the northern side of the Greater Antilles (Allen and Costello, 1972). Off the Florida east coast, depth of occurrence was 9 to 74 m (30-243 ft) while off North Carolina, south of Cape Hatteras, calico scallops were reported at depths of 13 to 94 m (43-308 ft) (Allen and Costello, 1972). Roe et al. (1971) reported depth distributional differences off Florida, noting scallops south of Cape Canaveral were generally found in shallower water than north of the Cape. However, Sutherland (unpublished report) reported that scallop beds located north of Cape Canaveral were not always found in deeper water than those south of the Cape. The beds usually occur in open marine water rather than estuarine areas (Waller, 1969).

Calico scallop beds are generally distributed on the continental shelf parallel to the coastline. These beds are most abundant off Cape Lookout, North Carolina; Cape Canaveral, Florida; and Cape San Blas, Florida, in the northeastern Gulf of Mexico. On the Cape Canaveral grounds, scallops occur in long narrow bands, or beds, more than 800 m (2,625 ft) long and several hundred meters wide. A calico scallop bed near Cape Lookout, North Carolina, was

elliptical and 15 km (9.3 mi) long. Off Cape San Blas, in 1957, a bed 16 km (9.9 mi) long by 8-16 km (5.0-9.9 mi) wide was located (Bullis and Ingle, 1959). The greatest concentrations of these scallops appeared to be near coastal prominences (Allen and Costello, 1972).

Populations of calico scallops were located in 1977 offshore of the South Carolina/Georgia border in 37-45 m (121-148 ft) (Anderson and Lacey, 1979). The scallop bed was elliptically shaped and oriented perpendicular to the coast.

Maturity in Atlantic calico scallops is correlated with age rather than size (Roe et al., 1971). Scallops may spawn intermittently many times during the spawning season. No data on fecundity of Atlantic calico scallops was located. Water temperatures may stimulate spawning. Atlantic calico scallops are hermaphroditic, ejecting first sperm and then eggs into the water where fertilization occurs. Part of the North Carolina Atlantic calico stock may result from larvae transported northward from the Cape Canaveral grounds by the Gulf Stream. However, oceanographic data suggest that most larvae would be retained at Cape Canaveral. Larvae settle as spat in 14 to 16 days and attach to substrates with byssal threads from the foot. Spat attach to navigation buoys, other floating objects, and dead or living mollusk shells. The spat remain attached until they reach about 2.5 cm (1 in) shell height; they then detach and can swim. Small scallops swim more readily, and adult scallops can swim 30 cm (1 ft) with one squirt (Allen and Costello, 1972). Unattached scallops have been reported from hard sand, sand with shell, and a smooth sand-gravel-shell substrate. They reach commercial shell height of 4 to 4.5 cm (1.6 to 1.8 in) in 6 to 8 months, and have a life span averaging only 18 to 20 months, with a maximum of 24 months(Allen and Costello, 1972). Monthly mortality is about 12 to 23 percent, and varies seasonally (Roe et al., 1971). Disappearance of Atlantic calico scallops from a particular area commonly occurs, and the size of the stock shows considerable annual fluctuations. Declines and mass mortalities have occurred on the grounds off North Carolina. Possible causes include migration, poor larval transport from elsewhere, and increased fishing pressure following introduction of shucking and eviscerating machines. Spawning stock is maintained because (1) not all beds are harvested each year; (2) the spawning stock includes scallops too small to market; and (3) individuals at densities too low to harvest. Atlantic calico scallops filter small particles such as unicellular algae from the water as food. Predators on juvenile and adult scallops include seastars, gastropods, squid, octopus, crabs, sharks, rays, and bony fishes.

Substrates required by calico scallops vary with scallop size. Under natural conditions, the spat usually attach to dead or living mollusk shells (Allen and Costello, 1972). However, spat has been found attached to navigation buoys (Waller, 1969) and plastic floats (Pequegnat et al., 1967). Allen (1979) reported that young calico scallops attach to a variety of materials in addition to calico scallop shells. Young scallops were found among attached hydroids, but it was not determined that spat attach to hydroids or erect bryozoans before attaching to shell. The dependence of spat on shell for setting and survival has not been studied.

Larger, unattached scallops have been reported from bottoms of hard sand (Rivers, 1962), sand and shell (Cummins et al., 1962), quartz sand (Hulings, 1961), smooth sand-shell-gravel (Struhsaker, 1969), and sand and dead shell (Drummond, 1969). Sutherland (unpublished report) described the environment of the scallop grounds off Cape Canaveral as consisting of shell fragment sands predominantly. Shelf sediments off Cape Canaveral average 60 percent calcium carbonate content; conversely, shelf sediments off Georgia average only 10 percent. High carbonate sediments off Cape Canaveral lie along the western boundary of the northerly flowing Gulf Stream and southern flowing counter currents.

Salinities of areas where calico scallops occur range between 31‰ and 37‰. However, in the laboratory at Florida State University, small scallops taken from waters off Panama City,

Florida, have been grown at a salinity range of 25‰ to 30‰ (R.W. Menzel, Fla. State Univ., Tallahassee, Fla.; pers. comm.).

Depths of the heaviest concentrations of calico scallops off Cape Canaveral from 1960-1967 ranged from 26-49 m (85-161 ft), as recorded by exploratory fishing cruises (Miller and Richards, 1980). The most productive area of the shelf in the South Atlantic Bight for calico scallops occurs in the open shelf zone at 33-40 m (108-131 ft), an area with stable warm temperatures (Miller and Richards, 1980). Inshore waters (to 18 m or 59 ft) are cooled below 15˚C (59˚F), and offshore waters (55 m or 180 ft) are subjected to cold water intrusions off Cape Canaveral, Florida, leaving the intermediate shelf zone with warm temperatures (Miller and Richards, 1980). This warm shelf zone had temperatures ranging from 20˚ to 23˚C (68˚-73˚F) during February-March 1973 and was bounded on both sides by colder water (Mathews and Pashuk, 1977). Deep, cold water intrusions may have favorable impacts on calico scallops by initiating spawning and producing an abundance of phytoplankton for food, or unfavorable impacts by lowering temperatures below 15˚C (59˚F), causing mortalities of scallops (Miller et al., 1981). Off Cape Canaveral, bottom temperatures 15˚C (59˚F) occurred in depths as shallow as 40 m (131.2 ft) (Leming, 1979).

Relative abundance of the calico scallop varies with scallop size both within and between areas, seasonally and annually. They are generally most abundant off the Florida east coast near Cape Canaveral, with lesser concentrations near Cape Lookout, North Carolina and Cape San Blas, Florida. Concentrations have also been reported from the eastern Gulf of Mexico between Sanibel Island and Dry Tortugas, and 96.5 km (60 mi) offshore of the South Carolina/ Georgia border. Scallop abundance fluctuates at each area, with good years followed by years when none are available.

The Cape Canaveral scallop grounds are among the largest in the world, extending over 321.8 km (200 mi) from St. Augustine to near Stuart, Florida. Sutherland (unpublished report) made estimates of the calico stock distribution and abundance from data obtained with RUFAS (to visually capture the scallop resource) and tumbler dredges (to obtain samples). He found the bed width was highly variable and ranged from 6.7 to 2,633.5 m (22 to 8,640 feet). Juvenile calico scallop beds in 1970 surveys accounted for almost 4 percent of scallop distribution. Scallop occurrence was uniformly less than 4 percent of completed transect miles.

Figures 51a and 51b were provided by representatives of the calico scallop industry during scoping meetings and public hearings on calico scallop management and present recent calico scallop harvest areas/distribution, spawning locations, and shell distribution off southeast Florida. Additional information on calico scallop biology, harvest and distribution is presented in the Calico Scallop Fishery Management Plan (SAFMC, 1998e)

3.3.8.2 Essential Fish Habitat for Calico Scallops

The essential fish habitat for calico scallops is the unconsolidated sediments including hard sand bottoms, sand and shell hash, quartz sand, smooth sand-shell-gravel, and sand and dead shell in 43-308 ft (13 - 94 m) with concentrations occurring on the Cape Canaveral grounds (Stuart to St. Augustine, Florida) and sporadically occurring northeast and southwest of Cape Lookout, North Carolina in 62-102 ft (19 - 31 m), and offshore of the South Carolina/Georgia border in 121-148 ft (37-45m). In addition, the Gulf Stream is an essential fish habitat because it provides a mechanism to disperse calico scallop larvae.
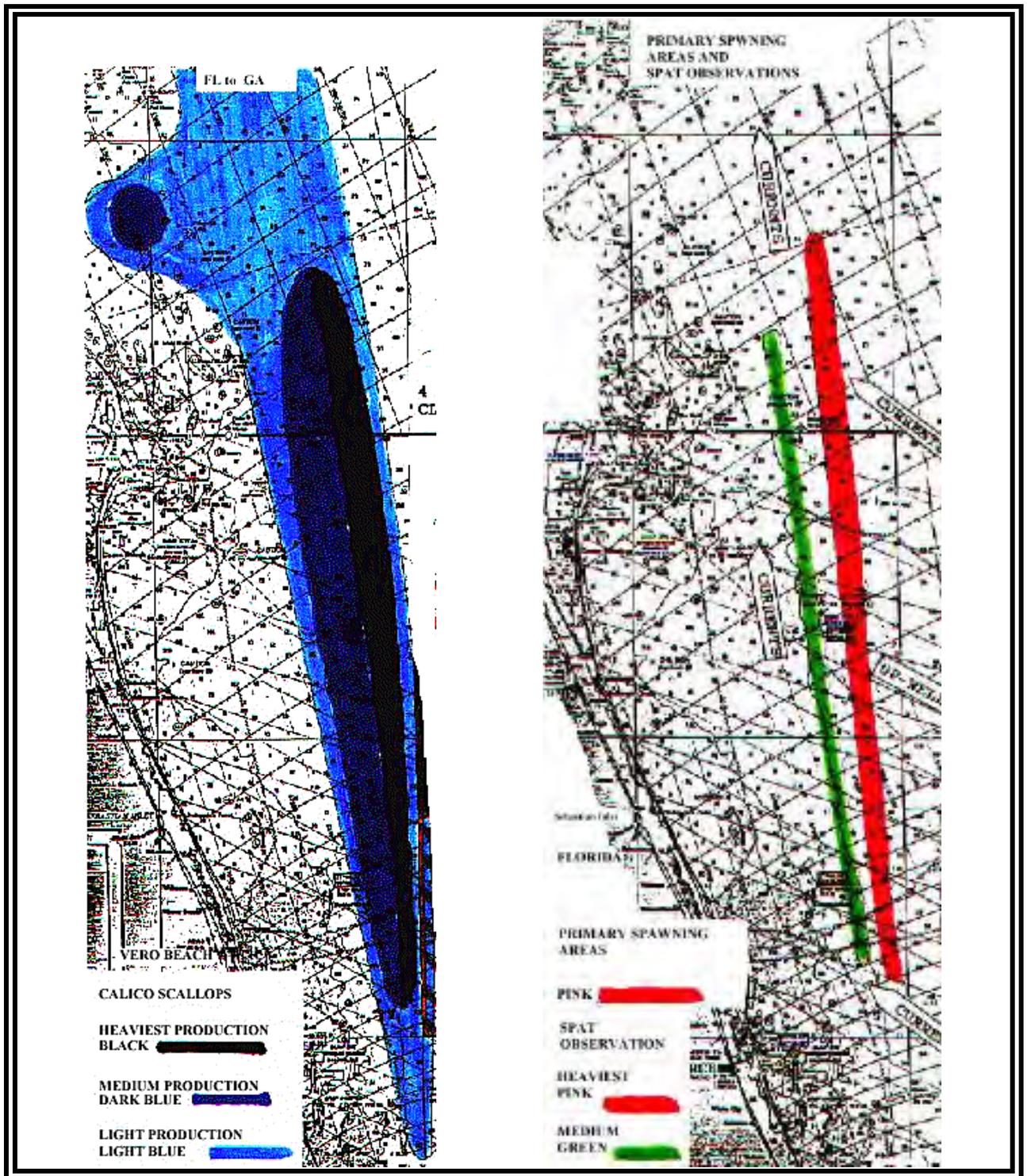
Figure 51a.   Calico scallop spawning areas and fishing grounds (Source: William Burkhardt, Calico Scallop Advisory Panel.)
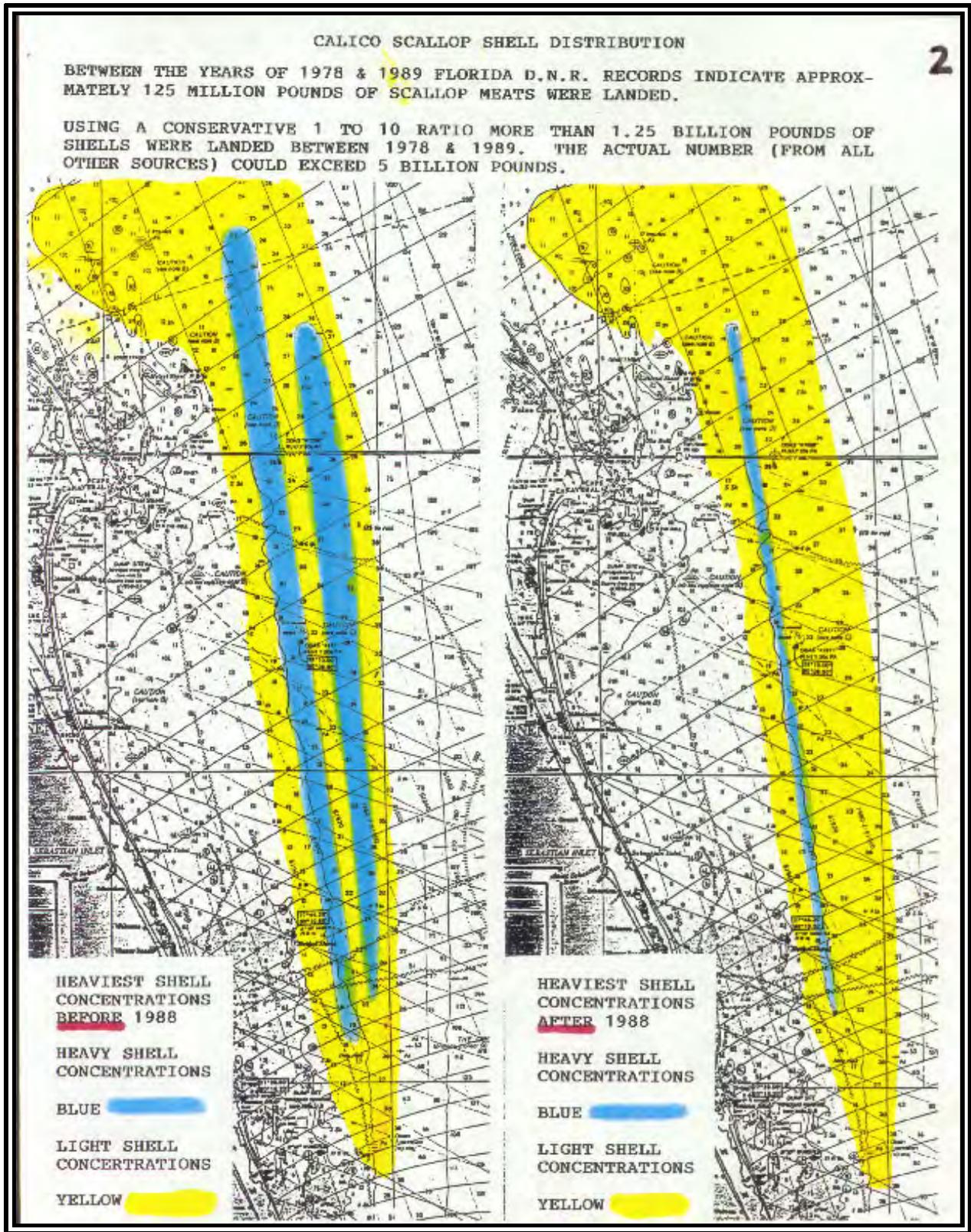
Figure 51b. Calico Scallop shell distribution (Source: William Burkhardt, Calico Scallop Advisory Panel.)

3.3.9 *Sargassum* Habitat
3.3.9.1 Description of the Species, Distribution and Environmental Requirements
See Section 3.2.3.1.1 and the Sargassum Fishery Management Plan (SAFMC 1998d) for a detailed description of Sargassum as essential fish habitat.

3.3.9.2 Essential Fish Habitat for *Sargassum*
Essential fish habitat for pelagic *Sargassum* is where it occurs in the EEZ and state waters. In addition, the Gulf Stream is an essential fish habitat because it provides a mechanism to disperse *Sargassum*.

Because of the importance of the extra-jurisdictional pelagic *Sargassum* occurring in the Sargasso Sea outside the EEZ, the United States should pursue all other options under the Magnuson-Stevens Act and other laws to protect *Sargassum* in international waters.

3.3.9.3 Essential Fish Habitat - Habitat Areas of Particular Concern for Sargassum
Establish the following areas as Essential Fish Habitat-Habitat Areas of Particular Concern (EFH-HAPCs) for pelagic *Sargassum*: The distribution of pelagic *Sargassum* within the South Atlantic Council's EEZ and state waters (all essential fish habitat).

3.3.10 Other Managed Species use of Essential Fish Habitat
The descriptions of the essential fish habitat types presented in Sections 3.1, estuarine habitats, and 3.2, offshore marine habitats, identify many species managed by other regional, Federal or State authorites. For example bluefish, and summer flounder are identified in many of the habitats described in the South Atlantic region. In addition, highly migratory pelagic resources including the tunas, billfish, sharks and swordfish (list below) use pelagic habitats identified as essential fish habitat in the South Atlantic.

Highly Migratory Pelagic Species in Secretarial FMPs:

Swordfish
  swordfish, *Xiaphias gladius*
Atlantic Tunas
  western Atlantic bluefin, *Thunnus thynnus*
  Atlantic bigeye, *T. obesus*
  Atlantic yellowfin, *T. albacares*
  Albacore, *T. alalunga*
  Skipjack, *Katsuwonus pelamis*
  sevengill shark, *Heptranchias perlo*
SMALL COASTAL SHARK SPECIES:
Angel sharks - Squatinidae
  Atlantic angel sharks, *Squatina dumerili*
Hammerhead sharks - Sphyrnidae
  bonnethead, *Sphyrna tiburo*
Requiem sharks - Carcharhinidae
  Atlantic sharpnose shark, *Rhizoprionodon terraenovae*
  blacknose shark, *Carcharhinus acronotus*
  Caribbean sharpnose shark, *Rhizoprionodon porosus*
  finetooth shark, *Carcharhinus isodon*
  smalltail shark, *Carcharhinus porosus*

Atlantic Billfishes
  sailfish, *Istiophorus platypterus*
  white marlin, *Tetrapturus albidus*
  blue marlin, *Makaira nigricans*
  longbill spearfish, *Tetrapturus pfluegeri*
PELAGIC SHARK SPECIES:
Cow sharks - Hexanchidae
  bigeye sixgill shark, *Hexanchus vitulus*

  sixgill shark, *Hexanchus griseus*
Mackerel sharks - Lamnidae
  longfin mako, *Isurus paucus*
  porbeagle shark, *Lamna nasus*
  shortfin mako, *Isurus oxyrinchus*
Requiem sharks - Carcharhinidae
  blue shark, *Prionace glauca*
  oceanic whitetip shark, *Carcharhinus longimanus*
Thresher sharks - Alopiidae
  bigeye thresher, *Alopias superciliosus*
  thresher shark, *A. vulpinus*

Highly Migratory Pelagic Species in Secretarial FMPs (cont.)

LARGE COASTAL SHARK SPECIES:

Basking sharks - Cetorhnidae
  basking shark, *Cetorhinus maximus*

Hammerhead sharks - Sphyrnidae
  great hammerhead, *Sphyrna mokarran*
  scalloped hammerhead, *S. lewini*
  smooth hammerhead, *S. zygaena*

Mackerel sharks - Lamnidae
  white shark, *Carcharodon carcharias*

Nurse sharks - Ginglymostomatidae
  nurse shark, *Ginglymostoma cirratum*

Requiem sharks - Carcharhinidae
  bignose shark, *Carcharhinus altimus*
  blacktip shark, *C. limbatus*
  bull shark, *C. leucas*
  Caribbean reek shark, *C. perezi*
  dusky shark, *C. obscurus*
  Galapagos shark, *C. galapagensis*
  lemon shark, *Negaprion brevirostris*
  narrowtooth shark, *Carcharhinus brachyurus*
  night shark, *C. signatus*
  sandbar shark, *C. plumbeus*
  silky shark, *C. falciformis*
  spinner shark, *C. brevipinna*
  tiger shark, *Galeocerdo cuvieri*

Sand tiger sharks - Odontaspididae
  bigeye sand tiger, *Odontaspis noronhai*
  sand tiger shark, *Odontaspis taurus*

Whale sharks - Rhinocodontidae
  whale shark, *Rhinocodon typus*

3.3.11 Anadromous and Catadromous Species use of Essential Fish Habitat

The South Atlantic Fishery Management Council decided, at its March 5, 1998 meeting, to include a description of habitats used by anadromous and catadromous species in the South Atlantic in the Habitat Plan. The Council noted, in so doing, that the Magnuson-Stevens Act requires Councils to comment on projects proposed for authorization by federal or state governments which have the potential to effect habitats, including essential fish habitats, of anadromous species. The Final Rule for Essential Fish Habitat, for the purpose of compliance with the Magnuson-Stevens Act, defined anadromous species under the authority of the Council as those which inhabit the EEZ for any portion of their life cycle. This section therefore describes the species which occur in the South Atlantic waters of the EEZ, and which are therefore deemed to be under the authority of the Council at some life stage. This text describes the species which occur, their distribution, and the habitats which they use, including those which would be defined as Essential Fish Habitat if there was a Council plan for amendment. Information in the accounts for these species is taken largely from the U.S. Fish and Wildlife Service/U.S. Army Corps of Engineers Species Profiles report series, and from the Atlantic States Marine Fisheries Commission Fishery Management Plans and stock assessment documents or National Marine Fisheries Service Recovery Plan for the shortnose sturgeon. These references are cited in the individual accounts for each species.

3.3.11.1 Alewife

The alewife (*Alosa pseudoharengus*) is a moderate-sized member of the clupeid (shads and herrings) family which is an important forage species for both Council-managed (bluefish)

and Atlantic States Marine Fisheries Commission-managed (weakfish and striped bass) species. Its normal life history is that of an anadromous form, in which adults spawn in the spring in coastal rivers, and juveniles return to the ocean to grow and mature. It has also been widely stocked in inland freshwater lakes and reservoirs where it lives and reproduces entirely in freshwater and serves as a prey base for game fish such as largemouth bass, striped bass and catfish. The species is under the management of the Atlantic States Marine Fisheries Commission.

3.3.11.1.1   Description of the Species and Distribution

The alewife is a moderate-sized member of the herring family, with a grey to grey-green back and silvery sides. They range in size from about 230 mm (9 in) to over 330 mm (13 in). Alewives begin spawning at age three, have usually spawned once by age four, and have all spawned by age five. Fecundity in females ranges from 60,000 to 100,000 eggs (Fay et al. 1983). Spawning populations are younger in the south, with fish in North Carolina being primarily age three, and none older than age four. The percentage of repeat spawning is also less than 10 percent in NC (Fay et al. 1983). Spawning occurs in the spring, started earlier in the south and later in the north. Alewives generally spawn 3-4 weeks before blueback herring in areas where the two species co-occur. Alewives begin spawning at minimum water temperatures of 10.5° C (51° F) and select a wide variety of spawning sites. Eggs of alewife hatch at approximately 50 to 360 hours, depending upon temperature. The alewife yolk-sac stage lasts from 2-5 days. Larval alewives range in size from 4.3 to 19.9 mm (0.2-0.8 in). Transformation to the juvenile stage occurs at about 20 mm (0.8 in). Like juvenile blueback herring, juvenile alewives may initially exhibit upstream movement, later moving downstream as fall approaches. Emigration occurs between June and November of the first year of life. Emigration of juvenile alewives may be stimulated by heavy rainfall, high water, and sharp declines in water temperatures. Adult alewives were sampled offshore during National Marine Fisheries Service trawl surveys. The majority of catches occurred in less than 100 m (328 ft). Alewives were more abundant than blueback herring when all samples were combined. Alewives were most abundant at depths between 56 and 110 m (184 and 361 ft). Catches of the species were confined to areas north of 40 degrees north latitude in summer and fall. Winter catches were between 40 and 43 degrees north latitude. Spring catches were distributed over the entire Continental Shelf. Alewives primarily consume zooplankton, although fish eggs, crustacean eggs, insects, insect eggs and small fishes may be eaten in some areas or by larger individuals.

The alewife is reported to range from Newfoundland south to South Carolina. However, surveys conducted by Rulifson et al. (1982) in 1980 and repeated 12 years later (Rulifson 1994) indicate that the species occurs in coastal rivers only in the NC portion of the Council's area of jurisdiction, although it could occur offshore of other South Atlantic states in waters of the EEZ. In North Carolina, populations were reported in the North, Pasquotank, Little, Perquimans, Yeopim, Chowan, Meherrin, Roanoke, Cashie, Scuppernong and Alligator Rivers (all tributaries of Albemarle Sound); Tar-Pamlico, Pungo, Neuse, and Trent Rivers (tributaries to Pamlico Sound); New River; Cape Fear, North East Cape Fear and Brunswick Rivers; and White Oak River. Status of these populations is presented in Table 4 of Rulifson (1992). All populations were listed as either "declining" or "status unknown" as of 1992.

3.3.11.1.2   Habitat and Environmental Requirements

Spawning habitats for alewives can vary from streams only a few meters (yards) wide to larger rivers. Although some authors have reported that alewives ascend further upstream than

blueback herring, others believe that upstream distribution is a function of finding appropriate spawning habitats. Alewives use standing water, oxbow lakes and mid-stream areas as spawning sites, as well as coastal ponds with an open connection to the ocean. Optimum hatching temperature was 18° C (64° F). Temperatures below 10° C resulted in the absence of a functional jaw in alewives. Alewives apparently tolerate salinity changes well. In the South Atlantic Council's area of jurisdiction, alewife occur only in the coastal rivers and estuaries of North Carolina, and in the offshore marine areas as described above.

3.3.11.2   American Shad

The American shad (*Alosa sapidissima*) has long been viewed as the premier species of the shad and herring family, and has a long tradition of supporting both commercial and recreational fisheries along the east coast since the early 1800's. It was the most valuable food fish on the east coast prior to World War II. In recent years, the sport fishery for the species has become more important economically that the commercial fishery. The species is the target of major restoration programs in the northeast and is beginning to be the focus of such programs in the South Atlantic. The Atlantic States Marine Fisheries Commission management plan for the species is currently being amended.

3.3.11.2.1   Description of the Species and Distribution

The American shad is the largest member of the herring family (Facey and Van Den Avyle 1986). Large females may reach a total length of 600 mm (23.6 in) and a weight of 5.4 kg (11.9 lb). American shad have a greenish to bluish-metallic luster on the back and are bright silver on the sides. There is usually a dark spot on the shoulder, just behind the posterior edge of the gill flap, which may be followed by 3 to 27 smaller spots. American shad are believed to enter their natal streams to spawn, entering when water temperatures are between 10 and 15° C. The peak of spawning migration generally occurs progressively later in the year from south to north, with the earliest spawning migration in the St. Johns River, FL. Peak spawning occurs in mid-January to mid-February in FL, and may occur through mid-June in the Roanoke River, NC (Kim Sparks, Department of Zoology, NC State University, personal communication). Spawning usually occurs in fresh water over substrates of sand, gravel and mud, at water temperatures of 14 to 21°C. The range of fecundity is about 100,000 to 600,000 eggs per female. Most American shad from rivers in the South Atlantic die after spawning. There are some repeat spawners in South Atlantic river systems, with the percentage generally increasing from south to north. American shad eggs generally hatch in 4-6 days at 15-18 degrees C. Larvae are about 7-10 mm (0.3-0.4 in) long upon hatching, and absorb the yolk by the fifth day. Larvae develop into juveniles after 4-5 weeks at lengths of about 25 mm (1 in). Juveniles usually form schools and move downstream at rates dictated by water temperature and current velocity. They reside in the downstream portions of coastal rivers and their associated estuaries, migrating to sea at about 90 mm (3.5 in). Emigration usually begins when temperatures drop below 15.5° C. Juveniles migrate to the Bay of Fundy and then to the Gulf of Maine where they join the adults each summer. They probably move southward and spend the winter in the mid-Atlantic area. American shad become sexually mature at age 3-5 in North Carolina for males and ages 4-6 for females. Adults which survive spawning leave the rivers and move to the Gulf of Maine where they remain through the summer and early fall. They consume a variety of invertebrate organisms and may prey on small fishes in some areas. Juvenile shad consumed amphipods, aquatic insects and terrestrial insects.

According to the recent survey by Rulifson, (1994), American shad occur in the following South Atlantic river systems and their attendant estuaries: NC--North, Pasquotank, Little, Perquimans, Yeopim, Chowan, Meherrin, Roanoke, Cashie, Scuppernong and Alligator Rivers (Albemarle Sound tributaries); Tar-Pamlico and Neuse Rivers (Pamlico Sound tributaries); New River; and Cape Fear, North East Cape Fear and Brunswick Rivers (Cape Fear River estuary); SC--Waccamaw, Little Pee Dee, Great Pee Dee and Black Rivers (Winyah Bay); Santee River, Cooper River and Ashley River (Charleston Harbor); Edisto, Ashepoo and Combahee Rivers (ACE Basin); Sampit River; Salkehatchie River; Lynches River and Savannah River; GA--Savannah, Ogeechee, Altamaha, Oconee, Satilla, Ocmulgee and St. Marys Rivers; and FL--St. Marys, Nassau, St. Johns, Pellicer and Tomoka Rivers.

3.3.11.2.2   Habitat and Environmental Requirements

American shad require spawning habitats in inland portions of coastal rivers with water temperatures of between 14 and 21° C, with appropriate substrates and current velocities. Juvenile shad can tolerate sharp salinity changes, which allows them to use both the fresh and saline portions of estuarine nursery areas. Adults typically remain in the estuarine portion of their natal systems for 2-3 days before moving upstream. Dissolved oxygen values of at least 4.0 mg/l are required in spawning areas and values below this level can result in mortality of eggs and larvae. Proper development of American shad requires water velocities that keep the eggs suspended in the water column. Spawning commonly occurs in velocities of 30.5 to 91.4 cm/sec (1-3 ft/sec). Preferred spawning habitats seem to be shallow areas dominated by sand or gravel substrates. At sea, adults appear to prefer depths of 50-100 m, in the areas noted above.

3.3.11.3   Atlantic Sturgeon

The Atlantic sturgeon (*Acipenser oxyrinchus*) is currently the subject of a major amendment to the Atlantic States Marine Fisheries Commission's management plan for the species (Atlantic Sturgeon Plan Development Team 1998), a new stock assessment (Kahnle et al. 1998), and a Status Review conducted by the National Marine Fisheries Service and U.S. Fish and Wildlife Service (Atlantic Sturgeon Status Review Team 1998). The species is the largest fish to inhabit freshwater on the east coast(Van Den Avyle 1984), and historically formed the basis of significant subsistence and commercial fisheries. Stocks are depressed range wide, and a moratorium on possession of the species is in effect in state waters and is being recommended for federal waters.

3.3.11.3.1   Description of the Species and Distribution

Atlantic sturgeon are one of two species of anadromous sturgeon which occur on the east coast of the United States. Historically, the species was abundant in most large coastal rivers. It has a long slender body with five rows of bony plates, called scutes, which give it the appearance of being armored. Larger individuals develop relatively shorter snouts, smooth scutes from wear, and the lower lobe of the caudal fin becomes relatively longer. Atlantic sturgeon females historically grew to great sizes, with one reportedly 427 cm (14 ft) in length and weighing 368 kg (811 lbs). Sexes are indistinguishable except during the spawning season when females are swollen with eggs. Spawning migrations in the South Atlantic begin in February and occur later to the north. In the Winyah bay system, SC, adults first appear when water temperatures were 7-8 degrees C. Spawning during late May and early June occurred in downstream areas of the Pee Dee River that are bordered by palustrine forested wetlands, with substrates characterized by relatively low current velocities, turbid water, and sand and silt bottom substrates with an

abundance of organic debris (Van Den Avyle 1984b). In most other systems, Atlantic sturgeon prefer spawning sites with relatively hard substrates and flowing water. Eggs are demersal and adhesive and usually attach to substrate or submerged vegetation. Hatching times vary from 94 to 168 hours depending upon temperature. Fecundity for SC females is estimated at between 871,800 and 1,616,992 eggs for fish of 48-104 kg. Newly hatched fry are approximately 11 mm (0.4 in) long. Young-of-the-year Atlantic sturgeon are found in their nursery areas, the lower portions of coastal rivers and their associated estuaries. Young Atlantics may spend several years in freshwater before migrating to sea. Juvenile Atlantics which were tagged and subsequently recaptured tended to move southward along the coast during November through January and northward during late winter and early spring. While in the estuarine nursery areas, juveniles generally occupied tidally influenced freshwater during warmer months and moved to brackish estuaries during colder periods. Tagging studies have repeatedly shown that juvenile Atlantic sturgeon wander widely, with fish tagged in SC being recaptured in NC and VA. Atlantic sturgeon are very long-lived. In SC waters, males spawned first at 5-13 years of age, and females at 7-19 years. Females also do not spawn annually, but spawn at irregular intervals. Sturgeon are benthic feeders, with protrusile mouths which resemble vacuum cleaner hoses. They are likely opportunistic feeders, feeding upon a variety of benthic macroinvertebrates in the Atlantic ocean as adults and in estuaries as juveniles. Recorded food items include polychaete worms, snails, shrimps, amphipods and isopods in marine/estuarine areas and aquatic insects, amphipods, oligochaete worms and mayfly larvae in freshwater areas.

Current distribution of the Atlantic sturgeon in the South Atlantic is reviewed in the draft of Amendment 1 to the Atlantic States Marine Fisheries Commission management plan (Atlantic Sturgeon Plan Development Team 1998) and the draft Status Review Report (Atlantic Sturgeon Status Review Team 1998). Based on the documented presence of either age 0 or 1 juveniles and/or mature males and/or females in spawning condition during the last five years (1993 to present), populations are thought to exist in the following systems: NC--Albemarle Sound and tributaries; Pamlico Sound and tributaries, including the Tar-Pamlico; Cape Fear River and tributaries; SC--Winyah Bay and tributaries (Waccamaw, Little Pee Dee, Great Pee Dee, Black Rivers); Santee River; Cooper River; ACE Basin (Ashepoo, Combahee and Edisto Rivers); and Savannah River; GA--Savannah River; Ogeechee River; Altamaha River; and Satilla River; and FL--no known spawning populations currently.

3.3.11.3.2   Habitat and Environmental Requirements
Spawning areas for Atlantic sturgeon have not been identified in all South Atlantic Rivers at this time. Identification of these habitats is a stated need in the current stock assessment (Kahnle et al. 1998). Nursery areas are the downstream portions of coastal rivers which support Atlantic sturgeon, and their associated estuaries. Nursery areas in the Waccamaw and Edisto Rivers are broad, downstream reaches which are tidally influenced and have hard sand or shale substrates. Salinities in such areas ranged from 1-5 ppt in the Edisto and 0-3 ppt in the Waccamaw. The Atlantic sturgeon's feeding mode reflects an adaptation to gathering food from relatively soft-bottom substrates which are frequented by macroinvertebrates. The demersal, adhesive eggs suggests the need for reduced flow velocities of well-oxygenated water, low levels of suspended solids during incubation, and relatively hard-bottom substrates in spawning areas.

3.3.11.4   Blueback Herring
The blueback herring (*Alosa aestivalis*) is a small species of the herring family which is also an important forage species for other species managed by the Council and Commission. It

is preyed upon by the same species that prey on alewife and other clupeid species. It is a schooling species which spawns in the lower portions of the tributary rivers of estuaries along the east coast from Nova Scotia to the St. Johns River in Florida (Fay et al. 1983). It, along with alewife, historically has formed the basis of an important commercial fishery, as well as being an important link in estuarine and marine food webs, forming a linkage between zooplankton and top predators.

3.3.11.4.1   Description of the Species and Distribution

Blueback herring have a blue to blue-green back and silver sides with a prominent dark spot on the shoulder. In contrast to the alewife, bluebacks have a black peritoneum lining the body cavity. They range in size from around 230 mm (9 in) at age three to around 313 mm (12.3 in) at age eight or nine. Bluebacks vary more than alewives in age of first spawning, though in general their maturation rates are similar (Fay et al. 1983). Fecundity of blueback herring females ranged from 45,800 eggs in a 238 mm (9.4 in) individual to 349,700 from a 310 mm (12.2 in) fish. Blueback begin spawning at warmer temperatures than alewives, around 14 degrees C (57 F). Both species cease spawning when water temperatures rise above 27 degrees C. Both species scatter their eggs and spawn in groups. Blueback herring eggs hatch in approximately 55 to 94 hours, depending upon the temperature. Yolk-sac larvae average 5.1 mm (0.2 in) at absorption and remain in the stage for 2-3 days. Larval blueback herring range from 4-15.9 mm (0.2-0.6 in) in length. Larvae appear to prefer areas with less than 12 ppt salinity. Transformation to the juvenile stage is completed at about 20 mm (0.8 in) in length. Juveniles may exhibit an initial upstream movement during the summer, followed by downstream movement beginning in October. Juveniles exhibit diel movement, moving toward the bottom during the day and toward the surface at night. Emigration from estuarine nursery areas occurs between June and November of their first year. Little information is available on the species once emigration to sea has occurred. Catch data from National Marine Fisheries Service trawl surveys indicate that bluebacks spend most of their time offshore in water depths of less than 100 m (328 ft). Bluebacks were most abundant, north of Cape Hatteras, at depth between 27 and 55 m (89 and 180 ft). Catches of bluebacks in summer and fall were confined to the areas north of 40 degrees north latitude. Winter catches were between 40 and 43 degrees north latitude. Spring catches were distributed over the entire Continental Shelf portion of the study area (Fay et al. 1983). Blueback herring, like alewives, are primarily zooplankton feeders. Young-of-the year bluebacks consumed various species of copepods.

Bluebacks have a broader range in the South Atlantic, occurring in coastal rivers of all four states. Rulifson's (1994) recent survey indicates that the species occurs in the following river systems: NC--North, Pasquotank, Little, Perquimans, Yeopim, Chowan, Meherrin, Roanoke, Cashie, Scuppernong and Alligator Rivers (all tributaries of Albemarle Sound); Tar-Pamlico, Pungo, Neuse, and Trent Rivers (tributaries to Pamlico Sound); New River; Cape Fear, North East Cape Fear and Brunswick Rivers; and White Oak River; SC--Waccamaw, Little Pee Dee, Great Pee Dee, Lynches and Black Rivers (tributaries of Winyah Bay); Santee River; Cooper River; Ashley River; the Edisto, Ashepoo and Combahee Rivers (ACE Basin); Sampit River, Salkehatchie River; and Savannah River; GA--the Savannah, Ogeechee, Altamaha, Oconee, Satilla, Ocmulgee and St. Marys Rivers; and FL-- the St. Marys, Nassau, St. Johns, Pellicer, Moultrie and Tomoka Rivers.

3.3.11.4.2   Habitat and Environmental Requirements

Blueback herring are reported to prefer spawning sites with fast currents and associated hard substrates; however, in South Atlantic coastal rivers, they frequently use flooded back swamps and spawn in and among the vegetation of aquatic bed habitats. Preferred temperatures of juveniles ranged from 20 to 22 degrees C, but they were encountered in the field at temperatures ranging between 11.5 to 32 degrees C (53-89 F). Bluebacks are apparently highly tolerant of salinity changes, since direct transfers of adults from fresh water to salt water and the reciprocal produced no mortality. The species requires coastal rivers, associated palustrine forested and aquatic bed wetland habitats, and downstream estuaries as well as the offshore marine environment for completion of its life cycle.

3.3.11.5   Hickory Shad

The hickory shad (*Alosa mediocris*), is a medium-sized member of the shad family which has a center of abundance in the mid-Atlantic region of the east coast (Klauda et al. 1991). Its biology and life history are not as well known as other shad and herring species. In contrast to American shad, it was not important to historical commercial fisheries, but in more recent years has provided the basis for an important recreational fishery in some South Atlantic rivers such as the Roanoke in NC.

3.3.11.5.1   Description of the Species and Distribution

Hickory shad are grey-green along the back, with iridescent silvery or sometimes bronzy sides. They are distinguished from other anadromous clupeid fish by the presence of a strongly projecting lower jaw, among other features. Hickory shad reach a maximum length of about 600 mm (23.6 in). They are usually the first of the anadromous clupeid to ascend spawning rivers in the spring, when water temperatures are 12 or 13 degrees C. Spawning can occur as early as March in southern rivers. Little information is available about hickory shad spawning activity, but it is thought that they spawn largely at night. Fecundity ranged from 61,000 eggs in two-year old females to over 500,000 eggs in older females. Eggs hatch in 48-72 hours at temperatures between 18 and 21 degrees C. Larvae are 5.2-6.5 mm (0.2-0.3 in) in length. The yolk sac is fully absorbed at four to five days of age.   Postlarvae transform to juveniles at 10-35 mm in length (0.4-1.4 in). Young hickory shad leave the freshwater and brackish portions of rivers in the early summer and migrate to estuarine nursery areas at an earlier age than the other clupeid species. Studies in the Neuse River estuary of NC suggest that young hickory shad may migrate directly to saline areas and not use the fresher portions of estuaries. The distribution and migration of hickory shad once they depart to oceanic waters is essentially unknown, although they are occasionally harvested along the coast of southern New England during summer and fall. This suggests that they may migrate in a pattern similar to that of American shad. The age of hickory shad populations in the South Atlantic ranged from two to eight years. Repeat spawning occurs, but percentages are variable. Food habits of juvenile hickory shad have not been studied. Adults are primarily fish eaters, but also consume squid, fish eggs, small crabs and pelagic crustaceans. Adults apparently do not feed during the spawning migration.

In the South Atlantic region, hickory shad are documented as occurring in the following river/estuary systems (Lee et al. 1980 et seq., Rulifson 1994): NC--Chowan, Roanoke and Scuppernong Rivers (Albemarle Sound tributaries); Tar-Pamlico, Neuse, Trent Rivers (Pamlico Sound tributaries); New River; Cape Fear and North East Cape Fear Rivers; SC--Waccamaw, Little Pee Dee, Great Pee Dee, Black, Santee, Cooper, Ashley, Edisto, Ashepoo, Combahee, Sampit, Salkehatchie, Savannah and Lynches Rivers; GA--Savannah, Ogeechee, Altamaha,

Oconee, Satilla, Ocmulgee and St. Marys Rivers; and FL--St. Marys, Nassau, St. Johns and Tomoka. The most recent comprehensive survey (Rulifson 1994) indicated that status of the species was unknown in about half of the SC rivers and all FL rivers.

3.3.11.5.2   Habitat and Environmental Requirements

Information on the habitat requirements of hickory shad is sparse. Major spawning sites for hickory shad are in the freshwater reaches of coastal rivers, including tributary streams and flooded back swamps. Studies of conducted in the Roanoke and Neuse Rivers, NC and the Altamaha River, GA, suggest that the species may prefer tributary streams and flooded back swamps as spawning habitat, rather than the main river channel. Hickory shad eggs have been collected in water temperatures ranging from 9.5 to 22 degrees C. Dissolved oxygen levels at egg collection sites ranged from 5-10 mg/l. Juveniles were collected in salinities ranging from 10-20 ppt. No additional information is available on the habitat requirements of this species.

3.3.11.6   Shortnose Sturgeon

The shortnose sturgeon (*Acipenser brevirostrum*) is a federally-listed endangered species, for which a Recovery Plan is currently being prepared (NMFS 1997). The species occurs in South Atlantic rivers, and on occasion in marine waters. There are apparently no documented records from the EEZ in the South Atlantic (Mark Collins, SC Department of Natural Resources, personal communication to R.W. Laney);however, the species is included here since the Council also must consider the impacts of its plans on federally listed protected species. It is an anadromous species which historically, with the Atlantic sturgeon, formed the basis for a valuable commercial fishery. Information in this account is taken largely from the August, 1997 version of the draft Recovery Plan for the species (National Marine Fisheries Services 1997), with supplementation from other sources as cited.

3.3.11.6.1   Description of the Species and Distribution

The shortnose sturgeon occurs in large coastal rivers of eastern North America, historically from the St. John River in New Brunswick, Canada to the Indian River, Florida (NMFS 1997). The shortnose is a small species for sturgeon, reaching maturity at fork lengths of 45-50 cm (18-20 in) and maximum size of approximately 120 cm (47 in)(Dadswell et al. 1984). It differs from juvenile Atlantic sturgeon in having a shorter nose, wider mouth, and no enlarged bony plates between the base of the anal fin and the lateral row of scutes (see Figure 6 in Gilbert 1989).

Shortnose sturgeon are found in rivers, estuaries and the sea, but populations spend most of their time in their natal rivers and estuaries (NMFS 1997). In the southeast, the species is estuarine anadromous (i.e., spends most of the year in estuaries and ascends the freshwater portions of rivers to spawn in the spring).   Adults in rivers in the south Atlantic forage at the interface of fresh tidal water and saline estuaries. Spawning occurs in the early spring. At hatching, shortnose sturgeon larvae are blackish-colored, 7-11 mm (0.3-0.4 in) long and resemble tadpoles (Dadswell et al. 1984). Larvae have a large yolk-sac, poorly developed eyes and fins, and are capable of only limited swimming. It is likely that they hide under available cover at spawning sites. The yolk-sac is absorbed in 9-12 days, and larvae resemble miniature adults by about 20 mm (0.8 in) in length. They likely begin swimming downstream at this size. Larvae collected in the wild were in the deepest waters of the channel. Laboratory studies suggest that their is a two-stage downstream migration: a 2-day migration by larvae, followed by a residency period of young-of-the-year fish, then a resumption of migration by yearlings the second summer of life. Juveniles occur in or at the saltwater/freshwater interface in most rivers

(Savannah-see Hall et al. 1991; Altamaha-see Flournoy et al. 1992). Juveniles in the Savannah River use sand/mud substrate in depths of 10-14 m (33-46 ft) (Hall et al. 1991). Warm summer temperatures above 28 degrees F may severely limit available juvenile nursery habitat in some southern rivers. Summering habitat in the Altamaha River was limited mainly to one cool, deep water refuge (Flournoy et al. 1992). Adults which occur in freshwater or tidal fresh reaches of rivers in summer and winter often occupy only a few short reaches of the total river length. As with juveniles, adult summer habitat may be limited to cool, deep refugia.

Shortnose sturgeon historically occurred in most rivers of the four South Atlantic states from the Albemarle Sound system in NC through the Indian River system in FL. There have been no recent documented captures in the Albemarle Sound or any of its tributaries (Chowan and Roanoke Rivers being the major ones), or in the Pamlico Sound and its tributaries (Tar, Neuse Rivers). There are several recent reports of sturgeon from the Albemarle Sound which were allegedly shortnose, but there has been no confirmation by professional fishery biologists. There is currently a population of shortnose in the Cape Fear River and the NC portion of the Waccamaw River. In South Carolina, populations presently exist in the Winyah Bay system (Waccamaw, Pee Dee and Black Rivers), the Santee River, the Cooper River, the ACE Basin (Ashepoo, Combahee and Edisto Rivers) and the Savannah River. Georgia populations occur in the Savannah, Ogeechee, Altamaha, St. Marys and Satilla Rivers. Florida has shortnose presently only in the St. Johns River.

3.3.11.6.2   Habitat and Environmental Requirements

Shortnose sturgeon in the south Atlantic portion of the range require the use of large coastal rivers from the estuarine portions to upstream spawning areas. At present in the South Atlantic, populations exist in the Cape Fear River (NC); Waccamaw River (NC/SC), Pee Dee River (NC/SC) and Black River tributaries of Winyah Bay (SC); Santee River (SC); Cooper River (SC); the ACE Basin tributaries, Ashepoo, Combahee and Edisto Rivers (SC); Savannah River (SC/GA); Ogeechee River (GA); Altamaha River (GA); Satilla River (GA); St. Marys River (GA/SC); and St. Johns River (FL). Historic populations occurred in the Chowan River (NC) and likely Roanoke River and Albemarle Sound (NC); likely the Pamlico Sound and tributaries the Tar and Neuse Rivers (NC); possibly the North and New Rivers (NC); and Indian River (FL). These latter systems should be considered potential areas for restoration of shortnose sturgeon populations.

Habitat and environmental requirements of shortnose sturgeon are reviewed in Gilbert (1989). Shortnose require large rivers unobstructed by dams, or in which the dams are above their preferred spawning areas, or at which fish passage has been provided. Shortnose are apparently able to maintain completely freshwater populations (Connecticut River; Santee River). Preferred temperature ranges and upper and lower lethal temperatures for shortnose are not currently known. Shortnose sturgeon is seldom found in shallow water where water temperatures exceed 22 degrees C; however, in the Altamaha they were found at temperatures as high as 34 C. Temperatures at wintering sites ranged from 5-10 C in Winyah Bay. Shortnose spawning generally occurs earlier and at lower temperatures than Atlantic sturgeon. Dadswell et al. (1984) report that most shortnose spawn at between 9-12 C. Spawning habitat for shortnose in SC was reported to be flooded hardwood swamps along the inland portions of rivers . Shortnose sturgeon prefer waters of lower salinity than Atlantic sturgeon. The maximum salinity at which shortnose were found is 30-31 ppt, slightly less than sea water. In areas where shortnose sturgeon and Atlantic sturgeon co-occur, shortnose are typically found in waters less than 3 ppt. Adult sturgeon are typically found in areas with little or no current throughout their

lives, especially when they are present in the lower portions of rivers and in the estuaries. Shortnose have been reported from shallower waters in the summer (2-10 m; 6.5-33 ft) and deeper water in the winter (10-30 m; 33-99 ft). They have been observed feeding in heavily vegetated, muddy backwater areas; however, in general submerged aquatic vegetation does not appear to be an important factor in their life history.

3.3.11.7   Striped Bass
The striped bass (*Morone saxatilis*) is a wide-ranging species of considerable commercial and recreational importance. While all stocks of striped bass which occur in South Atlantic rivers are anadromous, it appears that only the Albemarle Sound stock is migratory to any degree. Riverine striped bass stocks in rivers to the south of Albemarle Sound apparently do not undertake oceanic migrations. All North Carolina riverine striped bass stocks are managed under the Atlantic States Marine Fisheries Commission's management plan. Remaining South Atlantic stocks are managed by individual state jurisdictions, or cooperatively in cases where states share a watershed. Striped bass have also been widely stocked in inland reservoirs as a game fish.

3.3.11.7.1   Description of the Species and Distribution
The striped bass is a larger-sized member of the perch family. It has an elongate, moderately compressed body. Dorsal coloration ranges from shades of green, to steel blue and almost black. Laterally, striped bass are silver with seven or eight horizontal black stripes, one of which always follows the lateral line. In contrast to the clupeids, striped bass have an anterior spiny dorsal fin, and also have sharp spines on the posterior edge of the gill flap. Striped bass spawn in the spring in fresh water or nearly fresh portions of coastal rivers in the South Atlantic beginning mid-February in FL to as late as mid-June in North Carolina. Most spawning occurs at temperatures of 18-21 degrees C. Peak spawning in the Savannah River occurred at 17 C, and in the Roanoke at 19 C. Eggs are semi-buoyant and require suspension by currents of at least 30 cm/sec. Buoyancy of the eggs may vary from river to river. Fecundity ranges from 15,000 to 40.5 million eggs, depending on the size of the female. Hatching time varies from about 30 to 80 hours, depending upon temperature. Striped bass have three larval stages: yolk-sac, fin-fold and post fin-fold. Yolk-sac larvae are 5-8 mm (0.2-0.3 in) in length and absorb the yolk at 7-14 days of age. Fin-fold larvae are 8-12 mm and remain in this stage for 10-13 days. Juvenile body form is attained at about 30 mm and 20-30 days. Little is known about the distribution and movements of juveniles in South Atlantic rivers. They do school and apparently prefer clean sandy substrates, but have been found over gravel beaches, rock bottoms and soft mud.
Juveniles move downstream to nursery areas which may include tidally-influenced fresh waters and estuaries. Maturation rates of striped bass in southern coastal rivers is not generally available. Striped bass are fairly long-lived, with migratory races living as long as 30 or more years. Aged fish in southern rivers were generally age 11 or less (see Hill et al. 1989, Table 3). Striped bass initially feed on mobile planktonic invertebrates, shifting to larger aquatic invertebrates and fish as they grow. In FL, juvenile striped bass feed predominantly on mosquito fish, mollies and freshwater shrimp, larger juveniles feed on threadfin shad, and adults feed primarily on schooling prey fishes, especially clupeids.

3.3.11.7.2   Habitat and Environmental Requirements
Preferred spawning sites vary. In the Roanoke River, NC, preferred spawning sites near Roanoke Rapids and Weldon are rocky and relatively deep, with relatively fast currents. Spawning habitat on the Roanoke is approximately 208 km (130 mi) upstream from the river

mouth and even further from the ocean. In other South Atlantic rivers, spawning sites are typically within 60 km (37.5 mi) of the coast, with some sites in tidally-influenced fresh areas. Actual spawning habitats for most South Atlantic rivers are specified in Table 2 of Hill et al. (1989). Sites identified include: NC--Tar-Pamlico River, km 90-238; Neuse River, NC Highway 55 to SR 1915 bridge; North East Cape Fear River, downstream of Lands Ferry; SC--Waccamaw-Pee Dee system, either the Pee Dee River or Intercoastal Waterway; Pee Dee River, upstream from US 301 bridge; Black River, upstream from US 701 bridge; Wateree River, downstream of km 51; Congaree River, km 8-85, but most near km 60; Lynches River, upstream of Highway 41 bridge; Cooper River, lower end of tailrace canal; Ashley River, near km 55; Combahee River, between US 17 and 17-A bridges; GA--Savannah River, km 30-40; Ogeechee River, km 47-55; Altamaha River, km 16; and FL--St. Johns River, Oklawaha River, Wekiva River, Black Creek and Dunn's Creek.

Juvenile striped bass prefer shallow areas with substrates ranging from sand to rock, in the lower portions of coastal rivers and estuaries. Normal development and hatching of striped bass eggs requires dissolved oxygen levels of at least 3-5 mg/l. Adequate current velocity is also a key factor influencing the survival of striped bass eggs, as noted above. Larvae require oxygen levels of 5-6 mg/l, and the optimal range for juveniles is probably 6-12 mg/l. Adult striped bass do not tolerate oxygen levels below 3 mg/l. Larval striped bass tolerate temperatures of 12-23 degrees C, with an optimal range of 16-19 C. Optimal temperature for juveniles is between 24-26 C. As striped bass grow, temperature preference shifts toward cooler waters. In southern rivers, the presence of thermal refugia in the form of springs, spring-fed streams, artesian upwellings may be essential to survival of adults during hot summers. Tolerance of salinity varies with age. Low salinities of 0-3 ppt enhance the survival of eggs and larvae. The range of salinity tolerances and optima generally expand with age. Combinations of high salinity and low temperature cause the highest mortality in young striped bass.

3.3.11.8   American eel

The American eel is the only catadromous species which occurs in the South Atlantic region. Catadromous species are those which live in freshwater as adults, but return to the Atlantic Ocean where they were spawned to complete their life cycle. The American eel supports valuable commercial and limited recreational fisheries throughout its range. Harvested adults are often shipped alive to markets in Europe. The juvenile eels, called glass eels or elvers, are highly valuable because they are used in aquaculture operations for growing out for market. The American eel is also an important prey species for larger marine and freshwater fishes.

3.3.11.8.1   Description of the Species and Distribution

The American eel has an elongate and snakelike body, with dorsal and anal fins which are confluent with the caudal fin, producing an apparent single fin which encompasses much of the body. The body is covered by minute embedded scales. Eels range in color from gray, through yellow to green on the dorsal surface and are usually lighter in color on the ventral side. Color changes with the change in life stage. Large females can reach 1270 mm (50 in) in length. The life cycle of the American eel includes oceanic, estuarine and riverine phases. Adult eels migrate from freshwater portions of inland rivers to the spawning area in the Atlantic Ocean, generally south of Bermuda and north of the Bahamas, centered about 25 degrees N and 69 degrees W. Maturity occurs beyond age 3 for males and age 4-7 for females in northern populations, but may occur earlier in the south. Fecundity is 10-20 million eggs per female. Hatching occurs in February through August, with the larval stage lasting a year or longer.

Larvae are 7-8 mm at hatching. The larval stage is called a leptocephalus, and the leptocephali drift with and are transported by ocean currents. The Gulf Stream is the principal means of transportation for larvae along the eastern seaboard of North America. Larvae are abundant in the Florida Straights and in the area between Bermuda and the Bahamas from April through August. The leptocephali metamorphose into a glass eel stage. Glass eels actively migrate toward land and fresh water, and as they approach coastal areas, external pigmentation develops and the body becomes uniformly dark brown or black. This stage is called an elver. Most elvers move into coastal estuaries and up coastal rivers in the late winter or spring of the year. They generally arrive earlier in southern rivers. Migrating elvers have been collected in January in FL and SC, and in January through May, with peaks in March and April, in NC. Elvers are typically 46-60 mm (1.8-2.4 in) in length in south Atlantic estuaries. Elvers occupy portions of estuaries near the salt-fresh water interface before ascending rivers. Once elvers cease their migration, they begin metamorphosis to the next phase called yellow eels. Some authors believe that yellow eels which remain in the estuarine portion of systems are predominantly male, while those moving further inland become female; however, such a pattern has not been consistently observed. Yellow eels remain in estuaries or rivers for up to 14 years before undertaking the spawning migration back to the Atlantic Ocean. Yellow eels begin metamorphosis into the final stage, called silver eels, in the fall prior to seaward migration. Eels are primarily nocturnal and have a diverse diet. Eels in freshwater feed on insects, worms, crayfish and other crustaceans, frogs and fish. Elvers in saltwater are planktivorous. Blue crabs and clams may be significant prey items in some estuaries. Eels serve as prey for both largemouth bass and striped bass.

The American eel historically occurred throughout the entire South Atlantic, in all coastal rivers and inland freshwater streams, lakes and ponds. In some watersheds, however, construction of dams has prevented juvenile recruitment and has effectively eliminated the American eel from that portion of the watershed above the dams (e.g. Roanoke River Basin in NC and VA). Investigations should be conducted in all South Atlantic rivers with dams to assess whether American eels have been eliminated from the upper portions of other southeastern watersheds.

3.3.11.8.2   Habitat and Environmental Requirements

Spawning occurs in the Atlantic Ocean at the general locality noted above. Depths at which spawning occurs are not known; however, larvae collected near Bermuda occurred only at depths between 550 and 2200 m (1800-7205 ft). Postlarval eels tend to be bottom dwellers and hide in burrows, tubes, snags, plant masses, other types of shelter, or the substrate itself. Presence of soft, undisturbed bottom sediments is important to migrating elvers as shelter.

American eels have broad tolerances for varying temperature and dissolved oxygen. Preferred temperature was 16.7 degrees C. Salinity may provide a key factor in American eel migration movements during the larval, glass eel, and elver stages, along with currents. Alterations in the pattern or magnitude of freshwater inflows into coastal rivers and estuaries could alter salinity and current regimes and thereby affect the number, timing and spatial patterns of upstream migrations by elvers. Since elvers can absorb 60 percent of their oxygen requirements through their skin, they are able to tolerate low DO conditions, as can adult eels, which can use both branchial and cutaneous respiration.

3.4   Essential Fish Habitat Degradation: Marine Biodiversity Implications

The protection of fish habitat is an essential component of marine biodiversity conservation (Norse, 1993). The conservation of biodiversity is fundamental to maintenance of

the characteristic structures and functions of ecosystems. The objectives of conservation and enhancement of Essential Fish Habitat under the Magnuson-Steven Act parallel objectives of the United Nations Convention on Biological Diversity, a binding international agreement adopted in 1993. To accomplish the objectives of conservation and sustainable use under the Convention, specific Articles address the requirement for identification and monitoring, sustainable use of components of biological diversity, research and training, and public education and awareness. In addition, one Article explicitly addresses the importance of marine protected areas, the need to restore degraded ecosystems, and the recovery of threatened species.

The National Research Council panel on marine biodiversity (NRC, 1995) concluded that to describe, understand, and predict changes in marine biodiversity, information is needed on: (1) patterns of biodiversity (mapping), (2) anthropogenic and natural processes that generate or alter these patterns, and natural processes that generated a given pattern (linkages and processes), and (3) consequences to ecosystem function of biodiversity change. Those changes are often due to environmental stressors resulting from human activities. These include effects of fishing, alteration of habitats by nearshore construction projects, and chemical pollution (summarized elsewhere in Section 4.0 of this document).

In requiring the FMCs, along with NMFS, to describe EFH (mapping), identify EFH (linkages and processes), identify stressors, and make recommendations on how best to restore degraded habitats, the Magnuson Act closely parallels the recommendations of other national and international forums. The major threats to biodiversity include overexploitation, introduction of alien species, unsustainable mariculture, land-based activities, and habitat alteration and destruction. Managing threats to biodiversity will require integrated marine and coastal area management, marine protected areas, and socio-economic alternatives. The encompassing goal is to maintain ecosystem structure and function. Research gaps that currently retard that goal are information on: (1) patterns of biodiversity (genetic, species, ecosystem), (2) effects of biodiversity changes on ecosystem function, (3) the effects of changes in habitat (quality and quantity) on biodiversity, and (4) alternative management models (socio-economic and biological). Successful implementation of measures to conserve and enhance EFH will be consistent with the now internationally agreed need for habitat and biodiversity conservation.

Several non-fishing effects on EFH may influence marine biodiversity in coastal areas of the southeast U.S. Of particular relevance to nearshore areas is the potential for faunal shifts in response to coastal urbanization, an infrequently considered issue of potentially high significance to biodiversity. For example, the majority of artificial habitats in nearshore waters of southeast Florida result from construction activities for waterfront access and shoreline stabilization, not fishery enhancement. Rip-rap , seawalls, and dock piles are replacing mangrove and grass shoreline habitat in large areas of southeast and east-central Florida via mitigation or restoration activities.

Extensive structural modifications of estuaries may result in species abundance shifts that are not attributable only to water quality and salinity changes induced by upland modifications. Increased channelization by dredging and the addition of rocky structures to the water column may favor shifts from "estuarine" assemblages to "reef" assemblages because of comparatively higher abundances and diversities of incoming ichthyoplankton and the replacement of vegetation with hard structure favoring reef species (Lindeman, 1997). Such shifts may not only involve relative species abundances but also longer nearshore residence times for the maturing life stages of certain reef species. For example, the artificial, 12 m deep reefs adjacent to the side of the leeward barrier island (the Government Cut jetties) of South Miami Beach may lengthen the time interval before maturing reef fishes undergo substantial offshore migrations. Adults of

many grunts and snappers (bluestriped grunts, sailors choice, gray snappers, porkfishes, etc.) are commonly found on these structures. In areas lacking artificially maintained inlets and the massive rip-rap jetties they require, these adult reef fish faunas would only be found on the deep reefs at the outer shelf edge, several kilometers offshore.

Reef species that remain in or near modified estuaries through reproductive maturity may ultimately reinforce faunal shifts. Inshore-spawned eggs and larvae are more likely retained within estuaries or coastal lagoons than eggs and larvae that would normally be spawned offshore. For example, reproductively active porkfishes, angelfishes, and other reef species occur on bridges within southeast Florida lagoons, presumably because of the steep vertical relief created by bridge construction and channelization. Pile structures supporting large bridges connecting barrier islands and keys generate eddies and other turbulence that can allow settlement of certain fishes. Perhaps more importantly, these structures often support large concentrations of planktivorous juvenile and adult fishes. Therefore, narrow gauntlets of predators may be present across bridged inlets and channels of southeast Florida. These could decrease numbers of larvae ingressing through channels while, paradoxically, providing significant habitat for juveniles and adult reef fishes (Lindeman, 1997).

Recognition of the importance of tidal channel and leeward barrier island areas as conduits of larval ingress into estuaries and as concentrated settlement sites and juvenile nurseries is needed. Gilmore (1988) found that seagrass beds associated with inlets possessed the richest faunas within the Indian River Lagoon, east-central Florida. Management agencies should place considerable emphasis on limiting negative habitat impacts in these areas. This goal is difficult in application because it may conflict with existing coastal management policies. For example, channels are often considered optimal areas for the siting of large marinas because of better flushing characteristics. However, construction of marinas and docks at previously vegetated channel shorelines increases depth and structural relief, and can ultimately favor greater colonization and inshore residence of reef species.

Inshore faunal shifts from estuarine to reef species operate at population through ecosystem levels and deserve recognition by management agencies and long-term evaluation by researchers (Lindeman, 1997). Superimposed on these factors is the role of anthropogenic modifications of freshwater runoff into estuaries; a factor which may also change existing faunal measures of biodiversity due to differential responses to salinity stress (Serafy et al., 1997).