2.0 DESCRIPTION OF RESOURCE AND HABITAT

2.1 BIOLOGY

Sharks belong to the Class Chondrichthyes, cartilaginous fishes that also include the rays, the skates, and the deepwater chimaeras (ratfishes). Sharks are primitive fishes characterized by skeletons lacking true bones. About 350 species of sharks have been described throughout the world. Seventy-three species are known to inhabit the waters along the U.S. East Coast, including the Gulf of Mexico and the waters around Puerto Rico and the Virgin Islands.

The earliest known sharks appear as fossils in the rocks of the Devonian period, ca. 400 million years ago. Early sharks evolved as pelagic predators, although they were not the large predators of today. Early sharks were small creatures, about 60 to 100 cm long, that were preyed upon by much larger armored fishes that dominated the seas. Sharks have maintained the role of pelagic predators for nearly 400 million years, competing with other adapted predators, such as ichthyosaurs and toothed whales. Sharks have survived competition for eons, evolving into the large and aggressive predators that dominate the seas today.

Although the number of species of sharks is relatively small when compared to the number of species of bony fishes (over 20,000), sharks are a diverse group. They range in size from the gigantic 12-m whale shark, the largest fish in the oceans, to the tiny pygmy shark that is fully grown at only 20 to 25 cm. There are fast-moving streamlined species such as mako and thresher sharks, and sharks with flattened, ray-like bodies, such as the angel sharks. There are basking sharks and whale sharks that feed by filtering small organisms from the water. The tiger shark eats large turtles, and the tiny cookiecutter shark feeds by carving plugs of flesh out of large fishes and whales. There are sharks that reproduce by laying eggs, as well as sharks that nourish their embryos through a placenta. Despite the great diversity in size, feeding habits, habitat, behavior, etc., there are some adaptations common to nearly all sharks. These adaptations have contributed greatly to the evolutionary success of sharks. Most of these common adaptations involve their feeding habits and reproductive modes.

Sharks are aggressive predators at or near the top of the food chain, with three exceptions: whale sharks, basking sharks, and megamouth sharks, all of which are filter-feeders. Most, however, are flesh eaters that have evolved very sensitive receptors that allow them to track wounded or injured prey. They have extremely sensitive smell receptors, eyes that can adapt to very dim light, electroreceptors that can, in the absence of scent or visual clues, detect prey buried in the sand, and

lateral line receptors that sense movement in the water. As predators, sharks must balance the energy spent in chasing and capturing prey against the energy obtained from eating it. Consequently, sharks usually select weak, sick, injured, or dying prey because such prey is easier to overcome than healthy individuals. In addition to their fine senses, sharks are armed with a formidable set of teeth and jaws that can produce considerable force. The teeth are replaced often, so sharks always have a sharp set capable of inflicting a clean bite.

The reproductive adaptations of sharks have contributed to their evolutionary success. The most significant of these are internal fertilization and the production of small numbers of large young, which hatch or are born as fully developed young or "pups." All sharks have internal fertilization. During mating, the male shark inseminates the female with copulatory organs, known as claspers, that develop on the pelvic fins. In most species, the embryos spend their entire developmental period protected within their mother's body. When development is complete, the young are born as active, miniature sharks. The young are large at birth. Large size reduces the number of potential predators and competitors, thus enhancing shark survival.

The number of young produced by most shark species in each brood is small, usually ranging from 2 to 25, although large females of some species can produce broods of 100 or more pups. The production of large-sized young requires great amounts of nutrients to nourish the developing embryo. Thus, sharks have evolved diverse means of nourishing their embryos, such as the production of eggs with very large yolks, the ingestion of egg yolks by the embryos, and the direct transfer of nutrients from mother to embryo through a yolk sac placenta. Traditionally, these adaptations have been grouped into three modes of reproduction: oviparity, ovoviviparity, and viviparity.

Oviparity in sharks is the most primitive condition, and it is a modified oviparity, different from that of the bony fishes. Oviparous sharks lay large eggs that contain sufficient yolk to nourish the embryo through development and allow it to emerge fully developed. These eggs are enclosed in leathery cases that are deposited on the sea bottom, usually attached to plants or rocks. There is no parental care or brooding in sharks. The only protection for the embryo is its tough leathery case, composed of protein fibers. The development of these eggs is temperature-dependent and hatching usually occurs in a few months to a year. The pups of oviparous sharks are somewhat small because their growth is limited by the amount of nutrients stored in the egg. The embryos of the oviparous whale shark, the largest living fish, measure only 36 cm, a size exceeded by the embryos of many smaller ovoviviparous or viviparous sharks. Oviparity is found in only four families of sharks: bullhead sharks, nurse sharks, cat sharks, and whale sharks.

Ovoviviparity, also known as aplacental viviparity, is the most common mode of reproduction in sharks. The eggs of ovoviviparous sharks hatch in the uterus before the embryos are fully developed. The embryos continue to grow in the uterus, nourished by yolk stored in the yolk sac, and without forming a placental connection with the mother. The embryos are born after their development has been completed. The brood size (litter size) is highly variable, depending on the reproductive strategy of the species. In some ovoviviparous sharks, such as the sand tiger, the yolk is absorbed very early in development. Thereafter, the embryos nourish themselves by swallowing unfertilized eggs and smaller embryos in the uterus, in a form of embryonic cannibalism called oophagy. Having eaten it's smaller siblings, usually only one embryo survives in each of the two uteri. Ovoviviparous sharks include cow, frill, sand tiger, goblin, mackerel, basking, thresher, false cat sharks, saw, angel, squaloid, ribbontail cat sharks, some nurse sharks, some smooth dogfishes, and some cat sharks.

Viviparity, or placental viviparity, is the most advanced mode of reproduction. The embryos of viviparous sharks are initially dependent on stored yolk but are later nourished by the mother through a placental connection. In viviparous sharks, the yolk sac comes in contact with the mother's uterus, and it becomes modified into a yolk sac placenta. Here the tissues of embryo and mother come in intimate contact, and nutrients can be supplied to the embryo. Being connected to the blood supply of the mother, the embryo has an abundant and continuous supply of nutrients. The embryo can thus be nurtured to a relatively large size at birth. Most placental sharks produce broods of two to a dozen, with a few exceptional pelagic species producing 20 to 40 young. Viviparity is confined to some smooth dogfishes, requiem sharks, and hammerheads.

Most species of sharks have gestation periods and ovarian cycles that last about a year. These two cycles may or may not run concurrently. In most of the larger carcharhinid sharks, the cycles do not run concurrently, but follow each other. For example, females will ovulate and become fertilized in the early spring or summer. They gestate for about a year, and give birth the following spring or summer. After giving birth, females begin to develop the eggs that will be ovulated the spring of the second year. Thus, most of these species reproduce every two years. In other species, such as hammerheads and sharpnose sharks, the ovarian cycle and the gestation periods run concurrently. Females carry developing embryos and developing eggs at the same time. Shortly after giving birth, these females ovulate, and are fertilized again. Thus, these species reproduce yearly. Other species have even longer gestation periods. The spiny dogfish has a gestation period of about 24 months, the longest known of any living creature.

Females of most species of sharks travel to specific "nursery" areas to give birth to their young at certain times of the year. These nurseries are discrete geographic areas, usually in shallow waters, or at least shallower waters than those inhabited by the adults. Frequently the nursery areas are in highly productive coastal or estuarine waters where abundant small fishes and crustaceans provide food for the growing pups. These areas are also free of large predators, thus the young sharks have enhanced chances of survival. In temperate zones, the young exit the nursery with the onset of winter; in tropical areas, the young may stay in the nursery for a few years.

Sharks are slow growing and slow maturing fishes. The most economically important sharks, the large coastal carcharhinids, have very slow growth rates. Several of the commercially important species, such as sandbar (Casey et al., 1985), lemon (Brown and Gruber, 1988) and bull (Branstetter and Stiles, 1987), do not reach maturity until 12 to 18 years of age. The life span of sharks in the wild is not known, but it is believed that many species may live 30 to 40 years or longer. The reproductive life span of these sharks is unknown.

In summary, sharks have a very low reproductive potential. Various factors determine this low reproductive rate: slow growth, sexual maturity not reached until 4 to 18 years, one- to two-year reproductive cycles, a small number of young per brood, and specific requirements for nursery areas. Therefore, sharks must be managed very conservatively.

2.2 ECOLOGICAL RELATIONSHIPS

As mentioned earlier, sharks are predators, except for basking sharks, whale sharks, and megamouth sharks. Whale sharks and basking sharks exceed 8 m in length, and are similar to some whales in feeding habits. Other sharks are at the apex of the food chain: white, mako, tiger, bull, and great hammerhead, all large species exceeding 3 m in length.

Ecologically, sharks can be divided into four broad categories: (1) coastal, (2) pelagic, (3) coastal-pelagic, and (4) deep-dwelling. Coastal species inhabit nearshore areas and the continental shelves. Examples are blacktip, finetooth, and sharpnose sharks. Pelagic species, on the other hand, range widely in the upper zones of the oceans, often traveling over entire ocean basins. Examples include mako, blue, and oceanic whitetip sharks. Coastal-pelagic species are intermediate in that they occur both inshore and beyond the continental shelves, but have not demonstrated mid-ocean or transoceanic movements. Sandbar, scalloped hammerhead, and dusky sharks are examples of coastal-pelagic species. Deep-dwelling species inhabit the dark, cold waters of the continental slopes and deeper waters of the

ocean basins. Examples of this category are most cat sharks and gulper sharks.

Tagging studies have shown that assignment of species to these categories must be somewhat arbitrary because several coastal-pelagic sharks have shown movements from the U.S. to the Bahamas, West Indies, and Mexico. For example, the sandbar shark has shown north-south movements along the U.S. east coast between Cape Cod and Texas. Sandbar sharks tagged off the northeast coast of the U.S. have traveled across the Florida Straits to Cuba and to Mexican waters as far south as the Yucatan. Some tagged sandbar sharks have traveled almost 5,000 km along the coast of North America and have been recaptured after 24 years. Other species (dusky, blacktip, night, silky, blue, shortfin mako, longfin mako, tiger, whitetip, spinner, and bignose) have also traveled between the U.S. east coast and the Gulf of Mexico. Detailed knowledge of the migrations of sharks between the U.S. EEZ and international waters will be required for the most effective management of these species, because they are available to several national and international fisheries.

The ecological relationships of sharks are poorly known. The effects of sharks on other fish stocks are not known, although some studies suggest that the removal of large sharks from an area results in the proliferation of the smaller shark species.

2.3 SPECIES IN THE MANAGEMENT UNIT

The shark management unit consists of 39 species in the Western North Atlantic Ocean. The management unit extends across state, Federal, and international jurisdictional boundaries. The species in the management unit were chosen for one or more of the following reasons: (1) they are frequently caught in commercial or recreational fisheries; (2) their low fertility and/or slow growth make them particularly vulnerable to overfishing; and (3) their habits make them vulnerable to indiscriminate killing. Sharks in the management unit were separated into three species groups for abundance assessments. The species in the management unit are listed in Table 2.1. The assessment groups are not ecological groups. They are groupings based on fisheries or where the species appear in the landings. Thus, one species could fit two assessment categories. However, for management purposes that species is listed only under one assessment group. For example, the silky shark and the bignose shark are found in both the pelagic environment and in deeper coastal waters, but for management purposes they are placed in the large coastal species group. Other species such as the Galapagos shark and the bigeye sand tiger shark are rare in U.S. waters, but they are similar to the commercially harvested dusky and sand tiger sharks, respectively. The former species are included in the management unit to prevent enforcement problems that would ensue from trying to discriminate among carcasses of similar species.

The smalltail shark has been reported in U.S. landings although there are questions about its presence in U.S. waters. It is included in the management unit to prevent enforcement problems like those explained above. The whale and basking sharks were included in the management unit, although they are not subject to organized fisheries at this time. They are included because their habits make them vulnerable to indiscriminate killing. The status of these species will be monitored by the OT, and appropriate actions may be recommended later through the framework regulatory adjustment procedure (Section 7.1.4) in the FMP. Additional species also may be incorporated into the management unit through the framework regulatory adjustment procedure.

2.4. SPECIES NOT IN THE MANAGEMENT UNIT BUT INCLUDED FOR DATA REPORTING

Most species included in the fishery for data reporting, but not in the management unit (Table 2.2), are small, deepwater sharks that are not target species, but are taken incidentally in directed shark fisheries, or in swordfish or tuna longlining operations. These species are not included in MSY estimates or included in any of the text tables or figures in any other sections of this FMP.

This group also includes two species known locally as "dogfish;" the spiny dogfish (*Squalus acanthias*) and the smooth dogfish (*Mustelus canis*). Unlike most species in Table 2.2, they are taken in considerable numbers in directed fisheries, and as bycatch in other fisheries, because they enter shallow water and are extremely abundant. These species are not overfished at this time nor confronted with such problems as finning, as are the species in the management unit, although finning of dogfish has been reported (Kurkul, 1990).

2.5 DESCRIPTION OF HABITAT

A detailed description of shark habitat has been prepared as a source document and is available upon request from the Regional Director.

2.5.1 CONDITION OF HABITAT AND IMPACTS ON SHARKS

Sharks are found in estuaries, nearshore areas, the continental shelf, continental slope, and open ocean. Many species are migratory and, like all other marine species, are affected by the condition of the habitat. Degraded habitat affects sharks by altering their ecological patterns and by reducing the availability of prey species.

Table 2.1

Sharks in the Management Unit, by Species Groups

Large Coastal Sharks

Sandbar	Carcharhinus plumbeus
Blacktip	Carcharhinus limbatus
Dusky	Carcharhinus obscurus
Spinner	Carcharhinus brevipinna
Silky	Carcharhinus falciformis
Bull	Carcharhinus leucas
Bignose	Carcharhinus altimus
Narrowtooth	Carcharhinus brachyurus
Galapagos	Carcharhinus galapagensis
Night	Carcharhinus signatus
Caribbean reef	Carcharhinus perezi
Tiger	Galeocerdo cuvieri
Lemon	Negaprion brevirostris
Sand tiger	Odontaspis taurus
Bigeye sand tiger	Odontaspis noronhai
Nurse	Ginglymostoma cirratum
Scalloped hammerhead	Sphyrna lewini
Great hammerhead	Sphyrna mokarran
Smooth hammerhead	Sphyrna zygaena
Whale	Rhincodon typus
Basking	Cetorhinus maximus
White	Carcharodon carcharias

Small Coastal Sharks

Atlantic sharpnose	Rhizoprionodon terraenovae
Caribbean sharpnose	Rhizoprionodon porosus
Finetooth	Carcharhinus isodon
Blacknose	Carcharhinus acronotus
Smalltail	Carcharhinus porosus
Bonnethead	Sphyrna tiburo
Atlantic angel	Squatina dumerili

Pelagic Sharks

Shortfin mako	Isurus oxyrinchus
Longfin mako	Isurus paucus
Porbeagle	Lamna nasus
Thresher	Alopias vulpinus
Bigeye thresher	Alopias superciliousus
Blue	Prionace glauca
Oceanic whitetip	Carcharhinus longimanus
Sevengill	Heptranchias perlo
Sixgill	Hexanchus griseus
Bigeye sixgill	Hexanchus vitulus

Table 2.2

Sharks Not in the Management Unit But Included For Data Reporting

Cat Sharks, Family Scyliorhinidae

Iceland cat shark	Apristurus laurussoni
Smallfin cat shark	Apristurus parvipinnis
Deepwater cat shark	Apristurus profundorum
Broadgill cat shark	Apristurus riveri
Marbled cat shark	Galeus arae
Blotched cat shark	Scyliorhinus meadi
Chain dogfish	Scyliorhinus retifer
Dwarf catshark	Scyliorhinus torrei

Dogfish Sharks, Family Squalidae

Japanese gulper shark	Centrophorus acuus
Gulper shark	Centrophorus granulosus
Little gulper shark	Centrophorus uyato
Kitefin shark	Dalatias licha
Flatnose gulper shark	Deania profundorum
Portuguese shark	Cetroscymnus coelolepis
Greenland shark	Somniosus microcephalus
Lined lanternshark	Etmopterus bullisi
Broadband dogfish	Etmopterus gracilispinnis
Caribbean lanternshark	Etmopterus hillianus
Great lanternshark	Etmopterus princeps
Smooth lanternshark	Etmopterus pusillus
Fringefin lanternshark	Etmopterus schultzi
Green lanternshark	Etmopterus virens
Cookiecutter shark	Isistius brasiliensis
Bigtooth cookiecutter	Isistius plutodus
Smallmouth velvet dogfish	Scymnodon obscurus
Pygmy shark	Saualiolus laticaudus
Roughskin spiny dogfish	Squalus asper
Blainville's dogfish	Squalus blainvillei
Spiny dogfish	Squalus acanthias
Cuban dogfish	Squalus cubensis
Bramble shark	Echinorhinus brucus

Sawsharks, Family Pristiophoridae

American sawshark	Pristiophorus schroederi

Smoothhound Sharks, Family Triakiidae

Florida smoothhound	Mustelus norrisi
Smooth dogfish	Mustelus canis

Offshore areas used by adult sharks are the least affected by habitat alterations and water quality degradation. Currently, the primary habitat threats are oil and gas development and production, offshore dumping of dredged material, disposal of chemical wastes, and discharge of contaminants into river systems. However, no studies are known of adverse effects on sharks from these activities.

Nearshore areas generally appear to be acceptable shark habitat, but local problem areas exist. For example, water quality may be reduced in areas affected by the plumes of major rivers. Local disturbances also result from periodic beach nourishment, dredged material disposal, and the dredging itself.

Estuarine nursery is the habitat area of greatest concern relative to sharks. Natural and human-induced alterations of this fragile environment have modified freshwater inflow and removed much of the suitable habitat. The amount of remaining wetlands suitable for shark production has not been quantified; however, Alexander et al. (1986) estimated that for the last 25 years, coastal wetlands have been depleted at an average rate of 80 sq km per year. In some areas, this rate may be even higher. For example, Gagliano (1984) estimated that natural and human-induced forces in Louisiana contribute to a yearly land loss, including marsh, of more than 130 sq km. Major effects result from erosion, sea level rise, subsidence, and accretion.

The estuaries also have been the most impacted by water quality degradation. The major human activities that impact the estuarine zone are: construction and maintenance of navigation channels; construction of levees and marinas; discharges from wastewater plants and industries; dredge and fill for land use development; agricultural runoff; ditching, draining, or impounding wetlands; oil spills; thermal discharges; mining, particularly for phosphate and petroleum; entrainment and impingement from electric power plants; dams; alteration of freshwater inflows to estuaries; saltwater intrusion; and nonpoint-source discharges of contaminants.

The degree to which habitat alterations have affected sharks is unknown. Turner and Boesch (1987) examined the relationship between wetland habitat area and the yield of fishery species dependent on coastal bays and estuaries, noting apparent stock declines following wetland loss, and stock increases following wetland gains. While most of the studies related to shrimp production, other similar trends may exist for other species. Thus, production of some shark species may well be at risk for loss of habitat.

2.5.2 HABITAT IN THE FUTURE

Coastal and marine habitat loss and degradation are major concerns to government agencies, conservation organizations, and private industry. The Presidential "no net loss" policy, habitat rehabilitation, the creation of new habitats, and broad-scale attacks on pollution are all important conservation efforts. There are more than 30 Federal agencies, as well as state and territorial governments, involved with coastal wetlands conservation, and thousands of laws aimed at their wise use, conservation, and management. Application of these laws by the appropriate agencies should modify these land-use demands and minimize the amount of coastal habitat loss.