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Species-Specific Distribution and Habitat Characteristics of Shark Nurseries in Gulf of Mexico Waters off Peninsular Florida and Texas

Robert E. Hueter* and John P. Tyminski
Center for Shark Research, Mote Marine Laboratory
1600 Ken Thompson Parkway, Sarasota, Florida 34236, USA

Abstract.—At least 16 species of coastal sharks from four families (Carcharhinidae, Sphyrnidae, Ginglymostomidae, Triakidae) utilize Gulf of Mexico waters off Florida and Texas as primary and/or secondary nursery areas. From 1991 to 2004, data were collected on 12,879 neonates, young of the year, and older juveniles of these 16 species in the U.S. Gulf of Mexico, primarily in coastal waters of the Florida peninsula and secondarily along the Texas coast. Five main areas of Florida (Yankeetown, Tampa Bay, Charlotte Harbor, Ten Thousand Islands, and Florida Keys) and three areas of Texas (Sabine Pass, Matagorda Bay, and Corpus Christi) were studied as shark nurseries. In general, most pupping activity in these gulf nurseries occurs in the late spring and early summer and the neonate and young-of-the-year animals inhabit the primary nurseries throughout the summer and into the fall. Declining water temperatures in the fall typically are associated with the exit of sharks from these natal inshore waters. In some cases, annual cycles of philopatric behavior are indicated whereby juveniles of both large and small coastal species migrate back to the nurseries in spring and summer. In these cases, primary nurseries for neonates and young of the year may function additionally as secondary nurseries for older juveniles. The importance of Florida and Texas coastal habitats in the early life history of Gulf of Mexico sharks underscores the need for conservation of these areas to help rebuild depleted shark populations.

Introduction

Mote Marine Laboratory in Sarasota, Florida has conducted shark research since the institution was founded as the Cape Haze Marine Laboratory in 1955. In 1965, Founding Director Eugenie Clark published one of the first comprehensive reviews of coastal shark biology in Gulf of Mexico waters (Clark and von Schmidt 1965). In 1991, the Center for Shark Research (CSR) was established at Mote Marine Laboratory in part to assist the National Marine Fisheries Service (NMFS) in the management of U.S. shark fisheries. Pursuant to this mission, the Mote CSR initiated in November 1991 a long-term research program on the early life history of coastal sharks inhabiting the Gulf of Mexico. The program was designed to utilize field surveys, animal collections, tagging and tracking, and other studies to discover the distribution of shark nurseries in the gulf, the biology of juvenile sharks in those nurseries, and the migratory patterns of fisheries-relevant shark species.

The first of these studies was a 1991–1993 project jointly funded by the Florida Department of Natural Resources (now part of the Florida Fish and Wildlife Conservation Commission [FFWCC]) and NMFS through the Marine Fisheries Initiative (MARFIN) program. This 2-year study assessed the relative importance of two southwest Florida estuaries, Tampa Bay and Charlotte Harbor, as shark nursery areas and examined potential fishing mortality of young sharks in the nurseries. Biological aspects of the early life history of these shark species, including distribution, feeding, and migration, also were investigated. A total of 1,892 sharks of 13 species was documented during the nearly 2 years of sampling in the study areas (Hueter and Manire 1994).

In 1995–1997, the Mote CSR conducted a second MARFIN project on shark nurseries, this time to assess Florida's gulf coastal areas specifically as nurseries for the blacktip shark *Carcharhinus limbatus*. The blacktip shark along with the sandbar shark *C. plumbeus* had become the two most important species in the U.S. East Coast shark fishery (NMFS 1993). The project also documented nursery areas of other shark species, quan-

* E-mail: rhueter@mote.org

tified relative abundance of juvenile blacktip and other sharks in these areas, determined bycatch mortality of these small sharks and associated fishes in gill-net fishing gear, and conducted basic biological studies of shark distribution, feeding, growth and reproduction in the Florida gulf. Monthly, random-stratified sampling by gill net was conducted in three Florida coastal areas (Yankeetown, lower Tampa Bay, and Charlotte Harbor). This project produced data on 3,227 sharks of 13 species, including 1,416 juvenile blacktip sharks (Hueter 1999).

Other NMFS-supported studies extended Mote CSR shark nursery research in the eastern Gulf of Mexico from 1993 to 2004, allowing consistent sampling of the juvenile sharks in those nurseries in the years between the two MARFIN projects (1993–1995) as well as the years subsequent to MARFIN funding (1997–2004). This research included exploratory surveys, standardized gill-net collections, abundance studies, and conventional tagging and acoustic tracking of juvenile sharks in nursery areas of the Florida gulf coast. Relative abundance studies of juvenile blacktip sharks in Yankeetown and Charlotte Harbor were resumed in 1999 and continued through 2004. In total, 1,031 gill net sets in 1993–1995 and 1997–2004 resulted in the capture of 8,264 sharks comprising 13 species, of which 5,010 sharks were tagged and released.

A number of other studies contributed to the 1991–2004 Mote CSR database on shark nursery areas in the eastern gulf. These studies include longline and drumline surveys along the southwest Florida coast and in the Florida Keys; collaborative field collections and shark tagging with FFWCC; field research on smalltooth sawfish *Pristis pectinata* ecology and behavior; research on juvenile blacktip shark movements and habitat using acoustic tracking; and studies of the endocrinology and reproduction of the bonnethead *Sphyrna tiburo*. These and related projects involved extensive field sampling of small sharks in eastern gulf coastal waters, resulting in the capture of 6,900 sharks of 16 species, with 5,402 sharks tagged and released.

From 1989 to 1999, Mote Marine Laboratory conducted the Gulf Coast Shark Census Tournament, a 100% catch-and-release shark sportfishing tournament operating along the southwest Florida coast in late June and early July each year. Over its 11 years of operation, the tournament involved more than 1,000 anglers catching, documenting, and releasing thousands of sharks, most of them small, inshore animals, many of which were juveniles in nursery areas. Because of the differing quality of data collected by anglers versus trained biologists, the tournament data have not been merged into the Mote CSR shark nursery database. However, in selected cases Mote CSR biologists accompanied tournament anglers to tag their catch, and this effort resulted in the tagging of 649 sharks of seven species. These data have been incorporated into the Mote CSR database.

In addition to these projects in the eastern gulf, the Mote CSR also has collected data on western Gulf of Mexico shark nursery areas along the Texas coast (in collaboration with recreational anglers and the Texas Parks and Wildlife Department [TPWD]) and in the southern gulf in Mexican coastal waters (in collaboration with Mexico's Instituto Nacional de la Pesca [INP]). The Texas research is an ongoing effort to study the exchange rate of western gulf sharks between the United States and Mexico. The work in Mexico with the INP is a long-term program established in 1994 to understand the status of Mexican shark resources and distribution of shark nursery areas in Mexico. Data from the Texas gulf coast studies have been incorporated into the Mote CSR shark nursery database reported here. The Mexican data are not reported here as they were not collected in U.S. waters, but a separate chapter on part of that work appears elsewhere in this volume (Hueter et al. 2007).

This paper presents an overview of results from these various Mote CSR studies of shark nursery areas along the eastern and western Gulf of Mexico coasts. The emphasis is on the spatial, temporal, and physico-chemical characteristics of these shark nurseries by geographic locality and species of shark. The information is compiled into profiles for the 16 species of juvenile sharks sampled by the Mote CSR and collaborators operating in peninsular Florida and Texas coastal waters of the Gulf of Mexico between 1991 and 2004.

Methods

Monofilament gill nets have been the most widely used gear type in Mote CSR shark nursery studies. From 1991 to 2004, a total of 2,907 gill-net sets were conducted in the study areas by the Mote CSR, out of 6,568 total sets of all gear types. Field collections utilized stretch mesh sizes of 7.6, 10.2, 11.4, 12.7, 14.0, and 15.2 cm. An 11.4-cm stretch mesh was the most often used (2,431 sets) due to its relatively high selectivity for small sharks and relatively low bycatch of other species. Standard technique used a net with a height of 3.05 m, a length of 366 m, and weighted to rest on the bottom. Typically, the net was anchored at both ends and allowed to soak for 1 h (from first mesh in to last mesh out) prior to retrieval, but other durations sometimes were used in exploratory surveys. After the net was deployed, location (by global positioning system), physico-chemical environmental characteristics (temperature, salinity, conductivity, dissolved oxygen by electronic meter), weather, bottom type, and other environmental data were collected. The net was checked at least once during the soak period and in some samplings was checked more often for the presence of sharks. In the case of standardized, quantitative sampling using a randomized, stratified design, 1-h sets of 11.4-cm stretch mesh gill nets always were used. Sharks collected in all gill-net deployments (and with most other techniques described below) were identified, sexed, measured (precaudal length [PCL], fork length [FL], total length [TL], and stretch total length [STL]) to the nearest centimeter, weighed to the nearest 0.1 kg, and either tagged and released or retained for study. In some cases, tissue samples (fin clips, blood, etc.) were taken from sharks prior to release for various studies. In addition to data on the shark catch, bycatch data (species identification, body measurements) were collected from all gill-net surveys.

In addition to gill-net sets, the Mote CSR database includes information on 1,268 longline sets conducted since 1991. Beginning in 2002, bottom longlines were used for abundance surveys targeting adult and large juvenile sharks in Florida gulf coastal waters primarily off Tampa Bay and Sarasota. This gear consisted of 50–150 hooks (9/0 J and 18/0 circle), 3-m gangions with a 1-m leader (stainless steel or monofilament), and a mainline of 1.6 km. The primary bait for these surveys was mullet *Mugil* spp. and little tunny *Euthynnus alletteratus*. A total of 34 longline sets of this type were conducted in 2002–2004. In addition, 145 longline sets were documented from 1995–1997 shark abundance surveys aboard the NMFS research vessel *Oregon II*, where Mote CSR tags were used to tag sharks of less than approximately 120 cm TL. These surveys conducted in the Gulf of Mexico offshore from Texas to Florida deployed 1.6 km of mainline with 100 3/0 shark hooks soaked for 1 h, using primarily Atlantic mackerel *Scomber scombrus* for bait. Longlines also were used as the primary gear type for inshore research on smalltooth sawfish. This project used a 366 m mainline, 14/0 and 16/0 circle hooks, a soak time of 1–2 h, and various types of bait, including mullet, pinfish *Lagodon rhomboides*, and crevalle jack *Caranx hippos*. Longline gear also was used during Mote CSR exploratory surveys of Tampa Bay and Charlotte Harbor (108 sets in 1992–1993). This work utilized 183–366 m of mainline with 50–60 hooks (5/0, 6/0, 7/0, 8/0 J-hooks) and a soak time of 1 h.

From 2001 to 2004, the Mote CSR deployed 2,327 drumlines during large shark surveys in gulf coastal waters, Charlotte Harbor, and the Florida Keys. This gear type consists of a cement block anchor attached to 20–40 m of line (depending on water depth) that runs to a surface float, and a 30-m heavy monofilament gangion secured to the bottom anchor by a swivel and terminating with a baited shark hook (16/0 or 18/0). Drumlines are ideal for selecting relatively large sharks, minimizing bycatch, and providing higher survivorship of caught sharks as they permit the hooked shark to swim in circles around the anchor. Although this gear type selects for larger animals, juvenile sharks occasionally are caught, and those are reported here.

Rod-and-reel was used in collection of sharks tagged in the Gulf Coast Shark Census Tournament from 1989 to 1999. Rod-and-reel also was the main gear used in a project investigating the behavioral ecology of juvenile blacktip sharks in Terra Ceia Bay, Florida (a small bay inside the Tampa Bay system). From 1999 to 2002, this project captured 158 sharks of three species using this gear type. Occasionally in other surveys, rod-and-reel was used concurrently with other gear types, such as gill nets or longlines, to augment the catch for tagging purposes.

Beach seines (61 m long × 1.82 m high × 1.3 cm mesh) were used on several occasions to collect small and large sharks in the surf zone and along sandbars near Sarasota, Florida. This gear was deployed from a shallow draft boat in a circular formation (in open water) or semicircular formation (with each end of the net on shore). The seine was then slowly drawn in to capture the sharks, either by hand or dip net. This technique minimizes the stress of capture and resulted in the collection of 30 sharks of two species.

In most cases, small sharks (less than approximately 1.5 m TL) caught and released alive in Mote CSR research were tagged with a nylonhead, plastic barb tag (Hallprint Pty Ltd, South Australia) inserted just below the first dorsal fin across the body midline, such that the tag head was firmly anchored in the cartilage and connective tissue below the fin. By the end of 2004, the total number of sharks tagged in U.S. waters using the Mote CSR Hallprint tags was 13,960 sharks. Other types of tags used in various Mote CSR elasmobranch studies have included Rototags, NMFS M-tags, Mote CSR M-tags, internal and external acoustic transmitters, electronic archival tags, and satellite pop-off (PAT) tags. Use of these tags accounted for another 1,041 tagged sharks in the Mote CSR database.

Results and Discussion

Shark nursery areas by geographic location

The following section provides summary descriptions of the main sampling areas where juvenile sharks were found (Figure 1). Reported physicochemical environmental characteristics (salinity, temperature, dissolved oxygen, depth) are based on mid-depth measurements taken during field collections and do not represent year-round ranges or conditions in all areas within the nursery. Maps of sampling effort by area (Figures 2–7) and species-specific environmental ranges for each life stage (Tables 1–5, 7) are presented. Neonates were defined as newborn sharks with an unhealed or open umbilical scar in the case of placental species (Castro 1993). In aplacental species (e.g., nurse shark *Ginglymostoma cirratum* and tiger shark *Galeocerdo cuvier*), young sharks at or near the published birth size (Natanson et al. 1999; Castro 2000) were classified as neonates, and sharks larger than the birth size but smaller than the published yearling size were classified

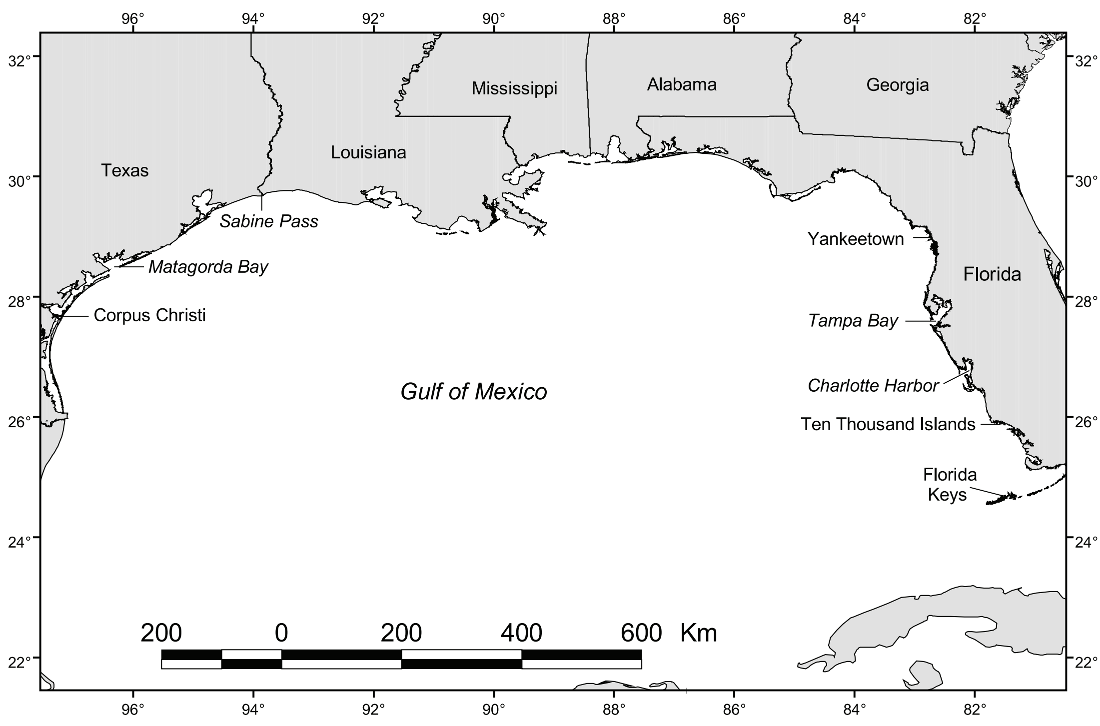

FIGURE 1. Shark nursery areas of the U.S. Gulf of Mexico coast (five main areas in Florida, three in Texas) studied by Mote Marine Laboratory's Center for Shark Research, 1991–2004.

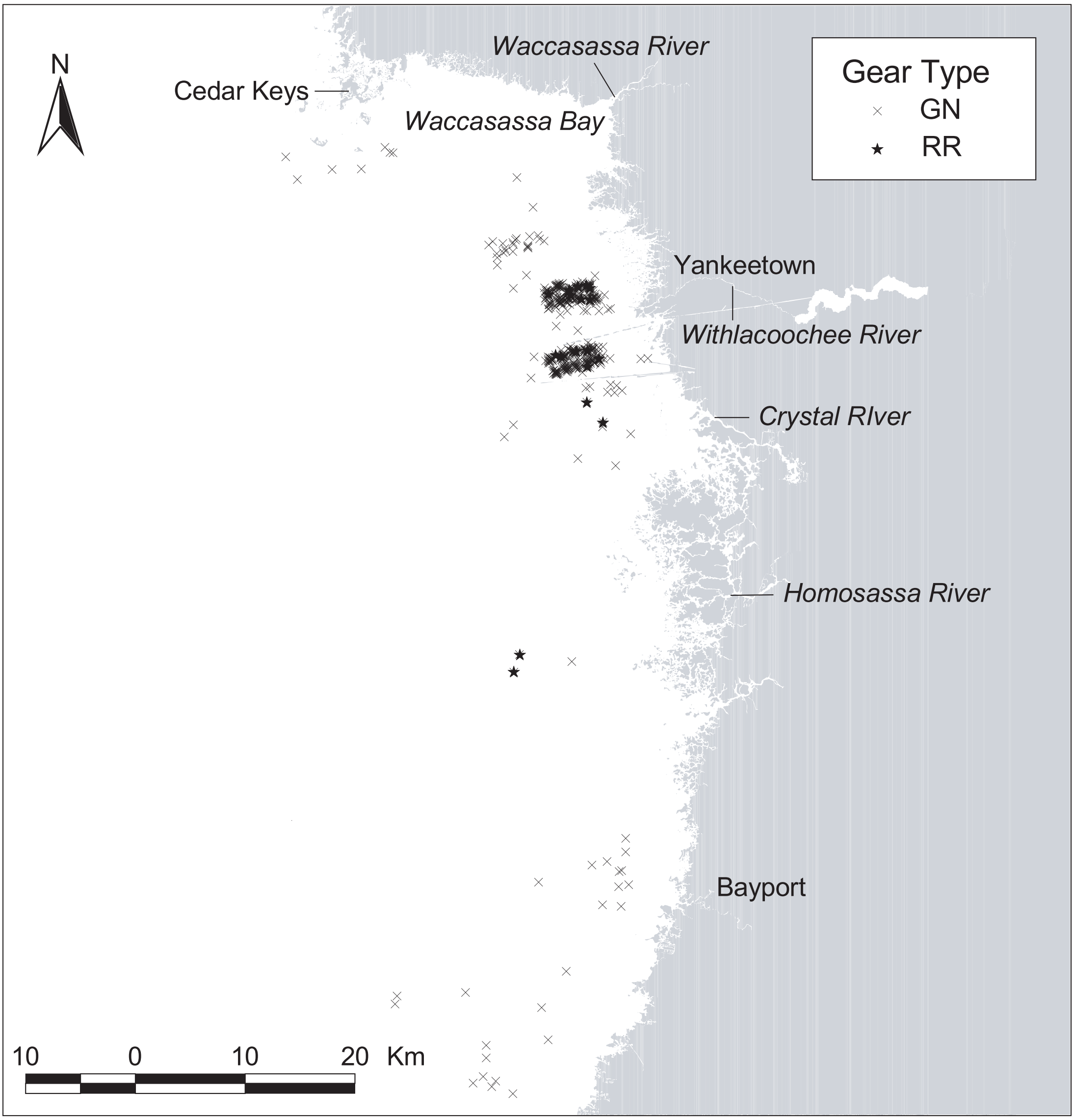

FIGURE 2. Shark nursery sampling near Yankeetown, Florida by gear type (gill net [GN], $N = 510$; rod-and-reel [RR], $N = 18$). Each symbol represents one set of the sampling gear.

as young of the year. The young of the year of placental sharks were defined as postneonatal, first-year juveniles with closed umbilical scars. Older juveniles of both placental and aplacental species were characterized as larger but immature post-young-of-the-year (YOY) sharks based on total length, lack of clasper development or calcification in males, and published size at maturity for females. Sample sizes (N) in Tables 1–5 refer to the number of specimens sampled for which physico-chemical environmental data were collected.

Yankeetown, Florida.—The coastal area near Yankeetown in the Big Bend region of Florida (Figure 2) is a relatively open and pristine stretch of northeastern Gulf of Mexico coastline that is marked by broad, shallow marine habitat, including sea grass beds, sand/mud bottom, and nearshore oyster reefs. The average depth of this nursery area is about 1.8–2.4 m with the outer,

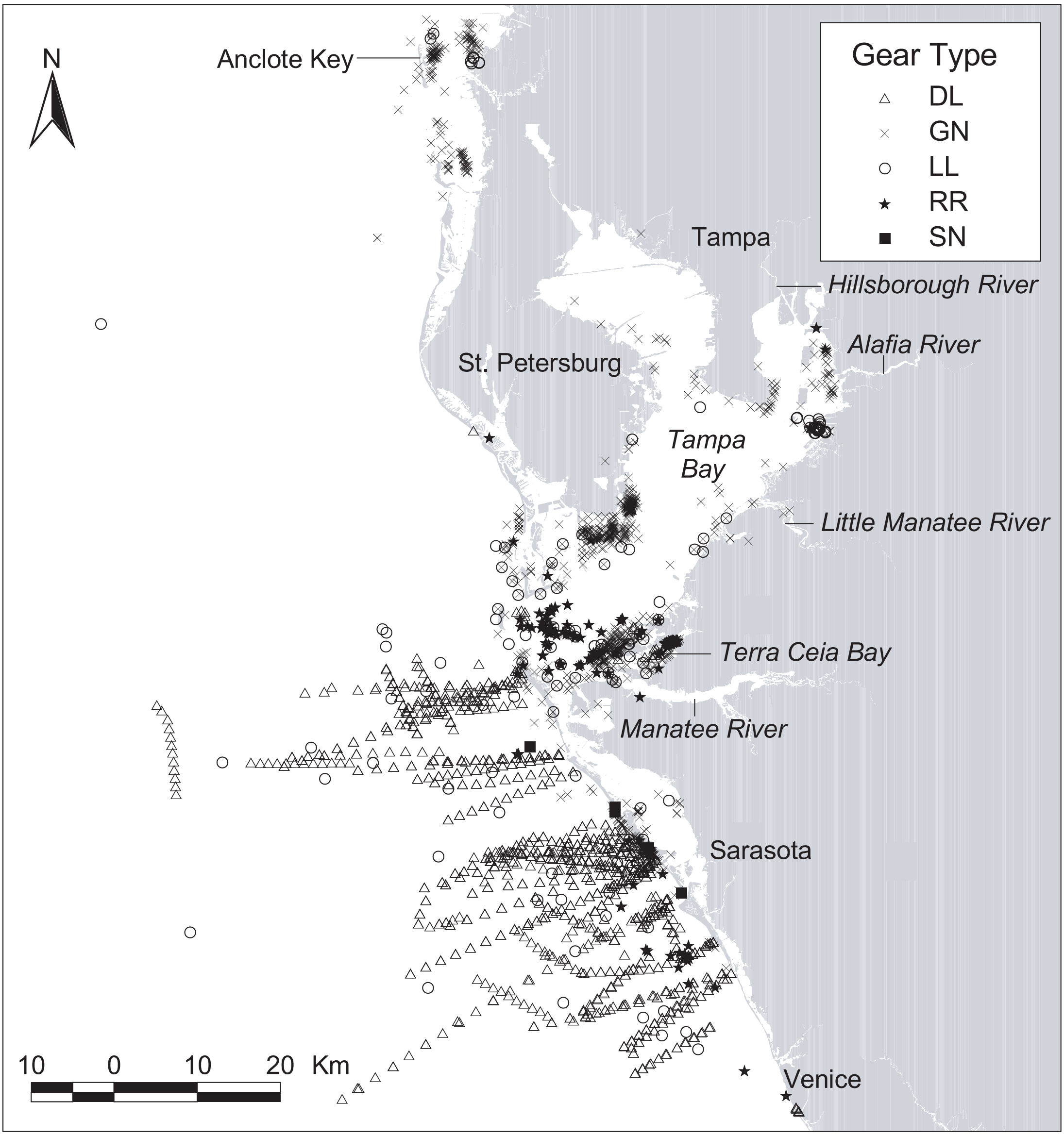

FIGURE 3. Shark nursery sampling in and around Tampa Bay, Florida by gear type (drumline [DL], N = 1,218; gill net [GN], N = 1,130; longline [LL], N = 136; rod-and-reel [RR], N = 180; seine net [SN], N = 6). Each symbol represents one set of the sampling gear.

less productive areas being about 4–5 m in depth. There is significant freshwater outflow into this region via the Waccasassa, Withlacoochee, Crystal, and Homosassa rivers. Mote CSR measurements have documented the salinity and temperature range in this area to be 15.8–34.9 parts per thousand (ppt) and 17.0–32.4°C, respectively. The adjacent land areas are sparsely populated and not industrialized, with the striking exception of a nuclear power plant south of the entrance to the Withlacoochee River. This plant produces a warmwater effluent, which enters the gulf on the inland side of the nursery area and is quickly dissipated, not affecting the nursery at large to any known significant extent. The Yankeetown nursery area extends north to Cedar Key (29.10°N, 83.05°W), including Waccasassa Bay, and as far south as Bayport (28.36°N,

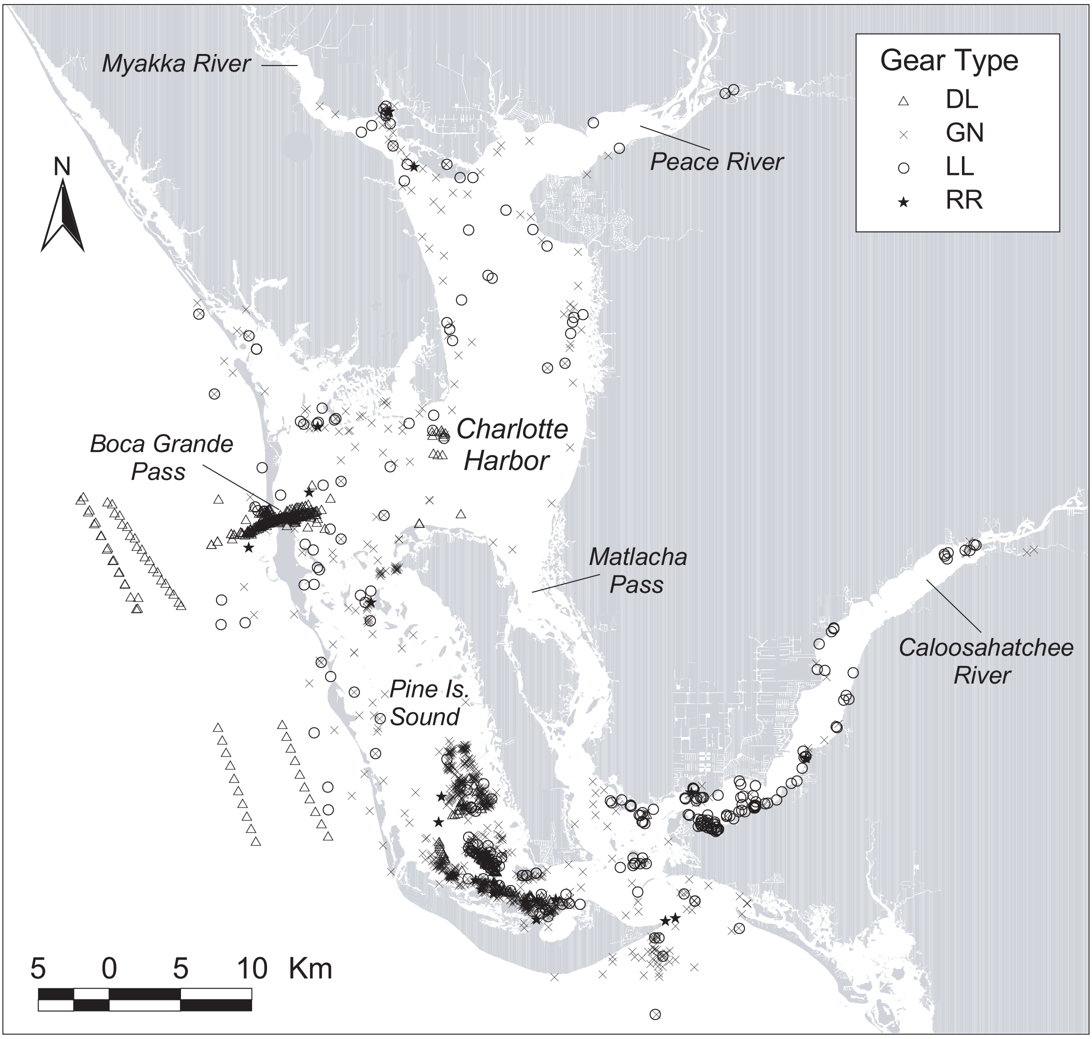

FIGURE 4. Shark nursery sampling in and around Charlotte Harbor, Florida by gear type (drumline [DL], N = 630; gill net [GN], N = 1,028; longline [LL], N = 262; rod-and-reel [RR], N = 30). Each symbol represents one set of the sampling gear.

82.78°W). This area is utilized as a nursery by at least 11 species of sharks (Table 1).

Tampa Bay, Florida.—Tampa Bay is a large, semi-enclosed estuarine system with a surface area of 896 km^2 and an average depth overall of 4.9 m (Figure 3). Depth beyond the coastal shoals averages about 3 m, increasing to 6–9 m in the middle of the bay. Entrances from the gulf into Tampa Bay range in depth down to 25 m. The system is characterized by the presence of sea grass, mangrove, and salt marsh habitats (Hueter and Manire 1994). Freshwater inflow is limited in the north primarily to a few small rivers on the eastern side, including the Hillsborough, Alafia, and Little Manatee rivers. On the extreme southern end, the Manatee River contributes significant amounts of freshwater into the bay. The Mote CSR has documented the salinity and temperature ranges in Tampa Bay nurseries to be 10.8–38.5 ppt and 14.0–33.0°C, respectively. With the adjacent cities of Tampa and St. Petersburg, Tampa Bay is exposed to significant industrial and other human impacts. In recent years, efforts to clean up the bay have improved water quality and subsequently have increased the distribution of sea grasses in the bay (Johansson and Greening 2000).

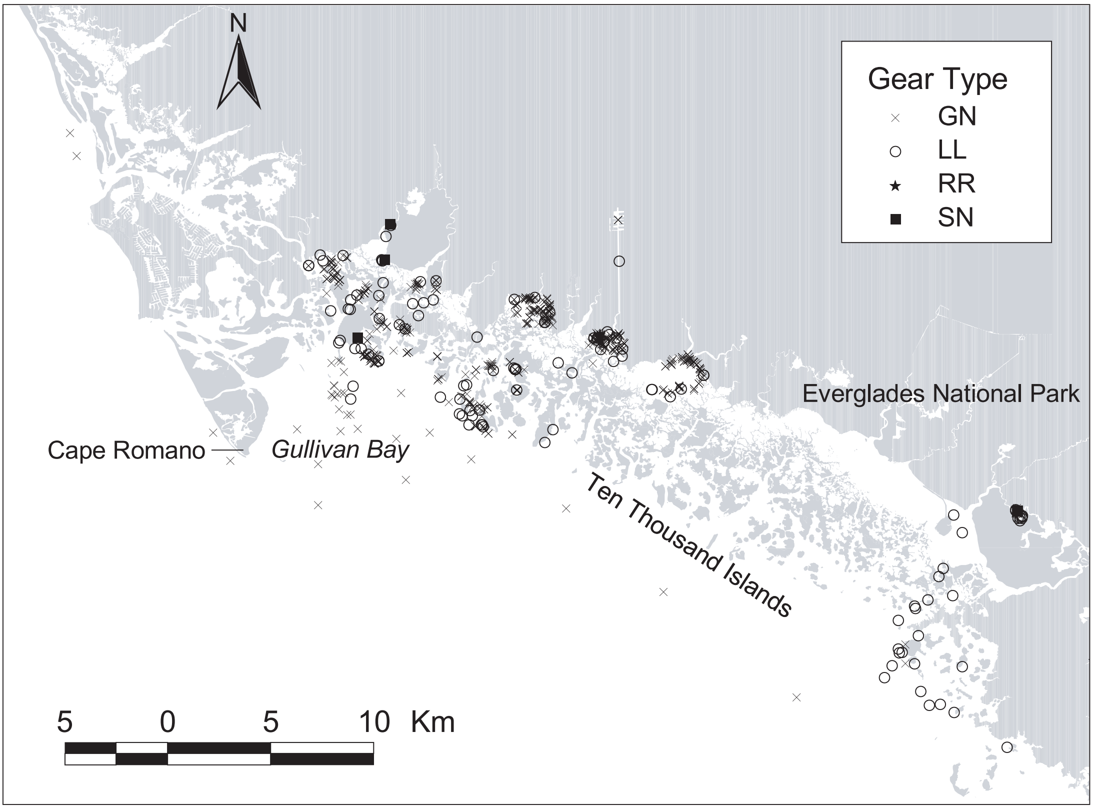

FIGURE 5. Shark nursery sampling in the Ten Thousand Islands area of Florida by gear type (gill net [GN], N = 390; longline [LL], N = 103; rod-and-reel [RR], N = 7; seine net [SN], N = 8). Each symbol represents one set of the sampling gear.

The Tampa Bay area is utilized as a nursery by at least 13 species of sharks. Species-specific habitat descriptions (Table 2) include data from outside the bay proper to as far north as Anclote Key (28.24°N, 82.80°W) and as far south as Venice (27.10°N, 82.47°W).

Charlotte Harbor, Florida.—Charlotte Harbor is a complex, semi-enclosed estuarine system with a surface area of 805 km^2 (Figure 4). The average depth overall in the entire estuary is 2.5 m while the depth averages about 3 m beyond the shoal areas and increases to about 4.5–6 m in the middle of the bay (Hueter and Manire 1994). Entrances from the gulf into the Charlotte Harbor system range in depth down to 22 m. Pine Island Sound and Matlacha Pass make up the southwestern and southeastern components of Charlotte Harbor, respectively. The overall system receives significant freshwater inflow from the Myakka and Peace rivers to the north and the Caloosahatchee River to the south and is characterized by the presence of sea grass, mangrove, and salt marsh habitats (Hueter and Manire 1994). The Mote CSR has documented the salinity and temperature ranges in this area to be 0.1–39.6 ppt and 13.8–34.3°C, respectively. The region adjacent to the harbor is moderately populated and industrialized, but many areas within the harbor are still relatively pristine and undeveloped. At least 13 species of sharks utilize Charlotte Harbor as a nursery area (Table 3).

Ten Thousand Islands, Florida.—The Ten Thousand Islands area of Florida's southwest gulf coast is located along approximately 40 km of numerous mangrove islands bordering inland, tannin-colored fresh and brackish bays to the northeast, and lush sea grass beds and sand communities in the coastal marine zone to the southwest (Figure 5). Features include Gullivan Bay on the western side and the Everglades National Park bordering the eastern side of the sampled region. In this area, the Mote CSR has conducted

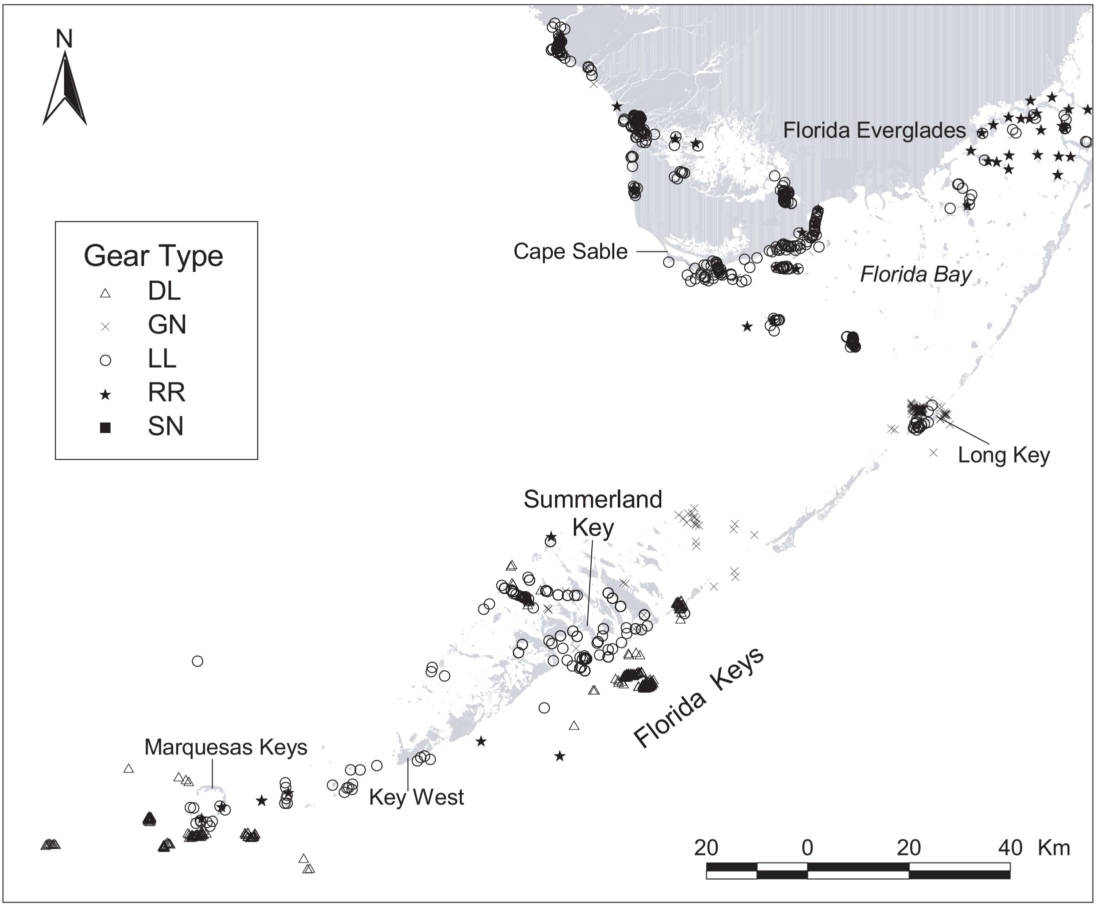

FIGURE 6. Shark nursery sampling in the Florida Keys and southern Florida Everglades by gear type (drumline [DL], $N = 412$; gill net [GN], $N = 180$; longline [LL], $N = 516$; rod-and-reel [RR], $N = 67$; seine net [SN], $N = 3$). Each symbol represents one set of the sampling gear.

several field projects and has worked in collaboration with researchers from the University of Basel and the Florida Department of Environmental Protection, whose separate results are reported elsewhere in this volume (Steiner et al. 2007). Salinity and temperature ranges documented by the Mote CSR in this area have been 0.2–41.6 ppt and 17.1–35.2°C, respectively. This relatively pristine area is very sparsely populated and not industrialized. At least eight species of sharks utilize the Ten Thousand Islands as a nursery area (Table 4).

Florida Keys.—The Florida Keys comprises a 200-km island chain on the southern tip of the Florida peninsula (Figure 6). This tropical ecosystem includes mangroves and sea grasses that grow on both the ocean (south/east) side and bay (north/west) side of the islands. Offshore coral reefs abound primarily on the ocean side. The bay side is relatively shallow and influenced significantly by water flow from the Florida Everglades. Human population in the Keys is limited by the lack of land area and there is minimal industrial development, but water quality and the ecosystem's general health have degraded significantly in recent decades. The Mote CSR's sampling efforts in this area have been mostly confined to the middle Keys and some surveys west of Key West, including the Marquesas Keys, but have not directly targeted nursery areas. Salinity and temperature ranges in this area have been documented to be 18.1–38.0 ppt and 15.0–33.2°C, respectively. Some data from smalltooth sawfish surveys conducted in the Everglades ad-

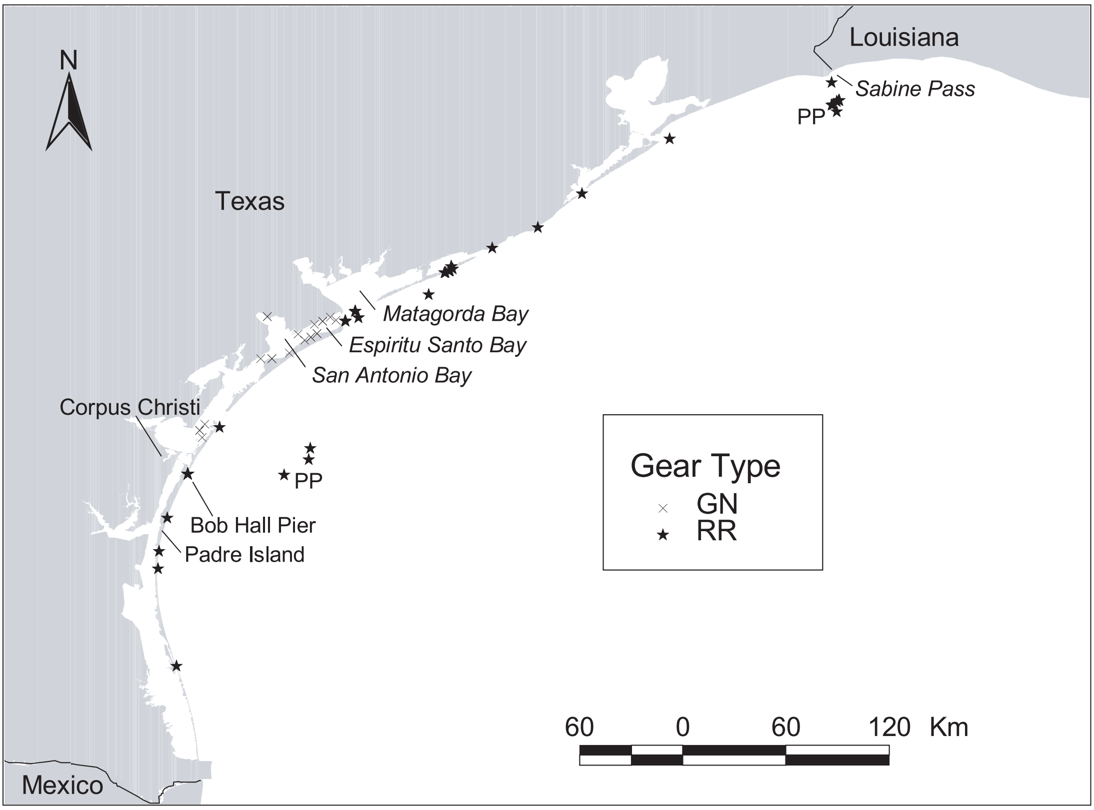

FIGURE 7. Shark nursery sampling along the Texas coast by gear type (gill net [GN], N = 43; rod-and-reel [RR], N = 15). Each symbol represents one set of the sampling gear. Only sets that captured at least one immature shark are shown; locations of zero-catch sets along the Texas coast are not available. PP = near petroleum platform.

jacent to the north side of the Keys have been included in the Florida Keys shark nursery habitat summary. In this area, salinity ranges 1.2–41.1 ppt and temperature ranges 14.7–35.2°C. At least nine species of sharks utilize the Florida Keys and southern Everglades as a nursery (Table 5).

Sabine Pass, Texas and nearshore petroleum platforms.—On the Texas coast in the northwestern Gulf of Mexico, Mote CSR shark-tagging efforts in collaboration with recreational fishermen focused on the Sabine Pass area, which lies on the Texas/Louisiana border and is the natural opening between Sabine Lake and the gulf (Figure 7). The salinity is highly variable in this area due to fluctuating flow rates from the Sabine River. Gulf waters surrounding nearshore gas/oil platforms (2–3 mi from shore) have salinities as low as 17 ppt. These platforms provide habitat that supports significant numbers of young sharks of several species. Immature stages of at least four species of sharks are found in this area (Table 6).

Matagorda Bay, Texas.—A collaboration with TPWD field staff permitted the tagging of juvenile sharks during TPWD spring/fall game fish surveys in the Matagorda Bay area (Figure 7). These surveys were undertaken primarily in the estuarine areas of Matagorda, Espiritu Santo, and San Antonio bays. These bays are protected by the Matagorda Peninsula and are fed primarily by the Colorado and Guadalupe rivers. Collaborations with recreational anglers also contributed data from the area around Matagorda Bay. Immature stages of at least seven species of sharks are found in this area (Table 6).

Corpus Christi, Texas.—Mote CSR collaborations with recreational fishermen were used in this area of the Texas coast (Figure 7) to tag young sharks, particularly blacktip sharks. Bob Hall Pier (BHP) was the main site of fishing activity at this

TABLE 1. Yankeetown nursery habitat summary by shark species and immature life stages (Neo = neonate, YOY = young of the year, OJ = older juvenile). *N* = stage-specific sample sizes with environmental data, TL = total length range of sampled sharks, Sal = salinity range, Temp = water temperature range, DO = dissolved oxygen range.

			TL (cm)		Sal (ppt)		Temp (ºC)		DO (mg/L)		Depth (m)	
Species	Stage	*N*	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Blacknose shark	Neo	1	48	48	32.2	32.2	30.1	30.1	–	–	–	–
Carcharhinus	YOY	4	46	50	28.3	33.0	30.1	31.5	6.9	6.9	2.4	3.4
acronotus	OJ	30	65	98	26.2	34.5	20.1	30.2	6.2	6.2	1.5	3.4
Spinner shark	Neo	0	–	–	–	–	–	–	–	–	–	–
C. brevipinna	YOY	2	61	72	21.0	26.0	29.0	30.1	–	–	1.8	4.0
	OJ	0	–	–	–	–	–	–	–	–	–	–
Finetooth shark	Neo	0	–	–	–	–	–	–	–	–	–	–
C. isodon	YOY	1	63	63	15.8	15.8	23.2	23.2	–	–	2.7	2.7
	OJ	0	–	–	–	–	–	–	–	–	–	–
Bull shark	Neo	1	77	77	27.4	27.4	28.2	28.2	–	–	2.1	2.1
C. leucas	YOY	3	79	88	22.0	22.0	23.3	23.3	–	–	1.8	1.8
	OJ	2	90	101	21.0	22.0	23.3	29.0	–	–	1.8	2.1
Blacktip shark	Neo	951	48	74	18.7	33.0	25.2	32.0	4.6	8.6	1.2	4.9
C. limbatus	YOY	1,689	51	83	15.8	34.5	19.9	32.0	4.8	8.6	1.5	5.5
	OJ	221	73	129	20.0	34.5	23.0	32.0	3.5	8.6	1.5	4.6
Sandbar shark	Neo	3	48	63	20.4	25.9	25.0	29.0	–	–	2.4	3.7
C. plumbeus	YOY	0	–	–	–	–	–	–	–	–	–	–
	OJ	0	–	–	–	–	–	–	–	–	–	–
Florida	Neo	0	–	–	–	–	–	–	–	–	–	–
smoothhound	YOY	0	–	–	–	–	–	–	–	–	–	–
Mustelus norrisi	OJ	1	70	70	30.9	30.9	21.0	21.0	–	–	2.7	2.7
Atlantic sharpnose	Neo	3	32	33	22.8	27.2	24.0	29.8	5.2	5.2	3.4	3.4
shark	YOY	9	32	50	17.0	33.9	23.2	29.6	4.8	6.9	2.4	3.4
Rhizoprionodon terraenovae	OJ	81	59	90	21.4	33.9	20.1	31.9	5.1	8.2	1.5	4.3
Scalloped	Neo	1	46	46	23.2	23.2	28.0	28.0	5.4	5.4	3.4	3.4
hammerhead	YOY	3	71	76	27.6	30.1	23.2	26.0	5.9	5.9	2.4	3.4
Sphyrna lewini	OJ	0	–	–	–	–	–	–	–	–	–	–
Great hammerhead	Neo	0	–	–	–	–	–	–	–	–	–	–
S. mokarran	YOY	18	64	89	20.8	33.9	23.9	31.5	5.3	7.6	1.8	5.5
	OJ	33	94	186	15.8	32.7	23.0	31.5	5.4	7.2	1.8	5.2
Bonnethead	Neo	0	–	–	–	–	–	–	–	–	–	–
S. tiburo	YOY	10	46	54	20.9	30.6	27.6	30.0	5.4	6.0	2.4	3.7
	OJ	510	49	88	19.3	34.3	21.0	32.4	4.3	8.6	1.5	4.9

location. The BHP is located on the Gulf of Mexico (eastern) side of Padre Island and extends 366 m into the gulf, where water depth below the pier averages 4.5 m. The bottom is mostly sand with some shell. Limited shark tagging also was conducted in the vicinity of offshore oil/gas platforms in this area. Immature stages of at least ten species of sharks are found in this area (Table 6).

Nursery areas by shark species

The following section provides general profiles of the 16 shark species (arranged alphabetically by genus, species) for which juveniles have been documented by the Mote CSR in U.S. Gulf of Mexico waters. Sample sizes (*N*) refer to the total number of specimens sampled from all Mote CSR studies combined. Detailed habitat characteristics for the juveniles of each species have been separated into the three developmental stages of neonate, YOY, and older juvenile sharks (Table 7). Reference to primary versus secondary nurseries follows the delineation by Bass (1978) and Simpfendorfer and Milward (1993). This separates the primary nurseries, where pupping occurs and where the neonates and young of the year live for a brief time, from the secondary nurseries, where the juveniles occur after leaving the primary nurseries and until they reach sexual maturity.

Carcharhinus acronotus.—The blacknose shark is a relatively common component of Mote CSR field sampling and occurs in the areas of Yankeetown, Tampa Bay, Charlotte Harbor, and the Florida Keys (Figure 8). Neonate blacknose sharks (*N* = 17, TL = 42–50 cm) are found along gulf beaches in the Tampa Bay area throughout the month of June. Young-of-the-year blacknose sharks (*N* = 118, TL = 36–62 cm) remain present through the warm months along gulf beaches and

TABLE 2. Tampa Bay nursery habitat summary by shark species and immature life stages (Neo = neonate, YOY = young of the year, OJ = older juvenile). *N* = stage-specific sample sizes with environmental data, TL = total length range of sampled sharks, Sal = salinity range, Temp = water temperature range, DO = dissolved oxygen range.

			TL (cm)		Sal (ppt)		Temp (°C)		DO (mg/L)		Depth (m)	
Species	Stage	*N*	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Blacknose shark	Neo	16	42	50	34.0	37.0	28.7	29.0	6.5	7.1	1.5	1.8
	YOY	100	36	62	28.2	34.7	27.0	30.0	3.3	6.5	0.6	7.0
	OJ	436	60	104	28.0	37.0	17.3	32.0	4.8	8.7	0.9	7.6
Spinner shark	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	15	48	71	27.4	34.0	28.7	31.7	5.1	7.1	0.9	4.0
	OJ	20	69	164	27.3	36.2	18.2	30.1	5.6	7.8	2.4	9.8
Bull shark	Neo	19	67	84	25.5	28.5	29.5	32.2	–	–	1.2	1.5
	YOY	56	68	94	16.1	34.0	16.1	31.0	5.0	8.2	0.9	4.6
	OJ	59	90	222	16.1	36.7	16.5	30.9	5.0	8.4	0.9	11.6
Blacktip shark	Neo	279	51	69	27.1	38.1	22.7	32.2	3.2	7.6	0.9	9.1
	YOY	390	49	88	20.2	37.0	16.2	32.2	3.7	8.6	0.9	9.1
	OJ	287	72	149	23.5	37.6	16.5	33.0	4.2	9.6	0.9	10.1
Sandbar shark	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	0	–	–	–	–	–	–	–	–	–	–
	OJ	4	120	180	32.2	34.4	17.2	23.6	7.2	7.6	8.8	11.3
Tiger shark	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	0	–	–	–	–	–	–	–	–	–	–
	OJ	4	178	235	30.5	36.5	26.7	30.2	6.6	7.0	12.2	14.2
Nurse shark	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	0	–	–	–	–	–	–	–	–	–	–
	OJ	6	121	170	32.7	33.2	17.5	23.1	7.6	9.7	1.8	10.1
Florida	Neo	0	–	–	–	–	–	–	–	–	–	–
smoothhound	YOY	0	–	–	–	–	–	–	–	–	–	–
	OJ	1	61	61	33.5	33.5	19.3	19.3	–	–	9.1	9.1
Lemon shark	Neo	5	60	66	26.8	32.6	22.0	25.4	5.9	9.6	0.6	1.5
Negaprion	YOY	8	65	86	30.0	38.5	19.1	33.0	6.5	7.3	1.0	1.2
brevirostris	OJ	10	108	234	33.9	37.6	20.4	30.6	5.5	6.7	1.2	13.7
Atlantic sharpnose	Neo	1	38	38	33.7	33.7	30.7	30.7	5.7	5.7	1.8	1.8
shark	YOY	132	35	63	26.3	36.6	18.4	30.3	4.8	8.6	0.9	4.0
	OJ	171	60	89	25.8	36.5	16.5	32.0	4.3	8.7	0.9	7.6
Scalloped	Neo	1	49	49	30.0	30.0	28.0	28.0	–	–	2.4	2.4
hammerhead	YOY	4	48	53	28.1	29.9	29.0	29.7	4.9	7.4	1.2	4.0
	OJ	1	102	102	30.7	30.7	27.2	27.2	–	–	4.3	4.3
Great hammerhead	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	3	70	79	32.2	34.2	30.0	30.1	6.3	6.3	1.8	4.0
	OJ	21	93	279	24.4	37.6	20.4	31.2	5.4	7.4	2.4	10.7
Bonnethead	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	56	30	55	22.3	35.3	16.1	31.0	5.0	9.4	0.6	6.1
	OJ	1,325	60	90	20.0	37.8	16.1	32.3	3.3	10.5	0.6	4.3

also in the estuarine areas of Tampa Bay and Charlotte Harbor. They migrate out of the area by late October. These neonate and YOY sharks are found in temperatures of 27–34°C and in salinities as low as 26.5 ppt. Older juveniles of this species (*N* = 469, TL = 60–104 cm) are present along the gulf beaches of Tampa Bay and Charlotte Harbor beginning in early March and remain present throughout the summer months. These older year-classes were a significant component of the shark catches in the annual Mote CSR-sponsored Shark Census Tournament in which fishing activity was concentrated in the Tampa Bay region, but older juveniles also are common in the areas of Yankeetown, Charlotte Harbor, and the Florida Keys. Juvenile blacknose sharks are rarely seen after October in the inshore gulf waters but are present in the Keys during the winter months. Tag-recapture data for this species suggest strong philopatric behavior and an annual homing cycle (i.e., seasonal returns to specific home areas on an annual basis; Hueter 1998; Hueter et al. 2005).

Carcharhinus brevipinna.—The spinner shark has not been a common component of Mote CSR field sampling along Florida's gulf coast but has been documented in collaborative studies in Texas. The primary pupping grounds for this spe-

TABLE 3. Charlotte Harbor nursery habitat summary by shark species and immature life stages (Neo = neonate, YOY = young of the year, OJ = older juvenile). *N* = stage-specific sample sizes with environmental data, TL = total length range of sampled sharks, Sal = salinity range, Temp = water temperature range, DO = dissolved oxygen range.

			TL (cm)		Sal (ppt)		Temp (ºC)		DO (mg/L)		Depth (m)	
Species	Stage	*N*	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Blacknose shark	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	14	44	58	26.5	26.5	34.0	34.0	6.2	6.2	1.2	1.8
	OJ	8	60	93	25.0	35.2	25.0	32.0	6.2	6.2	–	–
Spinner shark	Neo	3	66	71	–	–	–	–	–	–	5.2	5.2
	YOY	1	71	71	28.5	28.5	24.8	24.8	–	–	0.9	1.5
	OJ	0	–	–	–	–	–	–	–	–	–	–
Finetooth shark	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	0	–	–	–	–	–	–	–	–	–	–
	OJ	1	93	93	11.5	11.5	33.8	33.8	8.5	8.5	5.5	6.1
Bull shark	Neo	54	63	87	0.9	38.5	28.1	32.3	2.6	13.1	0.3	3.0
	YOY	73	55	95	0.9	33.3	16.4	34.0	2.6	8.4	0.3	3.7
	OJ	110	89	200	6.5	37.4	18.7	32.1	3.7	10.9	0.6	10.1
Blacktip shark	Neo	606	42	71	15.3	38.5	24.8	32.1	3.3	9.0	0.6	4.6
	YOY	846	50	87	18.9	39.6	19.6	33.2	3.3	10.8	0.9	4.0
	OJ	248	75	140	20.6	38.7	21.0	33.6	2.7	9.4	0.6	2.7
Tiger shark	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	0	–	–	–	–	–	–	–	–	–	–
	OJ	2	221	248	–	–	–	–	–	–	5.2	8.8
Nurse shark	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	0	–	–	–	–	–	–	–	–	–	–
	OJ	25	51	186	28.5	37.8	24.8	30.0	4.7	7.2	0.9	7.9
Florida smoothhound	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	0	–	–	–	–	–	–	–	–	–	–
	OJ	1	66	66	31.3	31.3	23.6	23.6	–	–	1.5	1.5
Lemon shark	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	0	–	–	–	–	–	–	–	–	–	–
	OJ	18	120	226	24.4	36.4	21.4	32.1	5.1	7.5	1.8	11.0
Atlantic sharpnose shark	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	7	40	53	28.6	34.8	29.0	31.1	4.9	6.2	0.9	4.9
	OJ	34	51	84	24.9	37.9	25.2	33.3	4.5	8.6	0.9	3.7
Scalloped hammerhead	Neo	2	49	53	32.6	38.5	27.0	28.6	5.3	5.3	1.8	3.0
	YOY	25	45	70	20.6	34.3	26.6	32.3	2.7	6.1	0.9	2.7
	OJ	0	–	–	–	–	–	–	–	–	–	–
Great hammerhead	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	5	74	84	34.5	34.9	30.0	30.0	–	–	2.7	4.0
	OJ	28	92	239	27.5	35.9	25.0	32.9	4.2	7.2	1.5	12.2
Bonnethead	Neo	2	29	36	15.4	27.0	27.8	30.9	6.7	6.7	1.4	2.1
	YOY	50	35	65	19.7	37.5	15.9	33.3	2.9	9.2	0.6	3.7
	OJ	1,176	60	86	15.3	39.6	19.6	33.3	2.9	8.6	0.3	4.3

cies in Florida are not clearly defined. Neonate spinners sharks (*N* = 3, TL = 66–71 cm) have been documented in mid-June in Charlotte Harbor, and young of the year (*N* = 37, TL = 48–73 cm) occasionally are seen during the summer months in the Tampa Bay and Yankeetown areas (Figure 9). Additionally, YOY spinner sharks are fairly common along the beaches and in the bays of Texas during the summer months and have been observed as late as mid-October. Juvenile spinner sharks (*N* = 56, TL = 69–164 cm) are found associated with nearshore oil platforms on the upper Texas coast, as well as in the coastal waters of Mississippi and Louisiana, during the warm months. In Florida, juvenile spinner sharks occasionally are seen along the beaches of Tampa Bay, entering estuarine areas with salinities as low as 17 ppt. Larger juveniles have been captured during shark surveys in the gulf coastal waters off Sarasota and Tampa Bay, particularly in December (Figure 10).

Carcharhinus falciformis.—The primary nursery areas for the silky shark *Carcharhinus falciformis* are presumably in deeper offshore waters, as no neonates or young of the year have been collected during Mote CSR directed field sampling or collaborative efforts. Older juvenile silky sharks (*N* = 4, TL = 91–109 cm) are present in gulf

TABLE 4. Ten Thousand Islands nursery habitat summary by shark species and immature life stages (Neo = neonate, YOY = young of the year, OJ = older juvenile). *N* = stage-specific sample sizes with environmental data, TL = total length range of sampled sharks, Sal = salinity range, Temp = water temperature range, DO = dissolved oxygen range.

			TL (cm)		Sal (ppt)		Temp (ºC)		DO (mg/L)		Depth (m)	
Species	Stage	*N*	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Blacknose shark	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	0	–	–	–	–	–	–	–	–	–	–
	OJ	1	92	92	33.6	33.6	27.7	27.7	5.7	5.7	3.0	3.0
Bull shark	Neo	51	66	85	4.6	31.9	27.8	31.9	2.8	7.1	0.3	1.2
	YOY	115	70	97	0.5	40.7	17.1	33.6	2.3	8.3	0.6	1.6
	OJ	157	92	190	1.7	41.1	18.2	35.2	2.6	8.6	0.6	2.0
Blacktip shark	Neo	18	52	67	18.9	41.1	26.1	33.6	3.7	8.6	0.9	3.0
	YOY	42	54	90	18.7	41.6	20.4	33.8	4.2	10.3	0.6	2.6
	OJ	6	77	150	26.2	37.7	20.7	27.2	5.2	5.7	1.2	2.2
Nurse shark	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	0	–	–	–	–	–	–	–	–	–	–
	OJ	8	110	120	21.8	28.5	29.6	30.7	1.7	5.8	0.9	5.5
Lemon shark	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	11	70	94	15.1	35.5	23.6	33.8	4.2	6.0	0.9	1.8
	OJ	33	87	207	15.1	39.1	20.7	33.8	1.7	6.8	0.9	1.6
Atlantic sharpnose	Neo	0	–	–	–	–	–	–	–	–	–	–
shark	YOY	1	50	50	25.3	25.3	30.0	30.0	–	–	1.5	1.5
	OJ	1	60	60	33.0	33.0	26.2	26.2	–	–	2.1	2.1
Great hammerhead	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	0	–	–	–	–	–	–	–	–	–	–
	OJ	5	92	144	24.9	28.1	25.1	31.0	5.4	7.8	0.9	3.0
Bonnethead	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	13	44	54	23.3	36.1	26.0	31.0	5.3	5.5	0.9	3.4
	OJ	52	52	78	16.6	40.9	20.6	33.6	4.1	7.3	0.6	2.1

TABLE 5. Florida Keys and southern Florida Everglades nursery habitat summary by shark species and immature life stages (Neo = neonate, YOY = young of the year, OJ = older juvenile). *N* = stage-specific sample sizes with environmental data, TL = total length range of sampled sharks, Sal = salinity range, Temp = water temperature range, DO = dissolved oxygen range.

			TL (cm)		Sal (ppt)		Temp (ºC)		DO (mg/L)		Depth (m)	
Species	Stage	*N*	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Blacknose shark	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	0	–	–	–	–	–	–	–	–	–	–
	OJ	4	62	93	33.6	35.6	27.7	32.5	5.4	6.8	1.5	2.4
Bull shark	Neo	6	74	85	4.6	8.0	27.8	31.5	2.8	6.5	0.3	1.2
	YOY	31	73	96	1.2	32.9	18.6	33.9	2.3	6.1	0.4	2.5
	OJ	244	92	201	4.6	34.8	17.1	35.2	2.9	9.7	0.6	4.3
Blacktip shark	Neo	9	58	62	29.1	35.0	29.7	31.6	3.7	7.4	1.2	2.1
	YOY	88	58	90	19.5	39.1	20.9	32.9	4.2	10.3	1.5	3.7
	OJ	65	73	136	30.0	37.7	20.4	32.5	3.7	7.6	1.2	3.0
Tiger shark	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	0	–	–	–	–	–	–	–	–	–	–
	OJ	6	180	271	30.9	35.8	17.3	27.9	4.3	7.3	4.6	7.0
Nurse shark	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	0	–	–	–	–	–	–	–	–	–	2.1
	OJ	205	49	212	25.7	38.9	17.3	32.9	2.9	11.5	0.3	12.2
Lemon shark	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	13	64	93	18.1	38.2	22.0	29.4	5.1	11.2	0.5	1.2
	OJ	209	85	230	19.2	39.9	18.7	31.8	3.9	10.8	0.6	4.6
Atlantic sharpnose	Neo	0	–	–	–	–	–	–	–	–	–	–
shark	YOY	0	–	–	–	–	–	–	–	–	–	–
	OJ	9	56	72	35.4	36.7	22.1	32.3	5.3	7.3	1.8	2.0
Great hammerhead	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	0	–	–	–	–	–	–	–	–	–	–
	OJ	24	124	277	26.3	35.3	22.0	30.9	3.4	6.6	6.1	12.2
Bonnethead	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	2	50	51	35.0	35.2	31.1	31.7	–	–	1.8	2.1
	OJ	258	52	88	26.8	38.0	17.0	32.5	3.7	10.0	0.6	8.5

TABLE 6. The number of neonate (Neo), young of the year (YOY) and older juvenile (OJ) sharks captured during Mote CSR tagging efforts in three areas of Texas (* Sharks captured offshore near petroleum platforms).

	Sabine Pass			Matagorda Bay			Corpus Christi			
Species	Neo	YOY	OJ	Neo	YOY	OJ	Neo	YOY	OJ	Totals
Blacknose shark	–	–	–	–	–	–	–	–	2	2
Spinner shark	–	2	27	–	5	1	–	9	–	44
Silky shark	–	–	–	–	–	–	–	–	2*	2
Finetooth shark	–	–	–	–	–	7	–	1	62	70
Bull shark	1	–	1	–	14	9	–	–	8	33
Blacktip shark	1	6	31	7	9	3	44	173	69	343
Sandbar shark	–	–	3	–	–	2	–	–	5	10
Atlantic sharknose shark	–	–	–	1	1	2	–	–	7	11
Scalloped hammerhead	–	–	–	–	–	–	14	12	1*	27
Bonnethead	–	–	–	–	–	2	–	–	1	3
Totals	2	8	62	8	29	26	58	195	157	545

offshore waters off Florida in August (Figure 10) and in the offshore waters off the lower Texas coast during April and May.

Carcharhinus isodon.—The finetooth shark is uncommon in the central to southern Florida Gulf but is more common in the northern gulf, including along the Florida panhandle and Texas coasts (Carlson and Brusher 1999). Primary nurseries for this species in the gulf have not been clearly identified (no neonates have been documented by the Mote CSR), but pupping presumably occurs in the northern gulf. One YOY finetooth shark was observed in the Yankeetown area of Florida (TL = 63 cm) in the month of October (Figure 9). Older juveniles (*N* = 70, TL = 66–127 cm) are commonly observed along the beaches of the lower Texas coast during spring and fall migrations. One older juvenile finetooth shark was found in Charlotte Harbor (Figure 10).

Carcharhinus leucas.—Young bull sharks are relatively common during the warm months along Florida's gulf coast and have been documented by the Mote CSR in the areas of Yankeetown, Tampa Bay, Charlotte Harbor, Ten Thousand Islands, and the Keys (Figure 11), as well as in Texas coastal waters. The primary nurseries for this species are typically in lower salinity estuaries and river mouths (as low as 0.9 ppt). Neonate bulls sharks (*N* = 158, TL = 54–87 cm) have been found in Yankeetown, Tampa Bay, Charlotte Harbor, Ten Thousand Islands, and Texas between the months of May and August. Young-of-the-year bull sharks (*N* = 326, TL = 55–97 cm) are found in these same areas throughout the warm months and remain in these primary nurseries until as late as November or until water temperatures fall to about 21°C. However, first-year bull sharks have been documented in Florida estuaries at temperatures as low as 16.4°C, returning to these nursery areas the following spring as early as March, and so these same Florida areas (Yankeetown, Tampa Bay, Charlotte Harbor, Ten Thousand Islands, and the Keys) also function as secondary nurseries for the bull shark. Older juveniles (*N* = 551, TL = 89–222 cm) return to these nursery areas in the spring as early as April and remain in the bays throughout the summer before undertaking their fall migration in October and November. Texas bull sharks show a similar temporal pattern. Although older juvenile bull sharks utilize estuarine nursery areas (1.7–41.1 ppt), they do not appear to venture as far into freshwater as the neonates and young of the year. Additionally, YOY and older juvenile bull sharks have been found in the warmwater effluents of Tampa Bay and Yankee-town power plants during the winter months. Presumably, these sharks become entrapped within these warm water plumes when the temperature of the surrounding water falls below the sharks' tolerance level, but definitive data are lacking.

Carcharhinus limbatus.—Understanding the nursery dynamics of the blacktip shark has been a major priority of the Mote CSR research agenda. The blacktip shark is common along the U.S. southeast coast (Castro 1996) and is a dominant component of both commercial and recreational shark fisheries in the southeastern United States (NMFS 2004). Of the five main Florida areas of study, Yankeetown has proven to be the most productive blacktip shark primary nursery followed by Charlotte Harbor, Tampa Bay, Ten Thousand Islands, and the Florida Keys (Figure 12). Neonate blacktip sharks (*N* = 1,933, TL = 42–74 cm)

TABLE 7. Summary of shark nursery habitat characteristics along Gulf coast of peninsular Florida for all species and immature life stages (Neo = neonate, YOY = young of the year, OJ = older juveniles). Includes all Florida study areas combined. *N* = stage-specific sample sizes with environmental data (which do not necessarily correspond with the total *N* values provided in species profiles in the text, since environmental data were not collected in all cases), TL = total length range of sampled sharks, Sal = salinity range, Temp = water temperature range, DO = dissolved oxygen range.

			TL (cm)		Sal (ppt)		Temp (ºC)		DO (mg/L)		Depth (m)	
Species	Stage	*N*	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Blacknose shark	Neo	17	42	50	32.2	37.0	28.7	30.1	6.5	7.1	1.5	1.8
	YOY	118	36	62	26.5	34.7	27.0	34.0	3.3	6.9	0.6	7.0
	OJ	488	60	104	25.0	37.0	17.3	32.5	4.8	8.7	0.9	60.4
Spinner shark	Neo	3	66	71	–	–	–	–	–	–	5.2	5.2
	YOY	21	48	73	21.0	36.1	24.7	31.7	4.6	7.1	0.9	69.5
	OJ	42	69	164	17.1	36.2	18.2	30.1	3.5	9.8	2.4	53.0
Silky shark	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	0	–	–	–	–	–	–	–	–	–	–
	OJ	3	91	100	33.7	33.7	25.7	25.7	–	–	25.6	44.2
Finetooth shark	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	1	63	63	15.8	15.8	23.2	23.2	–	–	2.7	2.7
	OJ	1	93	93	11.5	11.5	33.8	33.8	8.5	8.5	5.5	6.1
Bull shark	Neo	132	54	87	0.9	38.5	27.8	32.3	2.6	13.1	0.3	5.5
	YOY	278	55	97	0.5	40.7	16.1	34.0	2.3	8.4	0.3	4.6
	OJ	572	89	222	1.7	41.1	16.5	35.2	2.6	10.9	0.6	11.6
Blacktip shark	Neo	1,863	42	74	15.3	41.1	22.7	33.6	3.2	9.0	0.6	9.1
	YOY	3,055	49	90	15.8	41.6	16.2	33.8	3.3	10.8	0.6	9.1
	OJ	862	72	150	17.1	38.7	16.5	33.6	2.7	9.8	0.6	27.4
Sandbar shark	*Neo*	*3*	*48*	*63*	*20.4*	*25.9*	*25.0*	*29.0*	–	–	*2.4*	*3.7*
	YOY	0	–	–	–	–	–	–	–	–	–	–
	OJ	7	100	180	25.7	34.4	17.2	25.7	7.2	7.6	8.8	29.3
Tiger shark	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	9	87	101	31.8	34.7	29.5	30.8	4.9	4.9	20.1	49.4
	OJ	14	102	271	30.5	36.5	17.3	30.2	4.3	7.3	1.6	58.5
Nurse shark	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	0	–	–	–	–	–	–	–	–	–	–
	OJ	244	49	212	21.8	38.9	17.3	32.9	1.7	11.5	0.3	12.2
Smooth dogfish	Neo	0	–	–	–	–	–	–	–	–	–	–
Mustelus canis	YOY	0	–	–	–	–	–	–	–	–	–	–
	OJ	1	73	73	35.8	35.8	23.4	23.4	–	–	–	65.9
Florida	Neo	0	–	–	–	–	–	–	–	–	–	–
smoothhound	YOY	0	–	–	–	–	–	–	–	–	–	–
	OJ	1	61	61	33.5	33.5	19.3	19.3	–	–	9.1	9.1
Lemon shark	Neo	5	60	66	26.8	32.6	22.0	25.4	5.9	9.6	0.6	1.5
	YOY	30	64	94	15.1	38.5	19.6	33.8	4.2	11.2	0.5	1.8
	OJ	274	85	243	19.2	39.9	18.7	33.0	1.5	10.8	0.5	12.5
Atlantic sharpnose	Neo	4	32	38	22.8	33.7	24.0	30.7	5.2	5.7	1.8	3.4
shark	YOY	149	32	63	17.0	36.6	18.4	31.1	4.8	8.6	0.9	4.9
	OJ	340	51	90	21.4	37.9	16.5	33.3	4.3	8.7	0.9	43.9
Scalloped	Neo	4	46	53	23.2	38.5	27.0	28.6	5.3	5.4	1.8	3.4
hammerhead	YOY	32	45	76	20.6	34.3	23.2	32.3	2.7	7.4	0.9	4.0
	OJ	4	102	120	30.7	36.3	24.9	27.2	5.3	5.5	4.3	53.0
Great hammerhead	Neo	0	–	–	–	–	–	–	–	–	–	–
	YOY	26	64	89	20.8	34.9	23.9	31.5	5.3	7.6	1.8	5.5
	OJ	112	92	279	15.8	37.6	20.4	32.9	3.4	7.8	0.9	32.9
Bonnethead	Neo	2	29	36	15.4	27.0	27.8	30.9	6.7	6.7	1.4	2.1
	YOY	130	30	54	19.7	37.5	15.9	33.3	2.9	9.4	0.6	6.1
	OJ	3,322	49	90	15.3	40.9	16.1	33.6	2.9	10.5	0.6	8.5

have been documented in all five of these Florida areas, and significant pupping takes place along the Texas coast as well. Blacktip shark pupping begins as early as mid-April and can continue until as late as the first week of September, with the peak occurring in June. The primary nurseries can vary greatly in both water temperature and salinity (23–34°C and 15–41 ppt, respectively). Young-of-the-year blacktip sharks (*N* = 3,318, TL = 49–90 cm) remain in the nurseries throughout the warm months and begin their fall migration in October and November when water

FIGURE 8. Neonate, YOY, and older juvenile blacknose sharks *Carcharhinus acronotus* in peninsular Florida gulf coast waters. Each symbol represents a gear set capturing at least one documented specimen.

temperatures drop to around 20°C. Tag/recapture data suggest that first-year blacktip sharks leaving the north-central Florida nurseries (Yankeetown area) in the fall migrate south as far as the Marquesas Islands west of the Florida Keys (a minimum distance of 519 km; Hueter et al. 2005). Young-of-the-year blacktip sharks begin their northward spring migration back to the primary

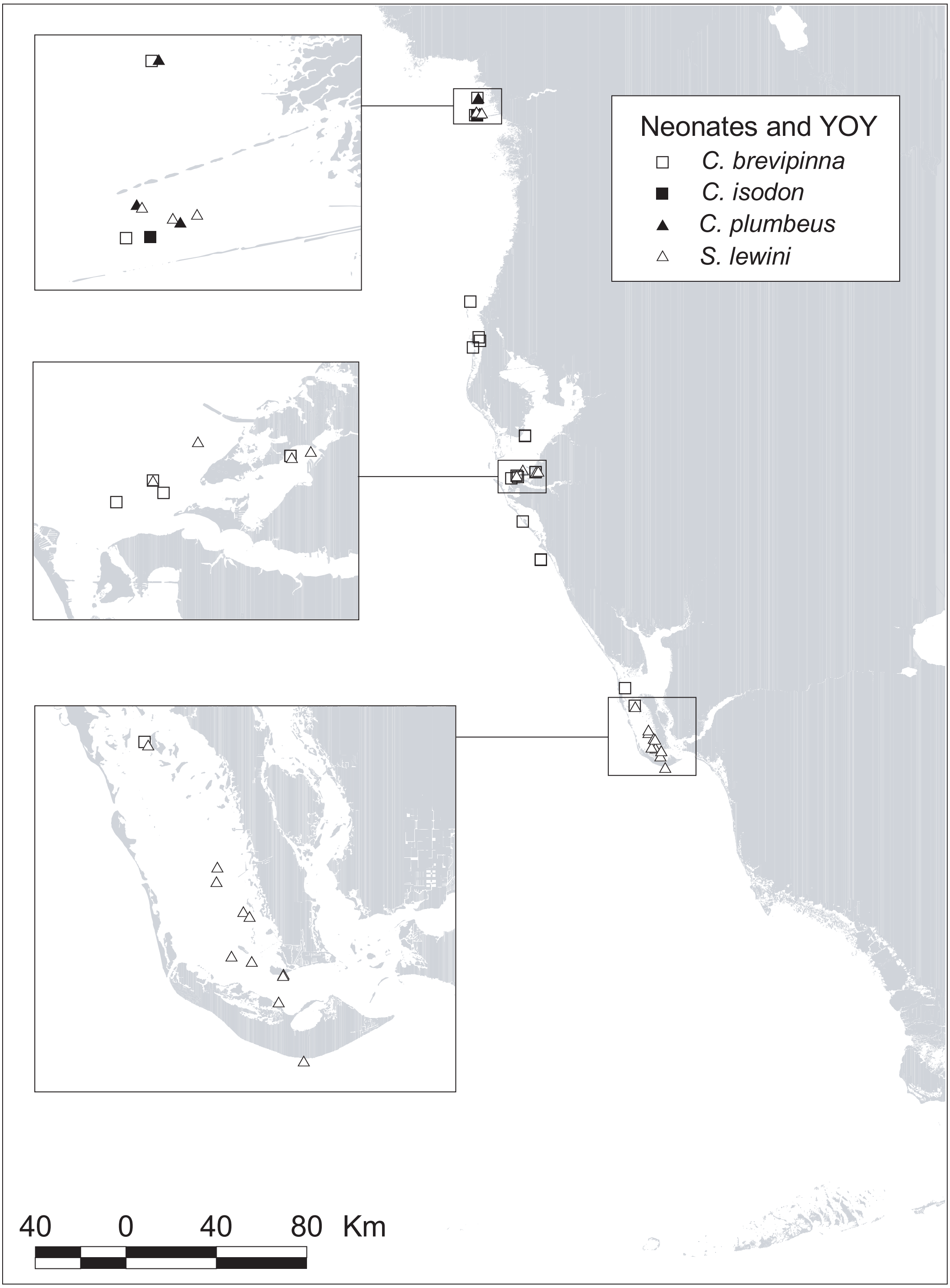

FIGURE 9. Neonates and young of the year of four species of sharks (spinner shark *Carcharhinus brevipinna*, finetooth shark *C. isodon*, sandbar shark *C. plumbeus*, and scalloped hammerhead *Sphyrna lewini*) in peninsular Florida gulf coast waters. Each symbol represents a gear set capturing at least one documented specimen.

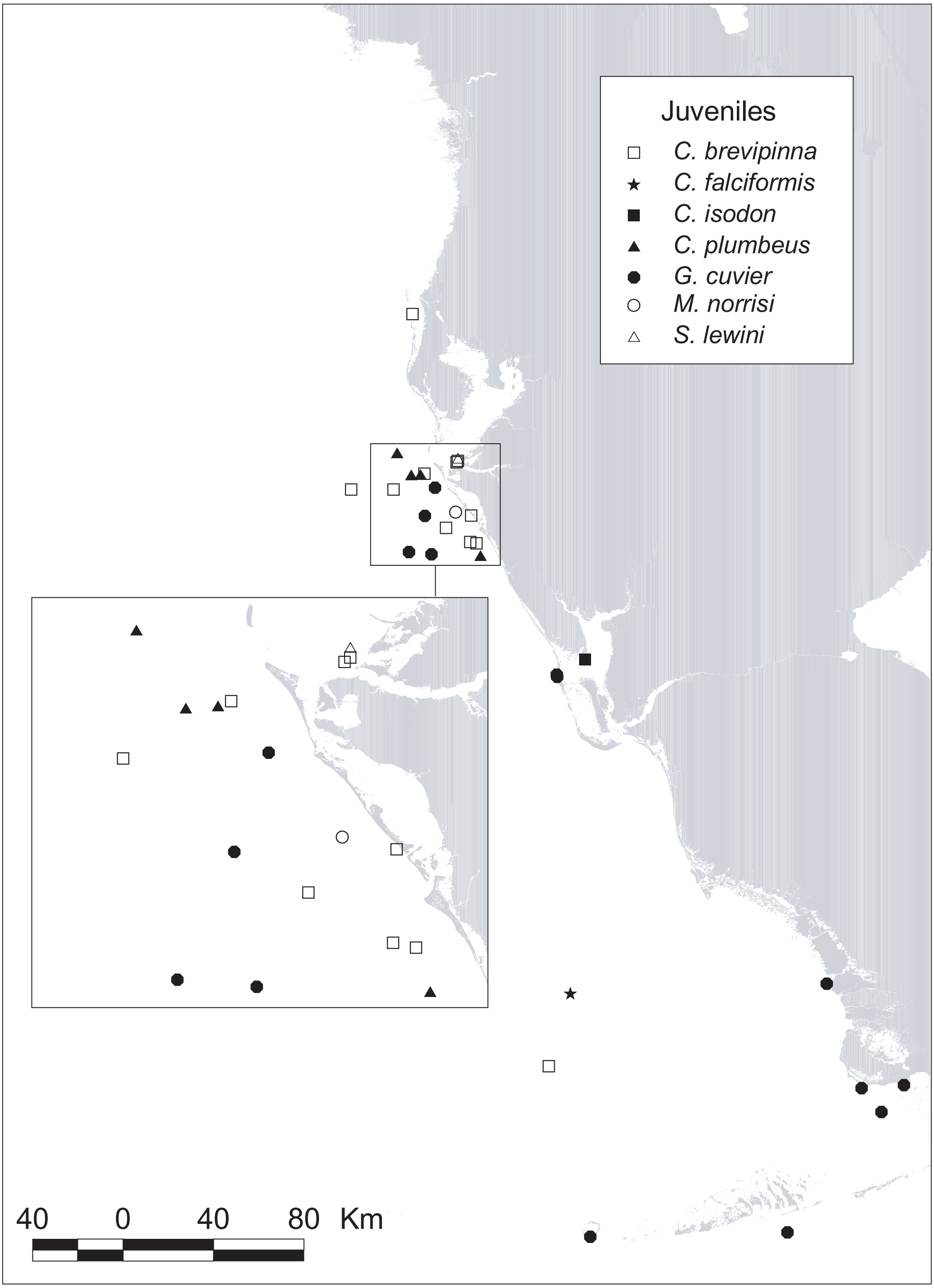

FIGURE 10. Older juveniles of seven species of sharks (spinner shark *Carcharhinus brevipinna*, silky shark *C. falciformis*, finetooth shark *C. isodon*, sandbar shark *C. plumbeus*, tiger shark *Galeocerdo cuvier*, Florida smoothhound *Mustelus norrisi*, and scalloped hammerhead *Sphyrna lewini*) in peninsular Florida gulf coast waters. Each symbol represents a gear set capturing at least one documented specimen.

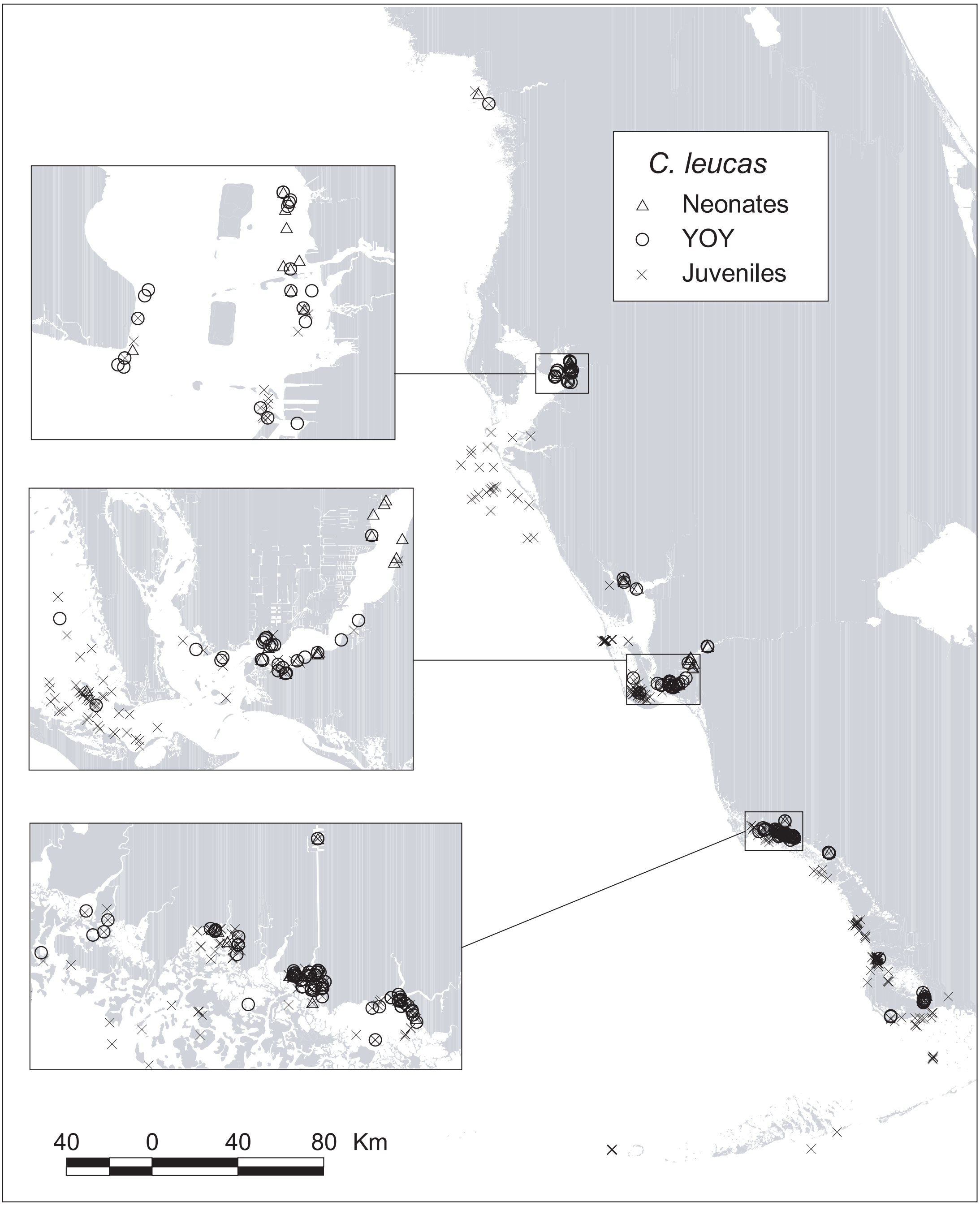

FIGURE 11. Neonate, YOY, and older juvenile bull sharks *Carcharhinus leucas* in peninsular Florida gulf coast waters. Each symbol represents a gear set capturing at least one documented specimen.

nursery areas as early as late February but more typically in March and April, and thus these areas function additionally as secondary nurseries for one-year-old as well as older juvenile blacktip sharks. Older juvenile year-classes (*N* = 962, TL = 72–150 cm) return to these nursery areas beginning in March and remain there throughout the summer before undergoing their fall migration in

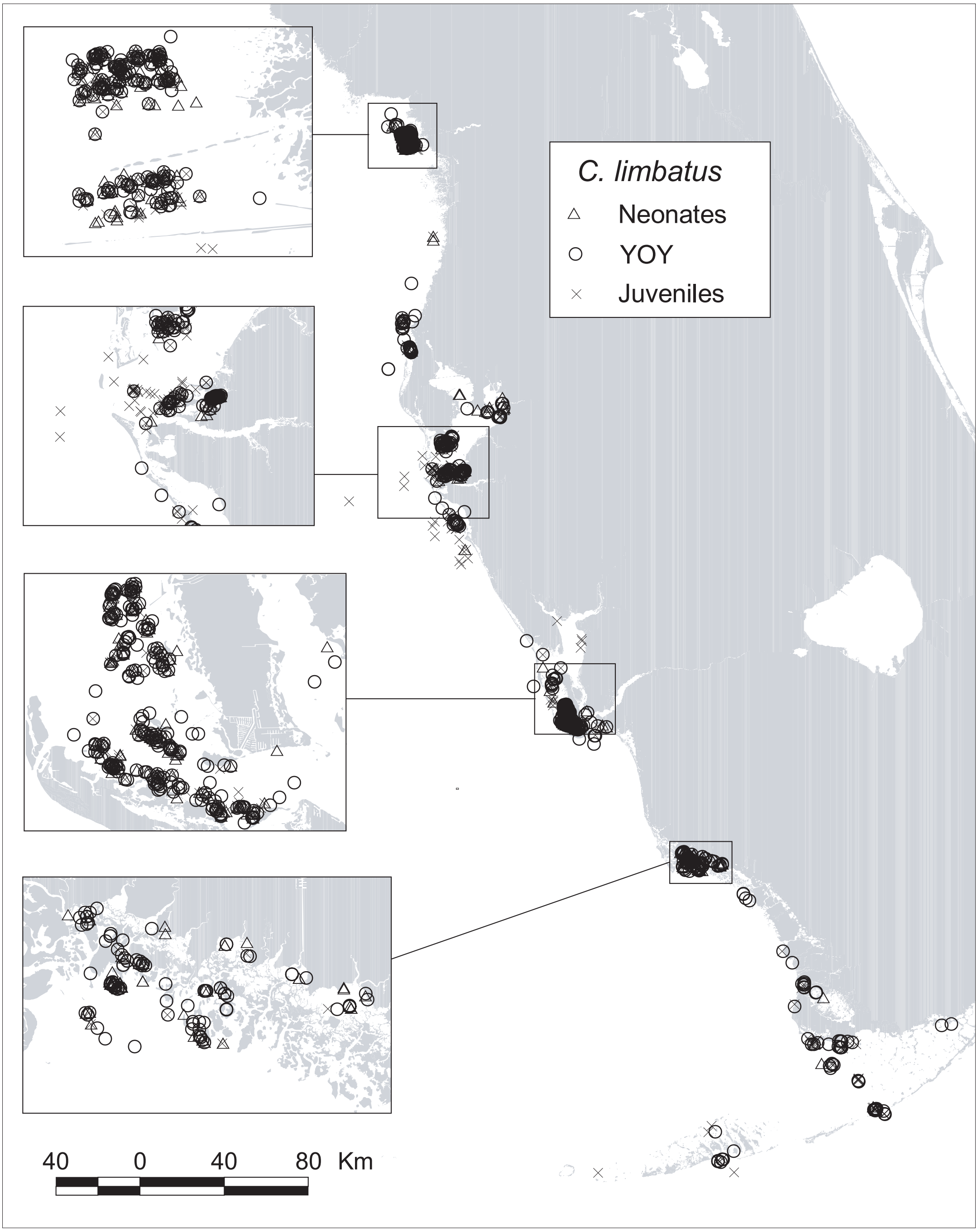

FIGURE 12. Neonate, YOY, and older juvenile blacktip sharks *Carcharhinus limbatus* in peninsular Florida gulf coast waters. Each symbol represents a gear set capturing at least one documented specimen.

October and November. These juveniles often move well into the estuaries and are found in salinities as low as 17 ppt. Mote CSR collaborative studies indicate that immature blacktip sharks also are commonly found associated with nearshore oil rigs during the warm months along the upper Texas coast as well as coastal areas of Mississippi and Louisiana. Similar to the bull shark, YOY and juvenile blacktip sharks have been found in the warmwater effluents of Tampa Bay and Yankeetown power plants during the winter months.

Carcharhinus plumbeus.—Young sandbar sharks have not been found to any significant extent along the central and southern gulf coast of Florida but appear to be more common in the northeastern gulf (Carlson 1999). A few neonates of this species (*N* = 3, TL = 48–63 cm) have been documented in the spring and early summer in Yankeetown (Figure 9). Secondary nurseries for older juvenile sandbar sharks (*N* = 15, TL = 100–180 cm) have been found during the spring and summer along Florida's gulf coast off Tampa Bay (Figure 10), the upper Texas coast, and off Louisiana.

Galeocerdo cuvier.—Young tiger sharks are not commonly found in gulf nearshore waters of the Florida peninsula. Many of the juvenile tiger sharks in the Mote CSR database were captured on the *Oregon II* during NMFS longline surveys in which Mote CSR dart tags were used. As of the end of 2004, the Mote CSR database contained no records of neonate tiger sharks. Young-of-the-year specimens (*N* = 9, TL = 87–101 cm) have been collected during NMFS longline surveys (depths 20–50 m) in July and August along the Louisiana, Mississippi, Alabama, and Florida coasts. Older juveniles (*N* = 13, TL = 102–271 cm) have been documented occasionally in Florida coastal waters off Tampa Bay, Charlotte Harbor, the Ten Thousand Islands, and the Florida Keys (Figure 10) and during NMFS longline surveys off Mississippi.

Ginglymostoma cirratum.—Primary nurseries for the nurse shark have not been well documented, perhaps due in part to this species' small size at birth and ability to avoid entanglement in gill nets. No neonates or young of the year have been captured in any Mote CSR-directed field collections. Older juveniles (*N* = 314, TL = 49–212 cm), which have been caught on Mote CSR longline and drumline gear, are commonly observed from April to November in the areas of Tampa Bay, Charlotte Harbor, Ten Thousand Islands, and the Florida Keys (Figure 13).

Mustelus canis.—One juvenile smooth dogfish (TL = 73 cm) was documented in the Mote CSR database as part of a NMFS survey off Louisiana where depth to the bottom was 66 m.

Mustelus norrisi.—One juvenile Florida smoothhound (TL = 61 cm) was collected in the vicinity of Tampa Bay at a depth of 9 m off Longboat Key in December, when water temperature was 19.3°C (Figure 10).

Negaprion brevirostris.—Young lemon sharks are relatively common along Florida's southwest coast (Figure 14). Primary pupping grounds have been found in Mote CSR surveys as far north as the shallow grass flats of Tampa Bay where neonate lemon sharks (*N* = 5, TL = 60–66 cm) have been found in the month of May in multiple years (1992 and 1993), in water temperatures of 22–25°C. These Tampa Bay pupping areas most likely are on the northern fringes of lemon shark nurseries and probably contribute marginally to overall population recruitment. Young-of-the-year lemon sharks (*N* = 38, TL 64–94 cm) are found in the summer and fall in Tampa Bay, the Ten Thousand Islands, and the Florida Keys. A few YOY lemon sharks have been captured in December along the beaches of the southern end of the Tampa Bay area, presumably during their fall migration southward. Older lemon shark juveniles (*N* = 312, TL = 85–243 cm) are seen in the spring as early as March and remain in their secondary nurseries along Florida's gulf coast throughout the summer but have been rarely documented after November. Juvenile lemon sharks are seen throughout the year in the Florida Keys and southern Everglades.

Rhizoprionodon terraenovae.—The Atlantic sharpnose shark is a common species in coastal gulf waters. Juvenile Atlantic sharpnose sharks are frequently encountered in Florida in the Yankeetown, Tampa Bay, Charlotte Harbor, Ten Thousand Islands, and Florida Keys areas (Figure 15). Collaborative field efforts have identified nursery areas in several of the northern gulf states. Despite the widespread occurrence of this species, primary pupping grounds for the Atlantic sharpnose shark are not clearly delineated in the Mote CSR database, probably due to the size selectivity of the Mote CSR's primary gear (11.4-cm mesh gill net), which can miss the very small neonates of this species. Neonate Atlantic sharpnose sharks (*N* = 5, TL = 32–38 cm) have been found in the Florida areas of Yankeetown and Tampa Bay from May to July and along the Texas coast in July. Young-of-the-year Atlantic sharpnose sharks (*N* = 148, TL = 32–63 cm) are common throughout all the main Florida study

FIGURE 13. Older juvenile nurse sharks *Ginglymostoma cirratum* in peninsular Florida gulf coast waters. Each symbol represents a gear set capturing at least one documented specimen.

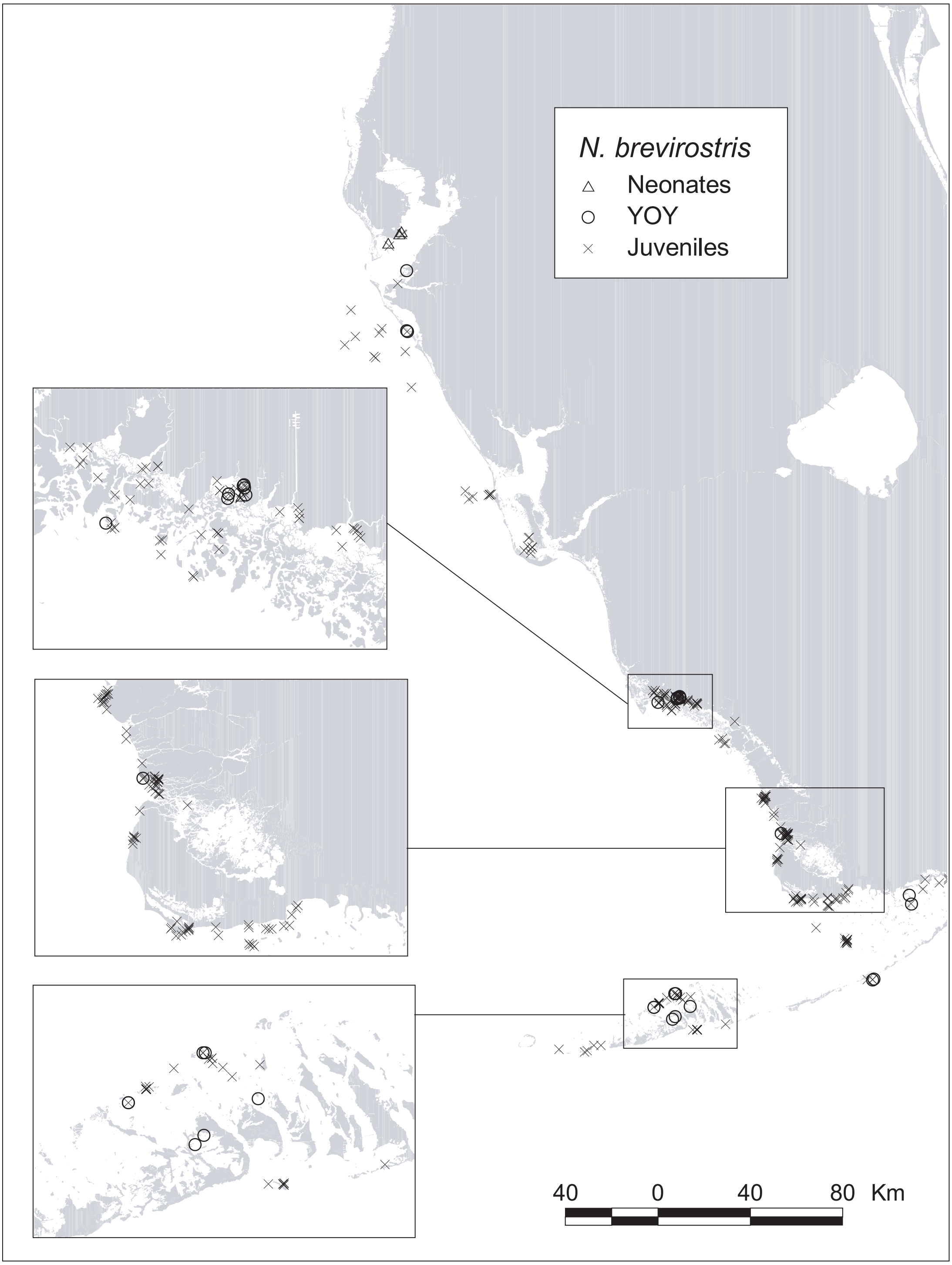

FIGURE 14. Neonate, YOY, and older juvenile lemon sharks *Negaprion brevirostris* in peninsular Florida gulf coast waters. Each symbol represents a gear set capturing at least one documented specimen.

FIGURE 15. Neonate, YOY, and older juvenile Atlantic sharpnose sharks *Rhizoprionodon terraenovae* in peninsular Florida gulf coast waters. Each symbol represents a gear set capturing at least one documented specimen.

areas with the exception of the Keys. Young-of-the-year Atlantic sharpnose sharks remain in their inshore and estuarine nurseries throughout the summer and into the fall before migrating out by November. As one year olds, these animals return to the nurseries the following spring as early as March. Older juvenile Atlantic sharpnose sharks (N = 334, TL = 51–90 cm) return to the secondary nurseries along Florida's gulf coast beginning in the early spring and are common in Texas nearshore waters by mid-May. The juveniles utilize these nearshore nursery areas throughout the summer, but offshore coastal nurseries also have been found off Texas, Louisiana, and Mississippi through longline surveys in the months of July and August. Similar to other species, juvenile Atlantic sharpnose sharks begin to migrate out of these nearshore nursery areas as water temperatures decline, and few are seen after November or when the water temperature falls below 20°C. Older juveniles, however, are found in the Florida Keys during the winter and also can be found in the warmwater effluents of Tampa Bay power plants during the coldest months.

Sphyrna lewini.—Young scalloped hammerheads are relatively uncommon in gulf nearshore waters of peninsular Florida. Neonates of this species (*N* = 18, TL = 46–53 cm) are observed along the beaches of the lower Texas coast in late spring and early summer and also are occasionally seen in the Yankeetown, Tampa Bay, and Charlotte Harbor areas at that time (Figure 9). Young-of-the-year scalloped hammerheads (*N* = 44, TL = 45–76 cm) are present in bays and nearshore nurseries during the summer months in the Florida areas of Yankeetown, Tampa Bay, and Charlotte Harbor (Figure 9) as well as along the beaches of the lower Texas coast. These first-year sharks typically move out of these areas by late October. Older juvenile scalloped hammerheads (*N* = 5, TL = 102–120 cm) occasionally are seen in the Tampa Bay area (Figure 10). Secondary nurseries for this species extend into deeper coastal waters particularly off Texas, where they have been captured during longline surveys and on rod-and-reel around offshore oil rigs at depths of at least 53 m.

Sphyrna mokarran.—The great hammerhead utilizes shallow inshore waters along Florida's gulf coast as nursery areas throughout the warm months. The location of their pupping grounds in this area is uncertain, as no neonates have been documented by the Mote CSR. The presence of YOY great hammerheads (*N* = 25, TL = 64–89 cm) in June and July indicates that pupping occurs in late spring and early summer, perhaps off the beaches in areas not sampled by the Mote CSR or farther offshore along Florida's gulf coast. Young-of-the-year great hammerheads can been found in the Yankeetown, Tampa Bay, and Charlotte Harbor areas throughout the summer but are seldom seen after October (Figure 16). The first-year animals return to the nursery grounds the following March and April. Older juvenile great hammerheads (*N* = 121, TL = 92–279 cm) often are found close to shore along Florida's gulf coast in the Florida Keys and the bays and estuaries of the Yankeetown, Tampa Bay, Charlotte Harbor, and Ten Thousand Islands areas (Figure 16). Longline surveys of Texas coastal waters also have revealed offshore secondary nurseries for this species.

Sphyrna tiburo.—Young bonnetheads are abundant in the bays and estuaries and along the beaches of Florida's gulf coast (Figure 17). The precise locations of bonnethead primary nurseries are not evident in the Mote CSR database, most likely due to the size selectivity of the sampling gear which, as with the Atlantic sharpnose shark, probably excludes the small bonnethead neonates. Late-term pregnant females are found in July and August in the areas of Yankeetown, Tampa Bay, and Charlotte Harbor. Two neonate bonnetheads (TL = 29 and 36 cm) were found in Charlotte Harbor in early September and mid-October at depths of 1–2 m. There appears to be significant latitudinal variation in the timing of bonnethead parturition, since pupping in the Florida Keys occurs in July whereas Tampa Bay bonnetheads typically pup in August (Parsons 1993; Manire et al. 1995). Young-of-the-year bonnetheads (*N* = 122, TL = 30–54 cm) in the central Florida gulf nurseries remain in these shallow areas through September and begin their fall southward migration in October when water temperatures approach 20°C. These first-year migrating animals often are found along the beaches in the late fall and winter, particularly during warming trends when water temperatures increase close to shore. Young-of-the-year bonnetheads begin returning to their warm-season nurseries by March and are found in the bays and estuaries of Florida's gulf waters throughout the summer. Older juvenile bonnetheads (*N* = 3,321, TL = 49–90 cm) are common throughout all five of the Mote CSR's Florida study sites as well as in Texas coastal waters. They often appear along the beaches in the late winter and early spring (February and March) and gradually move by April into the bays and estuaries, where they are found in salinities as low as 16.1 ppt. Tag-recapture data suggest they return to their natal areas and remain in these sec-

FIGURE 16. YOY and older juvenile great hammerheads *Sphyrna mokarran* in peninsular Florida gulf coast waters. Each symbol represents a gear set capturing at least one documented specimen.

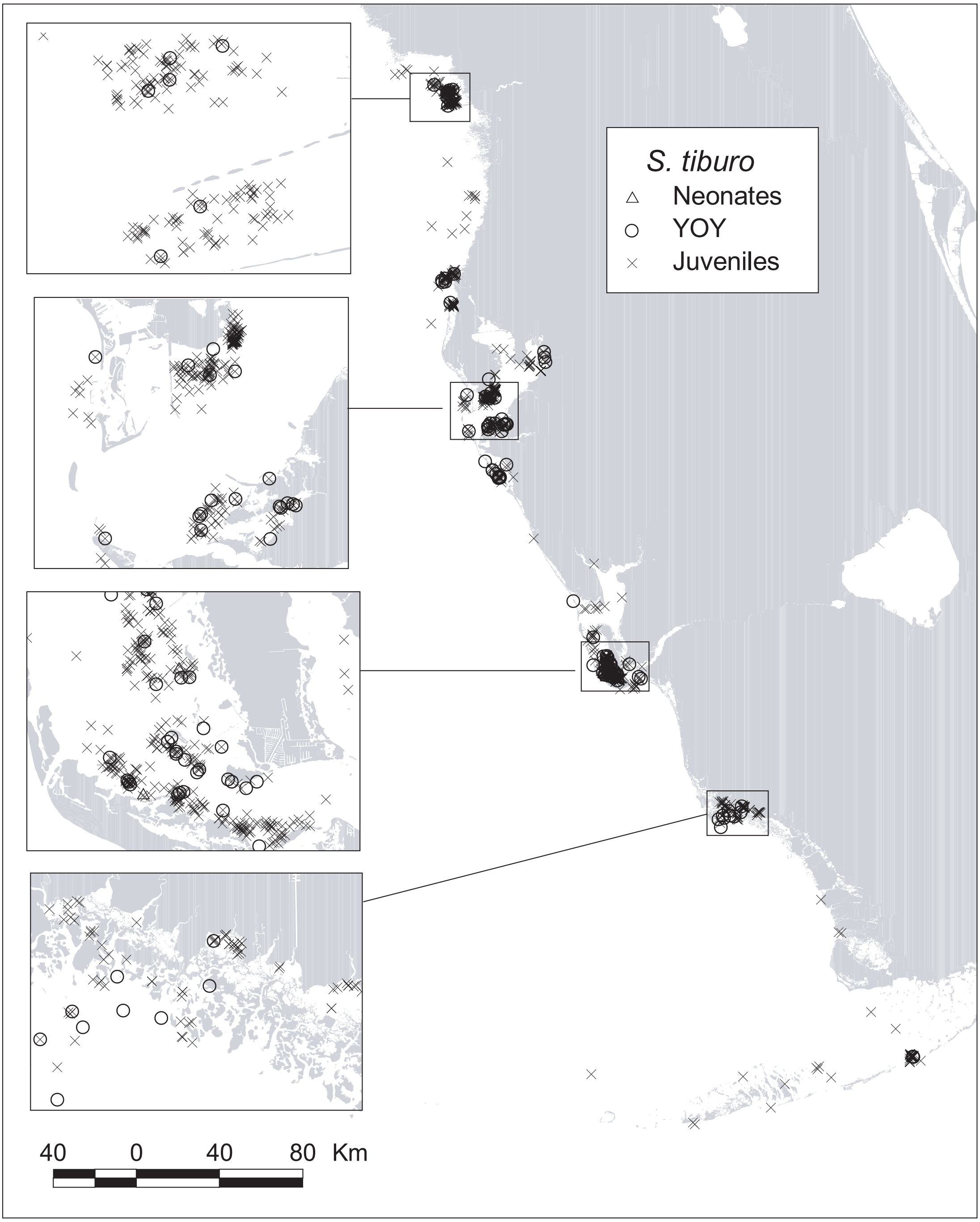

FIGURE 17. Neonate, YOY, and older juvenile bonnetheads *Sphyrna tiburo* in peninsular Florida gulf coast waters. Each symbol represents a gear set capturing at least one documented specimen.

ondary nurseries during summer and fall. The juveniles begin to leave the bays and estuaries in October when water temperatures drop to near 20°C. They are rarely found in the bays after November. During their fall migration, juvenile bonnetheads often are found along the beaches very close to shore in November and December. As with blacktip, bull, and Atlantic sharpnose sharks, bonnetheads are sometimes found during the winter months in the warmwater effluents of Tampa Bay power plants. In the Florida Keys, where temperatures are more stable, juveniles can be found at all times of the year.

Conclusions

From 1991 to 2004, Mote Marine Laboratory's Center for Shark Research collected data on 20,917 sharks of 16 species and four families that utilize coastal areas of the U.S. Gulf of Mexico. More than half of the sharks sampled (12,879) representing all 16 species were neonate, YOY, or older juvenile sharks that utilize these coastal areas as primary and/or secondary nurseries. These data present a broad view of the spatial and environmental characteristics of gulf nurseries for each species of shark. In these gulf areas, 15,001 sharks were tagged and released, and recapture data were received on 557 sharks (3.7%) by the end of 2004, revealing some temporal trends in juvenile and adult shark movement. Although each shark species has its own spatial and temporal patterns of habitat use, the following general trends have been observed in these gulf shark nurseries:

- At least 16 species of large and small coastal sharks depend upon the inshore and estuarine waters of the eastern and western Gulf of Mexico as primary and/or secondary nurseries for neonate, YOY, and/or older juvenile life stages.
- The majority of pupping activity typically occurs in late spring and early summer. Neonate and YOY sharks inhabit the primary nurseries throughout the summer and into the fall.
- As water temperatures begin to decline in the fall, the surviving YOY sharks leave the primary nurseries and typically undergo southerly, and in some cases offshore, migrations to secondary winter nursery areas.
- Surviving one-year-old juveniles return north/inshore to the secondary summer nurseries the following year, and in some cases for several years after that, beginning in early spring. Those juveniles that survive through their second summer leave the summer nurseries in the fall to return to their winter nursery areas.
- Annual cycles of philopatric behavior, in which juveniles migrate back and forth to specific primary and secondary nursery areas, are seen in large and small coastal shark species. In some cases, the natal nursery is used as a secondary nursery by older juveniles, which may continue to return to the natal nursery on an annual basis until they approach maturity. The precision of site fidelity by species is not yet known, but for juvenile blacktip sharks, Mote CSR studies indicate that up to half of the pups surviving their first summer in the natal nursery return to that same area and use it as a secondary nursery in subsequent years (Hueter et al. 2005). The possibility that mature females may navigate back to their own natal nurseries to give birth to their pups has been hypothesized (Hueter et al. 2005) but has yet to be verified in the Gulf of Mexico. Current research utilizing genetic analyses and tagging is continuing to test this philopatry hypothesis of shark migration (Keeney et al. 2003, 2005; Hueter et al. 2005).

It is clear from our results and those of other researchers (e.g., Castro 1993; Carlson and Brusher 1999) that the coastal waters of the southeastern United States, particularly those in the Florida Gulf of Mexico, provide important habitat as primary and secondary nursery areas for numerous coastal shark species. Many factors may play a role in making the Florida gulf coast in particular an important shark nursery area. These include the wide, shallow continental shelf contiguous to this coastline, the low energy environment along this shoreline, the many bays and estuaries along this coast, and the high productivity of fishes and other prey items for sharks in this area. The function of shark nurseries has been debated with most discussions pointing to either refuge from predators or access to abundant food resources as the driving ecological factors (Branstetter 1990; Simpfendorfer and Milward 1993). Both of these factors no doubt play a role in the evolution of nurseries, but Mote CSR studies have indicated that protection from predators may be the more important factor (Heupel and Hueter 2002).

Whatever the case, it is certain that many shark species, even long-distance migrators that utilize the open sea, are dependent on the inshore and estuarine waters of the U.S. Gulf of Mexico coast for critical stages in their life history. What is less certain are the various impacts of human development and industry on these sharks in this highly populated region. Habitat degradation and other anthropogenic perturbations can degrade the functionality of these important nursery areas (Hueter et al. 2005). Without attention to these impacts, any gains made by stock-rebuilding programs through fisheries regulation could be compromised by reduction of critical nursery habitat.

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