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The shark nursery of Bulls Bay, South Carolina, with a review of the shark nurseries of the southeastern coast of the United States

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Synopsis

Shark nurseries, or nursery areas, are geographically discrete parts of a species range where the gravid females of most species of coastal sharks deliver their young or deposit their eggs, and where their young spend their first weeks, months, or years. These areas are usually located in shallow, energy rich coastal areas where the young find abundant food and have little predation by larger sharks. Nurseries are characterized by the presence of both gravid females and free swimming neonates. Neonates are young bearing fresh, unhealed umbilical scars in the case of placental species, or those at or near the birth size in aplacental species. Bulls Bay, South Carolina, is a nursery for the blacknose, spinner, finetooth, blacktip, sandbar, dusky, Atlantic sharpnose, scalloped hammerhead, and smooth dogfish sharks. The lemon shark has its nursery in shallow waters of south Florida and the Bahamas. The bull shark has its nursery in the lagoons of the east coast of central Florida.

Introduction

Meek (1916) stated that, although it was not known with certainty at the time, the distribution of viviparous sharks indicated that 'the females resort to a particular region for the liberation of the young'. He also cited the observation that the young of the tope (soupfin shark), *Galeorhinus canis* (=*zyopterus*), and the smooth dogfish, *Mustelus canis,* are born in shallow waters and remain there after the larger fish have migrated into deep water.

Springer (1967) stated that sharks migrate to rather specific places where the females lay eggs or give birth to young, and that the evidence for special nursery areas for some sharks was 'rather strong'. He further stated that with the exceptions of the sandbar and bull shark, the species requirements for nursery areas may be limited by water depth and habitat type. Springer (1967) also stated that for all well-known shallow-water sharks, the young tend generally to concentrate in the shallower parts of the population range which typically represent nursery areas. Springer also suggested that the only important predators of sharks are other sharks, and that nursery areas may be chosen based on the absence of large sharks.

Castro (1987) briefly reviewed shark nursery areas off South Carolina, and stated that most species have a geographically discrete nursery, and that the nurseries are usually located in highly productive shallow waters, such as coastal marshes and estuaries, where the young can find abundant food. Castro also cited examples of several species sharing the same geographic area with some degree of temporal partitioning.

The objective of the present paper is to survey the

use of a nursery area off South Carolina by nine species of carcharhinoid sharks and to review the present knowledge of shark nursery areas off the east coast of the United States. It is intended to provide a starting point or basis for more detailed studies of shark nurseries, and to provide criteria for the delineation of the nurseries. The intensive shark fisheries that have developed along the east coast of the United States since 1985, have engendered a growing interest in protecting shark stocks. The mapping of nursery areas has been identified as a critical research need because of recruitment relationships (NMFS[1]). If shark stocks are to be managed or protected, a knowledge of the location and extent of the nursery areas will be of prime importance.

The data presented are based upon my observations over a twelve year period and the available literature. The specimens were made available to me through the cooperation and kindness of fishermen. In order to avoid hampering or delaying the processing of shark carcasses, it was often necessary for me to select one or two representative specimens, out of many similar sharks, to be examined in detail. Initially, these observations were incidental to a detailed study of the life history and embryonic development of the Atlantic sharpnose shark, *Rhizoprionodon terraenovae* (Castro 1988).

Materials and methods

Based on our present knowledge of their life history, the ontogenetic development of sharks can be divided into four periods: embryo, neonate (pup), juvenile, and adult. Embryo is the pre-hatching developmental period in the case of oviparous sharks, and the pre-parturition period in the case of viviparous species. Neonates are post-hatching or post-birth, free-swimming young bearing fresh, unhealed, or healing umbilical scars in the case of placental species, or those at or near the birth size in the case of aplacental or ovoviviparous species. For the placental species, the neonatal period terminates with the healing (closure) of the umbilical scar. The neonatal period probably lasts about a month or six weeks, based on observations of time of parturition and the presence of juveniles with healed umbilical scars. Juveniles are all the post-neonatal individuals prior to sexual maturation. In some species of sharks, the duration of the juvenile period may approach two decades or longer, thus it is likely this period can be subdivided into phases based on age, size, growth rate, habitat, or migratory patterns. However, the present status of the knowledge of sharks prevents use of more specific terminology than small or large juveniles for most species. Adults are the sexually mature individuals of the population.

Based on the observed distribution of sharks by size and sex, and on their migratory patterns, three different areas can be identified. These are: (1) adult feeding areas, (2) mating areas, and (3) nursery areas. Adult feeding areas comprise the largest part of the species range, being the areas where the adults live except for the times when they migrate to specific mating grounds or nursery areas. Mating areas are the areas where the adults congregate for the purpose of mating. Nursery areas, or simply, nurseries, are geographically discrete parts of the species range where the gravid females deliver their young or deposit their eggs, and where the young spend their first weeks, months, or years. The nurseries of oviparous sharks can be detected easily by the presence of egg cases and hatchlings in the same area. The nurseries of viviparous sharks can be detected by the presence of gravid females, neonates and small juveniles in the area. The mere presence of gravid females bearing term embryos in an area is not sufficient to determine a nursery area, because of the difficulties of determining nearness to birth, and because a near term female may readily migrate from one habitat to another many kilometers away to give birth. How close a given female shark is to giving birth can only be estimated after the total length of the young at birth is well known. Even when the size range at birth is known, it is still difficult to assess precisely how close to birth a given brood is, because the size of the embryos varies with the size of the mother, with the larger females usually having larger young. A considerable amount of

[1]NMFS. 1989. Draft secretarial shark fishery management plan for the Atlantic Ocean. NOAA/NMFS. Dept. of Commerce. St. Petersburg. 116pp.

confusion has been engendered by authors reporting females with 'near term young' (embryos) without giving their sizes. Embryos are usually fully formed externally and pigmented after the seventh month of a year-long gestation period, and they may appear ready for birth. For example, I found that the young of the Atlantic sharpnose shark are born at 280–340 mm TL during the last week in May to the second week in June off South Carolina. In early January the embryos are in their seventh month of the 11–12 month gestation period and they measure 250–270 mm TL, they are fully pigmented, and appear to be externally fully formed. In the last two to three months of gestation, embryos are very close to birth length, although their development is not yet complete. Most of the increase in length occurs in earlier gestation, while girth increases in the last two or three months.

The nursery may include several habitats and a broad geographical area or depth range. Most species of sharks mature very slowly, often taking years or decades to reach sexual maturity. Because many nurseries are located in the temperate zone, decreasing temperatures in late fall render the natal nursery unsuitable for young sharks, forcing them to migrate southward or into deeper waters. The observations recorded here are limited to the summer nurseries. Data on the winter nurseries of most species are lacking. Preliminary data suggests that the young migrate in the same general direction as the adults, although the time of migration is usually different.

Physical setting

Bulls Bay is an estuarine system composed mainly of salt marshes and barrier islands. The marshes are located between the mainland and the barrier islands and are dominated (94%) by smooth cordgrass, *Spartina alterniflora* (Mathews et al.,[2]Tiner 1977). A wide maze of tidal creeks and small marsh islands usually separates the barrier islands from the mainland. The barrier islands have a sandy beach facing the ocean and a high salinity marsh facing the mainland. Salinity is highly variable (28‰–35‰) due to the runoff from various rivers and creeks that empty into the area. The bottom slopes very gently seaward due to the very wide continental shelf of the area. We found that in the offshore areas fished, from 1 to 4.5 km from the beach, the depth ranged from 2 to 4 m.

Specimens were obtained using a variety of methods: gill nets, longlines, and shrimp trawl, over a twelve year period. Most specimens were obtained with a 15 cm stretched-mesh gill nets set in the seaward side of the islands at depths of 2–4 m. Total length (TL) was measured on a horizontal line between perpendiculars, from the tip of the snout to the tip of the tail, with the tail at its maximum rearward extension. This method avoids the uncertainty resulting from having the tail at different angles when different observers take the measurement.

Results

Species utilizing Bulls Bay and adjacent area as a nursery

Blacknose shark, Carcharhinus acronotus

The blacknose shark inhabits the western North Atlantic from North Carolina to southeastern Brazil (Bigelow & Schroeder 1948). It is abundant in coastal waters from the Carolinas to Florida and the Gulf of Mexico (Castro 1983). Litters consist of three to six pups that measure about 50 cm at birth (Castro 1983). Dodrill (1977) reported that from late April to mid-May the landings off Melbourne Beach, Florida were 'most with full term young'. His data shows pups 447–488 mm TL in late April, and 420–459 mm in early May. He also noticed the absence of blacknose sharks in landings from early July to late August, and suggested that some blacknose sharks may undertake small scale movements northward or offshore. Dodrill did not report seeing any specimens of blacknose sharks under 1030 mm TL from the Melbourne Beach area. Nevertheless,

[2]Mathews, T.D., F.W. Stapor, Jr., C.R. Richter, J.V. Miglarese & L.A. Barclay (ed.) 1980. Ecological characterization of the Sea Island coastal region of South Carolina and Georgia. Vol 1. Physical features on the characterization area. U.S. Fish Wildl. Serv., FWS/OBS-79-40. 212 pp.

Dodrill stated that the young are born at 417–495mm TL off Melbourne Beach, Florida, from mid-May to early June, perhaps assuming that the females he had seen were about to give birth. Schwartz (1984) reported four embryos 495–510mm removed from a female off North Carolina in June, and calculated the size at birth to be about 505mm TL. Schwartz (1984) also stated that based on his catch data, it appeared that blacknose pups rarely occurred off North Carolina, but that neonates and juveniles were caught from piers in the July-August sport fishery.

I found the blacknose shark to be extremely abundant during the summer in shallow water 2–4m deep from Folly Beach to Bulls Bay (Table 1). Adults constituted 30–50% of the gill net catch off Bulls Bay and Folly Beach, especially in late July and August. Two females carrying embryos 421–470mm were caught in Bulls Bay on 26 May 1987. Another female carrying 420–460mm embryos was caught off Charleston on 7 June 1980. The smallest free swimming specimen that I saw measured 512mm TL and was caught in a shrimp trawl off Charleston on 31 July 1981. Two pups 565–575mm were caught at a depth of 10m at the mouth of the Stono river on 19 August 1983. Juveniles 600–700mm were often observed in shrimp trawl catches off Folly Beach in late summer.

Spinner shark, Carcharhinus brevipinna

The spinner shark is a circumtropical species. In North America it ranges from North Carolina to Florida and the Gulf of Mexico (Castro 1983). The embryos are born at 600–750mm TL (Castro 1983). Numerous neonates, some bearing fresh umbilical scars, and juveniles were observed in gill net and shrimp trawl catches in the estuarine waters of South Carolina throughout the summer, indicating that parturition occurs in or near those areas. A juvenile 732mm TL, caught on 1 August 1991 in Bulls Bay, had a healed umbilical scar that was barely visible. Another specimen 729mm caught off Folly Beach on 11 August 1983 also had a healed umbilical scar. I only saw one gravid female carrying term (570–640mm) embryos, on 20 May 1988, in the gill netting operations in Bulls Bay. According to Steve Poston, the fisherman who caught that gravid female, a man very familiar with the identification of the shark species in the area, that was the only gravid spinner shark he had seen in that area in over 15 years of shark fishing with gill nets in shallow water. The only other gravid female that I saw in that area was a 2020mm TL female with recently ovulated eggs that was caught on a shrimp trawl off Charleston on 30 June 1980. The paucity of gravid females in shallow water (1.8–5m) gill net catches and the abundance of juveniles may indicate that parturition occurs in waters deeper than 5m, and that the young enter shallow waters, or, that the females make only brief incursions into shallow waters to deliver their pups and, thus are not likely to be captured. I never saw an adult male caught in estuarine waters by any means, although large juvenile males were common.

Finetooth shark, Carcharhinus isodon

The finetooth shark has been reported from New York to Florida and the Gulf of Mexico (Bigelow & Schroeder 1948), Trinidad (Castro 1993), and Brazil (Sadowsky 1967). Although it is very common off South Carolina in the summer (Castro 1983), there is very little published information on it (Compagno 1984). The extent of its nurseries along the east coast is not known.

Springer (1950) reported catching females carrying from one to six embryos 430–480mm off Salerno, Florida on 28 December. Springer estimated that, based on the winter capture, the finetooth shark gave birth to young about 480mm TL in December and January. It is likely that the embryos that Springer considered ready for birth at 480mm TL were actually midterm embryos. Dodrill (1977)

Table 1. Blacknose shark, number of embryos and size from term females from South Carolina nurseries.

Date	Female TL	# embryos	Embryo TL
21 Apr 1992	1135mm	5	404–426mm
14 May 1991	1370mm	4	484–506mm
26 May 1987	N.R.	5	421–470mm
26 May 1987	1353mm	5	421–451mm
28 May 1987	N.R.	6	389–409mm
7 Jun 1980	1290mm	4	420–460mm

N.R. = not recorded.

found this shark in the Melbourne Beach, Florida, area only from November to April, and noted that it appeared to move north in summer. Females carrying term embryos 450–550mm first appear in shallow water 2–3m deep in Bulls Bay in mid May (Table 2). I found no gravid females with term pups after the third week in June (Castro 1993). Gravid females were found in shallower water (2–3m deep) than the mating females (5–7m). Specimens of all sizes, from neonates (Table 3) to adults were found to be very common in shallow estuarine and coastal waters from late May to late September. The juveniles appeared before the adults entered the nursery in the spring, and remained there longer than the adults. I found juveniles as early as 22 March in waters 3–4m deep in Bulls Bay, and as late as 26 October off Charleston. Based on Dodrill's (1977) observations and mine off South Carolina, it appears that there is but one population of finetooth sharks off the east coast and that they give birth off the Carolinas in May and early June.

Blacktip shark, Carcharhinus limbatus

The blacktip shark is a circumtropical species. It ranges from New England, where it is rare, to Florida and the Gulf of Mexico (Castro 1983).

Wright (1981) stated that blacktips probably dropped their pups in the spring in the Florida Keys. However, his evidence is not conclusive about the blacktips giving birth off Florida area or about neonates being present in the area. Of the 320 specimens Wright mentioned, only three specimens examined by him measuring 730–740mm, and two specimens 670mm and 750mm TL examined by Gordon Hubbell are within the birth size of 550–742mm TL, the rest being much larger specimens. Because the presence of fresh umbilical scars was not noted in the specimens examined by Wright, it is possible that those specimens may have been older and may have been born somewhere else. Wright also reported only one female carrying 'near term embryos' (520–540mm) from that area seen 5 March 1979, all the other females reported carried much smaller embryos. Dodrill (1977), working off Melbourne Beach, Florida, reported that no females with full term young were caught adjacent to the beach after 15 May, and that by early June rather slender, post-partum females with no ovarian eggs and greatly expanded uteri were being caught. Dodrill (1977) also reported that no newborn young were seen along the beach during spring, summer or fall months, and that the smallest free swimming specimen seen by him measured 921mm TL and was caught in December.

Off South Carolina, from Port Royal Sound to Bull Bay, females were observed carrying term embryos (582–742mm TL) from mid-April to mid-June (Table 4), and numerous newborn blacktips 570–776mm with fresh umbilical scars were present from late July to mid-August. A specimen 653mm TL seen 15 June 1990 still had an open umbilicus. A 570mm TL specimen seen on 27 July 1981 had no visible umbilical scar. Adult females not carrying

Table 2. Finetooth shark, number of embryos and size from term females from South Carolina nurseries.

Date	Female TL	# embryos	Embryo TL
18 May 1990	1510mm	4	447–460mm
21 May 1990	1550mm	6	490–545mm Aborted 3 pups
22 May 1990	1467mm	2+	502,520mm Aborted 1+
23 May 1990	1555mm	6	542–561mm
24 May 1987	N.R.	4	456–495mm
28 May 1987	N.R.	4	530–552mm
30 May 1984	1525mm	3	525–549mm
30 May 1984	1550mm	4	535–553mm
30 May 1984	1560mm	4	527–546mm
31 May 1984	1548mm	5	450–482mm
31 May 1984	1590mm	4	542–553mm
16 Jun 1987	1360mm	3	483–490mm
18 Jun 1992	1438mm	4	437–503mm

Table 3. Finetooth shark neonates and small juveniles from South Carolina nurseries.

Date	TL mm	Condition of scar
15 Jun 1990	562	Open, 1mm
21 Jun 1990	551	Open, 2mm
21 Jun 1990	570	Healed
29 Jul 1992	620	Healed
11 Aug 1990	674	Healed, barely visible
19 Aug 1992	671	Healed, barely visible
20 Aug 1990	642	Healed

term embryos from mid-May to the first week in June usually had very fresh mating bites. Juveniles and adults of both sexes, including gravid females carrying small embryos, were caught in shallow coastal waters from Folly Beach to Bulls Bay until late September, when all blacktip sharks apparently leave the area.

Sandbar shark, Carcharhinus plumbeus

The sandbar shark is a cosmopolitan species that is abundant in the western North Atlantic, ranging from southern New England to Florida, the Gulf of Mexico and Brazil (Bigelow & Schroeder 1948). Springer (1960) gave the size at birth as 610mm TL (range 480–640mm). Castro (1983) stated that the young are born from March to April and measure about 600mm at birth, being somewhat smaller in the northern parts of the range.

According to Springer (1960) the principal nurseries of the western Atlantic population of sandbar sharks lie in relatively shallow water along the Atlantic coast of the United States from Long Island to Cape Canaveral. Nichols & Breder (1927) stated that females carrying young were taken in Great South Bay from 22 June to 5 August, and that the young measured about 560mm TL at birth. Thorne (1928) also reported taking gravid females with embryos about 560mm TL from 22 June to 28 August in Great South Bay. Jack Casey (personal communication) states, that in 1990 the northern end of the nursery extends only to Barnegat Bay in New Jersey, and that Great South Bay is no longer a nursery for the sandbar shark. According to Musick & Colcovoresses,[3] gravid sandbar sharks enter the lower Chesapeake Bay and the high salinity lagoons on the eastern shore of Virginia in May and June to deliver their pups. After giving birth these females migrate offshore to depths of 10–40m. The young remain in the estuarine nurseries until September, when the water temperatures drop below 18–20°C, and then migrate to warmer water south of Cape Hatteras. Hoese (1962) stated that young *C. plumbeus* (578–688mm) were abundant in bays near Wachapreague, Virginia, from July to September, and that small, recently born sandbar sharks were caught as late as 7 September off Virginia.

In South Carolina, gravid females were caught in Bulls Bay at depths of 1.8–3.0m during the first week in June. These females carried embryos 480–640mm TL (Table 5). I found that neonates and juveniles are common in shallow estuarine and coastal waters until late September. A 634mm TL neonate caught in Bulls Bay on 29 July 1992 had an open umbilical scar 8mm long. Springer (1960) reported that off the Carolina coast, the young move offshore to warmer waters and depths as great as 137m during the winter. After their winter absence, the young re-entered the nursery; I saw numerous juveniles 109–120cm TL caught in shallow water 3–4m deep off Bulls Bay in late March. Mature males were never found close to shore in summer but were occasionally caught there in late fall.

Springer (1960) stated that not one neonate sandbar shark had been taken South of Cape Canaveral, around the tip of Florida, or in the eastern Gulf of Mexico. Other authors (Clark & von Schmidt 1965, Dodrill 1977, Wright 1981) have corroborated the absence of neonate sandbar sharks south of Cape Canaveral, although older juveniles and adults are very common. Dodrill (1977), in an extensive survey of the sharks off Melbourne Beach, Florida, stated that he saw only older juveniles and adults 1784–2210mm TL. Wright (1981), in a comprehensive survey of the sharks of the Florida Keys, stated that there was no evidence that pups were dropped in that area or that young sandbar sharks occurred there as he did not record specimens under 1040mm TL. According to Springer (1960) a secondary nurs-

Table 4. Blacktip shark, number of embryos and size from term females from South Carolina nurseries.

Date	Female TL	# embryos	Embryo TL
13 Apr 1991	N.A.	4	605–620mm
24 Apr 1991	N.A.	4	582–625mm
09 Jun 1982	1760mm	3	580–605mm
14 Jun 1981	1740mm	5	704–742mm

[3] Musick, J.A. & J.A. Colcovoresses. 1986. Seasonal recruitment of subtropical sharks in Chesapeake Bight, USA. IOC/FAO Workshop on recruitment in tropical coastal demersal communities. Ciudad del Carmen, Campeche, Mexico, 21–25 April 1986. Intergovernmental Oceanographic Commission Workshop Report No. 44-Supplement.

ery area 'apparently lies in the northwestern part of the Gulf of Mexico'. This was based only on the capture of a few females with 'near full-term embryos' near the mouth of the Mississippi, and off the Texas coast, but there seem to be no other studies corroborating those observations.

Dusky shark, Carcharhinus obscurus

Dodrill (1977) reported that there were no gravid female dusky sharks close inshore in April, May, and June off Melbourne Beach, Florida, and suggested that the gravid females migrated offshore or northward and dropped their young in the northern part of their range in the summer. Very large gravid dusky sharks have been reported to me by fishermen fishing at depths of less than 7m, in Bulls Bay in late April and early May. Their large size prevented bringing them on board their small boats for processing or bringing them to shore. These fish were usually released by the fishermen if alive, or when dead, their large pups (up to 8kg) were removed and butchered. Thus, I only had the chance of examining a few term pups, and to confirm that gravid dusky sharks are present in Bulls Bay in late April and early May. A neonate 997mm TL with an open umbilical scar 6mm long was caught on 19 May 1991. Neonates 1018 and 1040mm TL with healing umbilical scars were caught there on 26 April 1985. Older juveniles 1200–1400mm TL were caught in gill nets set at depths of 3–5m in that area from mid-April to the third week in May. Generally, warmer water temperatures cause dusky sharks to move out of the area in late May. However, a 1032mm TL neonate with an open umbilical scar 8mm long was caught 12 June 1991.

Table 5. Sandbar shark, number of embryos and size from term females from South Carolina nurseries.

Date	Female TL	# embryos	Embryo TL
03 May 1990	1889mm	9	442–520mm
01 Jun 1983	2150mm	10	600–640mm
01 Jun 1984	2150mm	9	550–610mm
01 Jun 1984	2190mm	6	480–600mm
02 Jun 1984	2450mm	7	600–625mm
20 Jun 1985	2100mm	8	570–610mm

Atlantic sharpnose shark, Rhizoprionodon terraenovae

The Atlantic sharpnose shark ranges from the Bay of Fundy to Yucatan. It is most abundant from the Carolinas to Florida and the Gulf of Mexico (Bigelow & Schroeder 1948). It is a year round resident off South Carolina, being close to shore in the summer, and migrating to deep waters in winter (Castro 1983). Juveniles 500–600mm TL entered shallow waters (3–4m deep) of Bulls Bay as early as 22 March. Females entered shallow waters off South Carolina in mid-May. Pups are born at 300–350mm TL in coastal waters about 10m deep. Gravid females carrying term embryos larger than 320mm were captured from the third week in May to the third week in June (Table 6). Free swimming young 320–360mm TL with healed umbilical scars were collected on 2 June 1980 off Bird Key, Charleston. Parturition occurred in shallow coastal waters 9m or less, from late May to mid-June, based on catches of post-partum females and on the appearance of newborn young in large numbers in shrimp trawls. Thirteen specimens 292–350mm TL were obtained from a shrimp trawl off Folly Beach on 12 June 1982 at a depth of 4.5–6m. No adults were caught in that trawl. Adults and juveniles were found in waters less than 9m deep off South Carolina until late October when they migrate to deeper water. This migration coincided with the lowering of the water temperature below 20°. The latest catch occurred on 4 November 1980 when two juveniles 502 and 520mm TL were captured in a shrimp trawl off Charleston. The adults wintered in waters deeper than 30m off South Carolina, based on sporadic catches off Charleston during late January.

Bigelow & Schroeder (1948) reported neonates still showing traces of the umbilical scar from Florida in July. Gravid sharpnose females carrying term pups (Table 7) were also found off Daytona Beach at depths of 15–18m during the last week of May. Schwartz & Burgess (1975) stated that this species is one of the most abundant sharks in North Carolina estuaries from May to October, and that the young are born or encountered there starting in May. Thus, it appears that the Atlantic sharpnose shark has its nurseries in shallow coastal waters and estu-

aries from, at least, central Florida to North Carolina.

Scalloped hammerhead, Sphyrna lewini

The scalloped hammerhead is circumtropical. In our area, it ranges from New Jersey to Florida and the Gulf of Mexico. It is one of the most common summer sharks in the estuarine waters of the Carolinas and the Gulf of Mexico (Castro 1983). The young are born at 380–450 mm TL in the estuarine or coastal waters off South Carolina in summer (Castro 1983). Dodrill (1977) stated his belief that, off Melbourne Beach, parturition occurred close to shore as early as 1 June, based on the presence of adult females inshore during June and on the capture of a free swimming juvenile 382 mm TL with an unhealed umbilical scar in the surf off Melbourne Beach, on 1 June. He also reported that young juveniles 600–650 mm TL were found in the surf zone at Melbourne beach from mid-November to January.

In the hook and line sports fishery off South Carolina adult males were taken frequently, while gravid females were not taken. Springer (1960) and Clarke (1971) have stated their belief that the females do not feed just prior to delivery. Dodrill (1977) also reported a notable lack of hook and line landings of adult *S. lewini* while neonates were being caught off central Florida. The very few gravid females that I saw off South Carolina were taken in gillnets or in shrimp trawls in shallow water less than 3 m. Of three gravid females seen from 31 May to 12 June, it was possible to examine only one. This was a 274 mm TL female caught in about 2–3 m depth in Bulls Bay on 31 May 1984. It carried 20 pups, 312–420 mm TL. Neonates are seen off South Carolina as early as May. A neonate 400 mm TL was caught off Folly Beach 19 May 1981. Four neonates were caught off Morris Island on 19 May 1982, the smallest measuring 435 mm TL. I found that neonates bearing unhealed umbilical scars and larger juveniles were very common in both shrimp trawls off Charleston and in gillnet catches in Bulls Bay throughout the summer (Table 8). A 561 mm TL specimen caught 20 August 1992 had a healed umbilical scar visible only as a dark line 9 mm long, while a larger specimen 598 mm TL caught on that date had no visible umbilical scar. These observations and those of Dodrill (1977) and Wright (1981) indicate that the scalloped hammerhead has a very extensive nursery area along the east coast, ranging from central Florida to South Carolina. However, based on the few neonates or very small juveniles cited by Dodrill (1977) and Wright (1981) off Florida, it appears that the center of the nursery lies further north, probably off South Carolina.

Table 6. Atlantic sharpnose shark, number of embryos and size from term females from South Carolina nurseries.

Date	Female TL	# embryos	Embryo TL
12 May 1988	983 mm	5	302–311 mm
18 May 1982	998 mm	3	318–325 mm
18 May 1981	898 mm	2	327,327 mm
24 May 1981	1040 mm	5	330–335 mm
25 May 1983	860 mm	2	344,344 mm
24 May 1981	945 mm	4	321–325 mm
10 Jun 1979	964 mm	6	339–345 mm
11 Jun 1987	960 mm	5	297–307 mm
11 Jun 1987	980 mm	4	297–312 mm
11 Jun 1987	985 mm	4	287–293 mm
14 Jun 1987	1060 mm	6	334–351 mm
14 Jun 1987	930 mm	6	257–297 mm

Smooth dogfish, Mustelus canis

The smooth dogfish inhabits the western North Atlantic from the Bay of Fundy to Florida and the Gulf of Mexico, being common from Cape Cod to Charleston (Castro 1983). Off New England, the young are born between early May and mid-July, when neonates are often caught in pound nets (Bigelow & Schroeder 1948). The young are born at 340–390 mm TL. I found smooth dogfish gravid females and neonates with fresh umbilical scars to be quite common off South Carolina in late April and

Table 7. Embryo number and size from term female Atlantic sharpnose sharks from Daytona Beach nurseries.

Date	Female TL	# embryos	Embryo size
07 May 1991	1060 mm	7	351–379 mm
30 May 1986	991 mm	6	349–368 mm
30 May 1986	965 mm	5	292–349 mm
31 May 1986	965 mm	5	318–337 mm
31 May 1986	1016 mm	6	323–337 mm

May, just prior to the northward migration of the adults. Juveniles are occasionally caught throughout the summer: a 402mm TL juvenile was caught off Kiawah Island on 3 June 1982. Thus, the nursery area of the smooth dogfish population off the mid-Atlantic states appears to extend from New England to South Carolina, perhaps encompassing the range of that population.

Other species having nurseries along the coast of the southeastern United States

Lemon shark, Negaprion brevirostris

Adults of the lemon shark have been reported from New Jersey to Brazil (Bigelow & Schroeder 1948). It is a summer visitor off North Carolina, and only a stray to the north. It is common from South Carolina to Florida (Castro 1983). Along the east coast of North America, lemon shark nurseries are found in the shallow banks, lagoons, and flats around mangrove islands of Florida Bay and the Bahamas (Springer 1950, Gruber 1988). Gravid females carrying term pups measuring about 600mm have been observed in Florida Bay in May and June, swimming in very shallow water (Springer 1950). Wright (1981) reported catching newborn lemon sharks (610–650mm TL) during June and July in Florida Bay and in Biscayne Bay.

Gravid females with term pups 610–638mm TL were observed on two occasions, on 5 and 7 May in Bulls Bay and Charleston, South Carolina. These were the only two gravid females seen in the area in about ten years, although large males were commonly caught in bays at night. Based on the size of the pups and the time of the year, it appears that those females were about to give birth in the area. However, neonates were never observed in the area, in spite of extensive sampling of the shrimp trawl and gillnet catches. The smallest lemon shark I saw in the area measured 1023mm TL, and was caught on hook and line off Bird Key, near Charleston, on 3 August 1979. Therefore, the known nursery area of the lemon shark must be confined to South Florida and the Bahamas, until there is confirmation of parturition off South Carolina.

Gruber (1988), who studied the lemon shark in Bimini very extensively, reported that young lemon sharks are confined to the nursery grounds in the shallow seagrass flats around mangroves nursery grounds during the first year or two of life, and that juveniles remain within lagoons for at least the first five years of life. The home range of lemon sharks expands as the shark grows and when sufficiently large, they leave the lagoon to forage in deep reefs (Gruber 1988).

Table 8. Scalloped hammerhead, free swimming neonates and small juveniles from Bulls Bay and condition of umbilical scar.

Date	TL mm	Umb. scar mm
07 Jun 1990	441	Open, 3mm
15 Jun 1990	421	Open, 2mm
15 Jun 1990	420	Open, 3mm
18 Jun 1990	347	Open, 2mm
18 Jun 1990	433	Open, 3mm
18 Jun 1990	425	Healed
21 Jun 1990	463	Healed
21 Jun 1990	469	Healed
02 Aug 1990	490	Healed
02 Aug 1990	492	Not visible
04 Aug 1990	543	Not visible
10 Aug 1990	446	Healed
10 Aug 1990	541	Not visible
18 Aug 1992	512	Not visible
20 Aug 1992	561	Healed
20 Aug 1992	598	Not visible

Bull shark, Carcharhinus leucas

The bull shark is a cosmopolitan species that ranges in the western North Atlantic from North Carolina to Brazil, occasionally north to the vicinity of New York (Bigelow & Schroeder 1948). The nursery areas of the bull shark are in brackish water estuaries (Springer 1967). On the east coast, the bull shark uses the brackish lagoons of the central east coast of Florida as a nursery. Females 2400–2650mm TL, most carrying near term embryos (590–800mm TL), begin to appear in shallow inshore waters in late April (Clark & von Schmidt 1965, Dodrill 1977). Gravid females apparently leave the beach areas from May to July and enter the Indian River lagoon system to give birth. Dodrill (1977) never captured a female carrying full-term embryos from Brevard County beaches; nor captured newborn

young along the beaches during that period. Snelson et al. (1984) reported a female carrying embryos 608–706 mm TL collected on 8 May in Mosquito Lagoon, and stated that parturition apparently takes place in lagoonal waters in June and July. Females appear to leave the lagoon after birth (Dodrill 1977). Snelson et al. (1984) reported capturing small specimens, 735–858 mm TL, some bearing umbilical scars in the Indian River lagoon system from June to August. How long the pups stay in the shallow lagoons is not precisely known. Dodrill (1977) reported catching newborn bull sharks in the Indian River in July and August and that the newborn were absent in beach landings in June and July. Dodrill (1977) reported surf zone landings of bull sharks less than 1000 mm TL in November and January, suggesting that bull sharks do not remain continuously in the lagoonal system through out their first year of life. Thorson (1976) working in Nicaragua, reported that neonate bull sharks (500–800 mm TL) congregate in fresh water nurseries, and that juveniles 800–1000 mm were almost completely absent from freshwater and that they were presumably at sea. Snelson et al. (1984) suggested that some newborn *C. leucas* may move seaward through inlets to populate inshore coastal waters, perhaps spending an obligatory period at sea, and that the absence of winter captures of young sharks in the lagoons may reflect inactivity rather than emigration. If pups do leave the estuary during their first winter, many return the following spring. Juveniles 1200–1800 mm are present in lagoon waters year-round and apparently reside there for an unknown period of time, until they begin sexual maturation (Snelson et al. 1984). I saw juveniles 1500–1800 mm TL only occasionally in the South Carolina estuaries. A very large female carrying 600 mm TL pups was caught on 20 June 1990 in Bulls Bay. This was the only gravid female with large pups seen in the area by me.

Discussion

Most species of shallow water or coastal carcharhinid sharks appear to have specific nurseries where the young are born and where they spend their first weeks, months, or years. These nurseries are usually in shallow water, or at least in shallower waters than the areas inhabited by the adults. Springer (1967) stated that the only important predators of sharks are other sharks and that stomach contents gave ample evidence that sharks eat other smaller sharks. He also speculated that the young are produced in specific shallow water areas because they are relatively free from predation there, as large sharks are not usually found in shallow water. Bass et al. (1973, 1975) gave evidence for predation on sharks by larger sharks. Van der Elst (1979) also provided some evidence for large shark predation on small sharks. He analyzed twenty-one years of sports fishery catch return data to detect trends in shark catches off Natal, South Africa. The removal of large sharks from the study area resulted in a proliferation of juvenile sharks and small species. Van der Elst (1979) stated that *C. obscurus* and *O. taurus,* captive in the research tank of the Oceanographic Institute, very rarely eat any of the hundreds of teleosts present in the tank but instead they show a marked preference for small sharks. Predation by larger sharks include smaller conspecifics, for many species are known to be cannibalistic (Gruber 1988, Snelson et al. 1984, Dodrill 1977).

Many nurseries are located in high productivity areas such as coastal marshes, estuaries, or seagrass and mangrove ecosystems, where the abundant small fishes and shrimp provide food for young sharks. The juveniles remain in the nursery areas growing relatively rapidly for the first few months. In tropical waters, juveniles may reside continuously in the nursery for a few years. In temperate zones, cold winter temperatures force young sharks out of the nurseries into deeper waters or southward. They return to shallow coastal waters in the spring, usually preceding the appearance of the adults in those areas by a few weeks. In the fall the juveniles remain in the nursery for a few weeks after the adults have departed for warmer waters. In both tropical and temperate areas, juveniles remain in the nurseries, or at least remain there through most of the year, until they reach a size that allows them to join adult stocks. It is likely that, for some species, the nursery area may encompass more than one type of habitat. Given the prolonged maturation process of sharks, different ontogenetic stages may

utilize different habitats. The winter nurseries and the utilization of different habitats by different ontogenetic stages remain to be studied.

The shallow coastal waters of Bulls Bay and the adjacent barrier islands are a nursery for blacknose, spinner, finetooth, blacktip, sandbar, dusky, Atlantic sharpnose, scalloped hammerhead, and smooth dogfish sharks. The nursery is a shallow water, high productivity area where shrimp and small fishes, such as menhaden, are very abundant throughout the warmer months. In this nursery, dusky sharks give birth in April. Smooth dogfish give birth in April and May. The finetooth shark gives birth from the last week in May to the third week in June. The Atlantic sharpnose gives birth from the third week in May to the second week in June. The blacknose, blacktip, and sandbar give birth in June. The spinner and the scalloped hammerhead give birth in May and June. The young of the dusky shark leave the area shortly after birth, presumably they migrate north towards cooler waters. The young of the smooth dogfish also seem to migrate out of the area, although a few are caught in the summer. The young of the other species remain in the area until the fall.

In most of the carcharhinid sharks that have been studied (finetooth, sandbar, blacktip, lemon, spinner, and bull), the gestation and ovarian cycles run consecutively. Females give birth early in the summer, and, after parturition, they begin to develop the next batch of oocytes. These fish will ovulate and mate the following summer. Then, they will gestate for a year and give birth early in the summer of the second year. Thus, in late spring and early summer mature females can be observed bearing either ripe oocytes or term pups. Based on landings observed early in the summer in Bulls Bay the populations of the finetooth, sandbar, and blacktip sharks were divided into two groups. Half the mature females were found to be bearing ripe oocytes and mating bites, while the other half were carrying term young and giving birth. Gillnet catches in the area demonstrated that the gravid females are found in shallower water than the mating females. Shallow water sets produced gravid females while sets in deeper water produced mating females. Thus, in some species, only half of the adult female stock, the gravid females about to give birth, will enter the nursery in a given year.

In the scalloped hammerhead and in the Atlantic sharpnose shark, the ovarian and gestation cycles run concurrently. In late May and early June, mature, gravid females carry ripe oocytes and term pups. (The exception to this is just-matured females that carry only ripe oocytes.) These species drop their pups and mate shortly after parturition. Preliminary data on other sphyrnids, the bonnethead and the great hammerhead, indicates that they probably also have yearly reproduction. It is interesting to note that these species with yearly, instead of biennial, reproduction all share appendiculae on the umbilical cord. The relationship, if any, between appendiculae and yearly reproduction in placental sharks remains to be explored.

Our present knowledge of the nursery areas of the shallow water or coastal species of sharks is fragmentary. These knowledge gaps must be filled if we are to have effective, species-specific management of our shark resources. Effective management of the shark fishery will also require knowledge of other species in the fishery. It is likely that the oceanic, pelagic species, such as shortfin mako, *Isurus oxyrinchus,* oceanic whitetip shark, *Carcharhinus maou,* thresher shark, *Alopias vulpinus,* bignose shark, *Carcharhinus altimus,* and great hammerhead, *Sphyrna mokarran,* also have discrete nurseries. The delineation of their nursery areas must await future advances in our knowledge of those sharks.

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