Shark nurseries in the northeastern Gulf of Mexico

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Introduction

The importance of nursery areas for the conservation and maintenance of shark populations is becoming recognized by fishery management agencies. Since 1994, reports from the shark evaluation workshop (NMFS 1994, 1996, 1998) and the Fishery Management Plan for Highly Migratory Species (NMFS 1999) have identified the need for further delineation of nursery grounds with the monitoring of stocks in these areas.

In general, shark nurseries are areas hypothesized to be where gravid females give birth to young or lay eggs, and where the young spend their first weeks, months or years (Springer 1967). Castro (1993) reported that nurseries are usually located in geographically discrete areas in highly productive shallow waters, such as coastal marshes and estuaries, where the young can find abundant food. Springer (1967) 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. Further, Bass (1978) divided nursery areas into primary, areas where parturition occurs and the young occur for a short time, and secondary, areas where juveniles occur after leaving the primary nursery.

Abundance and species distributions of juvenile sharks may be related to a host of environmental parameters including but not limited to depth, bottom type, salinity, and temeperature. Shark nursery habitats have been reported in a variety of coastal habitats including bays (Simpfendorfer and Milward 1993; Musik et al. 1993; Castro 1993; Heuter and Manire 1994; Pratt and Merson 1996); estuaries (Snelson et al. 1984; Williams and Schaap 1992;); and coral reef lagoons (Clarke 1971; Stevens 1984; Gruber et al. 1988).

Although documentation of shark nursery areas has occurred along the US east coast (Musick et al. 1993, Castro 1993, Pratt and Merson 1996), the presence of shark nursery areas has been poorly documented in coastal areas of the northeast Gulf of Mexico (Carlson 1999). Along the Gulf of Mexico coastline there are many bays and estuarine habitats which may serve as nurseries. Habitats range from near-oceanic conditions to shallow-brackish water seagrass beds. Are these different habitats of varying importance for coastal sharks? Which species prefer which habitats? The objectives of this study were to report on the occurrence of shark nursery areas from coastal areas of the northeastern Gulf of Mexico. Further, attempts are made to quantitavely characterize nursery areas based on environmental characteristics.

Materials and Methods

Sharks were sampled with gillnets and longlines from March 1993-October 2000 as part of various studies on the distribution and abundance of sharks in the northeastern Gulf of Mexico. Because sampling was directed at various objectives, the variability in sampling design and methodology precluded quantification of a index of abundance (i.e., CPUE) throughout the length of the study. In general, gill nets were multi-paneled and ranged in length from 30.4 to 273.6 m. Stretched mesh sizes (SM) ranged from 6.9 cm (3.5”) to 20.3 cm (8.0”). Panel depths when fishing were 1.52 to 3.1 m. Webbing for all panels, except for 20.3-cm, was of clear monofilament, double knotted and double selvaged. The 20.3-cm SM webbing was made of #28 multifilament nylon, single knotted, and double selvage. The nets when set were anchored at both ends and fished on the bottom.

The longline was constructed of a mainline made of 152-m lengths of 425.8 kg-test monofilament line. Each 152-m length was connected by a 15.2-m length of 0.79-cm diameter braided polypropylene line. Depending on the number of hooks fished, the longline ranged in length from 76 to 335 m. Polyethylene floats or weights (1.3 kg) made of 1.5-m lengths of 136-

kg test monofilament line with a snap were attached to the mainline every 30.4 m. Gangions were placed at 15.2-m intervals along the mainline. Gangions (136-kg test) were 0.9-1.8 m long and hooks were size Mustad #12/0 or #3/0. Bait was either menhaden (*Brevoortia* spp.) or Atlantic mackerel (*Scomber scombrus*). The mainline, when set, was tethered to an anchor on each end with a 30.4-m, 0.79-cm polypropylene rope between the anchor and the end of the mainline. A buoy (3.6-m aluminum pole with 1.8-kg weight and 50.8-cm poly float), with a strobe light and flag extended 2.4 m above the float, was attached at each end of the mainline.

Survey design

For each survey period, the sampling gear was randomly set within each area or at a fixed station. Both random and fixed sets were designated on LORAN C coordinates. The nets and/or longlines were set over a 24 hr period at various times. In some surveys, the gillnets were checked and cleared of catch, or pulled and reset every 1.0-2.0 hr. In other surveys, gillnets were set at dusk, left to soak overnight, and hauled back the next day. For longlines, soak time ranged from 1.0-1.5 hr. Following each soak period, the longline was checked and all gangions that had caught sharks, been broken or damaged, or had damaged or lost baits, were removed from the mainline and a fresh-baited gangion attached. Sharks captured using either method were measured to the nearest cm for body lengths (precaudal, fork, total, and stretch total length) and data for sex and life history stage (young-of-the-year, juvenile, adult) were recorded. Sharks that were in poor condition were sacrificed for life history studies and those in good condition were tagged with a nylon-head dart tag and released. When funding permitted, sampling took place April to October of each year, occasionally from November to March.

Environmental data were collected prior to sampling. Mid-water temperature (°C), and dissolved oxygen (mg l^{-1}) was measured with a YSI Model 55 oxygen meter and light transmission (cm) was determined using a secci disk. Surface salinity (ppt) was measured with a refractometer. When possible, qualitative bottom type was recorded based on visual observation, sampling with a ponar grab, or visual inspection of the sediment type on the anchor.

Study area

Sampling sites were located in five major areas along the northeastern portion of the Gulf of Mexico, Apalachee Bay to St. Andrews Bay, FL (Figure 1). Physical and chemical characteristics of each area are found in Table 1. The eastern part of this area has irregular coastline, few beaches and enclosed bay systems. Some bay systems contain large amounts of submergent, *Thalassia* spp., *Syringodium* spp and *Halodule* spp., and emergent vegetation, *Spartina* spp. and *Juncus* spp. The western part has numerous barrier islands and sand beaches and is composed of semi-enclosed bays. Tidal amplitude in the bays is highest in Apalachee Bay and generally decreases toward the west.

Apalachee Bay is an open ocean bay without barrier islands separating the area from the open Gulf of Mexico. The bay is broad, shallow (average 3 m), and extends about 15 km offshore. Salinity ranges from 22-36 ppt and tidal amplitude averages 1.1 m. Wave energy is low and the area has large areas of submerged vegetation.

Sampling in the Apalachicola Bay system occurred in an the delta area between 0.5-3 km south of St. Vincent Island in the Gulf of Mexico where water depths average 5-10 m. The bay system surrounding this area is largely a line of barrier islands fronting the intersection of the

Apalachicola delta. As a result of river discharge, there is little submergent vegetation due to high turbidity. Salinity fluctuates from 19-39 ppt and tidal range is 0.73 m.

St. Joseph Bay transcends from a broad, shallow, heavily, vegetated habitat to a relatively deep oceanic habitat. It is connected to the Gulf of Mexico by a deep navigation channel. The southern portion of the bay contains large expanses of *Thalassia* spp., *Halodule* spp., and *Syringodium* spp. The entire bay surface area covers approximately 43,000 acres and maximum tidal range is 0.47 m.

Crooked Island Sound (St. Andrew Sound) is a small semi-enclosed marine lagoon. It is about 14.5 km long and 0.2-2.0 km wide and has water depths from 3.5-4.5 m deep (mean high tide). This system also contains expanses of submergent vegetation but generally only along the edges of the bay where the water depth averages 1-2 m. Salinity ranges from 25-36 ppt and tidal amplitude averages 0.42 m. The sound exchanges water with the Gulf of Mexico through a pass 0.5-2.0 km wide.

St. Andrew Bay consists of several embayments, averages 1.9-5.7 m deep, and covers an area of about 21,500 acres. Because of its proximity to Panama City, FL this bay is subjected to much anthropogenic activity from commercial and recreational activity such as shipping traffic by commercial tankers, municipal and industrial discharge and tourism. Salinity ranges from 13-32 ppt and tidal amplitude averages 0.48 m. The system exchanges water with the Gulf of Mexico via a human-made pass at the western end.

Statistical analysis

When effort was standardized (see Carlson and Brusher, 1999), correlations were examined among the most abundant species captured and environmental variables measured.

Results

Physical data

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Over the study period, a total of 15 species of sharks were collected with gillnets and longlines. For all areas combined, the Atlantic sharpnose shark, *Rhizoprionodon terraenovae*, a member of the small coastal management group, was the most abundant shark captured and the blacktip shark, *Carcharhinus limbatus*, was the most abundant species captured in the large coastal management group, using longlines and gillnets. The bonnethead, *Sphyrna tiburo*, was the second most abundant species captured in the small coastal group and overall was the third most encountered species. The remaining species commonly captured in decreasing abundance were the finetooth shark, *C. isodon*; spinner shark, *C. brevipinna*; blacknose shark, *C. acronotus;* scalloped hammerhead shark, *S. lewini* and sandbar shark, *C. plumbeus.* Other species caught but not consistently captured were Florida smoothhound, *Mustelus norrisi;* bull shark, *C. leucas*; lemon shark, *Negaprion brevirostris*; nurse shark, *Ginglymostoma cirratum*; tiger shark, *Galeocerdo cuvieri*; dusky shark, *C. obscurus* and great hammerhead shark, *S. mokarran*.

Overall species distribution varied by area (Figure -). The Atlantic sharpnose shark and bonnethead were the most abundant species captured in Crooked Island Sound. In Apalachee Bay, the Atlantic sharpnose and blacktip shark were the most frequently encountered. The bonnethead and Atlantic sharpnose shark were most commonly caught in St. Joseph Bay and St. Andrew Bay. The blacktip and finetooth shark were the most abundant species found in Apalachicola.

Tag/recaptures

A total of 1,117 sharks have been tagged and released since 1993 and 50 have been reported recaptured. This represents a recapture rate of 4.5%. The longest time at liberty was 2,461 days for an Atlantic sharpnose shark. This shark was recaptured in the same area, Crooked Island Sound, that it was originally tagged in. The largest distance traveled was for a blacktip shark that was recaptured offshore southwest of Tampa, FL. This shark traveled 205 nautical miles from Apalachicola Bay in 102 days.

Discussion

Comparison of abundance among areas

Despite some apparent differences in abundance among the various sampling areas, caution should be taken when making inferences about the importance of one area over another (using abundance as a indicator) without considering the problem of sampling bias. Because funding was not continuous and sampling was directed at various objectives, prior to 1996 the sampling gear (gillnets and longlines) and sampling strategy varied. Since selectivity functions have not been calculated for all species with the respective gear types, it cannot ascertained whether some species are naturally low in abundance in some areas sampled or whether this is an artifact due to sampling bias.

When effort was standardized (see Carlson and Brusher, 1999), correlations were examined among the most abundant species captured (log transformed CPUE) and environmental variables measured. Multiple linear regression was used to examine the relationship between shark abundance and temperature (°C), salinity (ppt), dissolved oxygen (mg l^{-1}), and light transmission (cm; measured as the depth of the photic zone). A significant relationship was found between abundance of spinner and scalloped hammerhead shark and water temperature (spinner:r^2=0.19, p=0.02; scalloped hammerhead; r^2=0.16, p=0.03), but not with salinity, dissolved oxygen, or light transmission ($r^2$0.05). All remaining species had poor correlation coefficients and non-significant relationships (Table 7).

Juveniles were the dominant life history stage captured in all areas sampled. It appears that species with larger juveniles and young-of-the-year (>50 cm TL) were found in Apalachicola. These species being blacktip, spinner and sandbar sharks. Species with smaller juveniles and young-of-the-year (<50 cm TL) (e.g. Atlantic sharpnose, bonnethead, and blacknose) were captured in more protected areas such as Crooked Island Sound and in the shallower areas of St. Joseph Bay and Apalachee Bay. The difference in spatial distribution among juveniles of different species may reflect an attempt to avoid predation (Springer, 1967; Branstetter, 1990) as all areas appear to have a high forage base. Crooked Island Sound is a small, semi-enclosed sound were few larger adult sharks were found. Thus, species with small neonates and juveniles may be selecting this area as a nursery based on low predation levels. Moreover, larger bull sharks where found in greatest abundance in Apalachicola and tiger sharks were captured only in the deeper areas of Apalachee Bay.

The poor relationship among environmental parameters and abundance suggest that additional environmental parameters not measured could be associated with habitat selection. Relationships may exist on multi-dimensions that would involve more robust statistical analysis that presented herein. Thus, more specific studies are needed to fully evaluate the interrelationships of abiotic and biotic factors and how they affect the abundance and distribution of sharks in nursery areas.

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Literature cited

Brown, C.A., and S.H. Gruber. 1988. Age assessment of the lemon shark, *Negaprion brevirostris*, using tetracycline validated vertebral centra. Copeia(3):747-753.

Branstetter, S. 1990. Early life-history implications of selected carcharhinoid and lamnoid sharks of the northwest Atlantic. *In*: H.L. Pratt Jr., S.H. Gruber and T. Taniuchi (eds.), Elasmobranchs as Living Resources:Advances in Biology, Ecology, Systematics and the Status of the Fisheries. p. 17-28. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 90.

Carlson, J. K., and J. H. Brusher. 1999. An index of abundance for coastal species of juvenile sharks from the northeast Gulf of Mexico. Mar. Fish. Rev. 61:37-45.

Grace, M. and T. Henwood. 1997. Assessment of the distribution and abundance of coastal sharks in the U.S. Gulf of Mexico and eastern seaboard, 1995 and 1996. Mar. Fish. Rev. 59(4):23-32.

Springer, S. 1967. Social organization of shark populations, *In*: P.W. Gilbert, R.W. Mathewson and D.P. Rall (eds.). Sharks, skates and rays. p. 149-174. John Hopkins Press, Baltimore, Maryland.

Clarke, T.A. 1971. The ecology of the scalloped hammerhead, Sphyrna lewini, in coastal lagoons. Hawaii. Pac. Sci 25:133-44.

Grace, M. 1996. Cruise Report: Oregon II. Coastal Shark Assessment. Bottom and Surface Longlining. National Marine Fisheries Service: Pascagoula, MS Laboratory. 17 pp.

Hueter, R.E. and C. Manire. 1994. Bycatch and Catch-Release Mortality of Small Sharks in the Gulf Coast Nursery Grounds of Tampa Bay and Charlotte Harbor. NOAA/NMFS/MARFIN Final Report NA17FF0378-01. 183 pp.

Musik, J.A., S. Branstetter, and J.A. Colvocoresses. 1993. Trend in shark abundance from 1974-

1991 for the Chesapeake Bight region of the U.S. mid-Atlantic Coast. NOAA Tech. Rep. NMFS 115.

Pratt, H.L. & R.R. Merson. 1996. Delaware Bay Sandbar Shark Nursery Pilot Study Progress Report. NOAA/ National Marine Fisheries Service Narragansett Laboratory 23 pp.

Olsen, A.M. 1984. Synopsis of biological data on the school shark Galeorhinus australis (Macleay 1881). FAO Fish. Synop., no. 139.

Simpfendorfer, C.A. and N.E. Milward. 1993. Utilisation of a tropical bay as a nursery area by sharks of the families Carcharhinidae and Sphyrinidae. Env. Biol. Fish. 37:337-345.

Snelson, F.F., Jr., T.J. Mulligan, S.E. Williams. 1984. Food habits, occurrence, and population structure of the bull shark, Carcharhinus leucas in Florida coastal lagoons. Bull. Mar. Sci., vol. 34, no. 1, p. 71-80.

Stevens, J.D. 1984. Life-history and ecology of sharks at Aldabra Atoll, Indian Ocean. Proc. R. Soc. Lond. B. 222:79-106.

Williams, H. and A.H. Schapp. 1992. Preliminary results of a study into the incidental mortality of sharks in gill-nets in two Tasmanian shark nursery areas. Aust. J. Mar. Freshwater. Res. 43:237-250.