FEEDING BEHAVIOR AND BIOLOGY OF YOUNG SANDBAR SHARKS, *CARCHARHINUS PLUMBEUS* (PISCES, CARCHARHINIDAE), IN CHINCOTEAGUE BAY, VIRGINIA[1]

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ABSTRACT

During the summers of 1977, 1978, and 1979 the feeding behavior and biology of young sandbar sharks were investigated in Chincoteague Bay, Virginia, using catch data obtained from rod and reel fishing. Mean catch per unit effort for the study was 1.02 sharks per hour, but yearly differences in catch per unit effort were found. Sandbar sharks were not caught before the first week in June despite substantial fishing effort prior to this time, both in 1977 and 1978. Catch per unit effort was higher at night than during the day but was not related to tidal current stage or speed. Captures were made at surface, mid, and bottom fishing depths. During the day, catch per unit effort was highest at the bottom fishing depth but did not differ among the three depths during the night. The blue crab, *Callinectes sapidus*, was found in 41.3% of the stomachs examined; 20% of the stomachs were empty, and the remainder contained various crustaceans and fishes. The proportion of empty or nearly empty stomachs was greater for night captures than for day captures. Yearly differences in sex ratio existed and the total length distribution of sharks measured suggested the presence of relatively distinct size classes.

The natural history of the sandbar shark, *Carcharhinus plumbeus*, has received considerable attention and is relatively well known. Tag returns (Casey 1976) and analysis of commercial shark fishery records (Springer 1960) have provided valuable information on the distribution and long-term movements of this species. These studies show the sandbar shark to be an abundant, migratory shark distributed in the western North Atlantic from Cape Cod, Mass., to West Palm Beach, Fla., during the summer and from the Carolinas into the Gulf of Mexico in the winter. From spring until late fall, young sandbar sharks spend much of their time along the mid-Atlantic coast in nursery areas consisting of shallow bays and sounds. In late fall the young move farther offshore and south to wintering grounds between North Carolina and Florida. According to Casey (1976), the young may repeat this cycle for up to 5 yr and then begin to occupy areas farther offshore and undertake longer north-south migrations. Other studies have made contributions concerning growth (Wass 1973), reproduction (Taniuchi 1971), and general ecology (Bigelow and Schroeder 1948; Clark and von Schmidt 1965; Bass et al. 1973; Lawler 1977).

One area in which information is lacking, not only for this species but for sharks in general, concerns feeding behavior. Although work has been conducted on the prey items of sharks (Bigelow and Schroeder 1948) and the role of various sensory modalities in locating prey (Hobson 1963; Kleerekoper 1969; Myrberg et al. 1976; Hodgson and Mathewson 1978; Kalmijn 1978), these areas have received little attention and are little understood. Other areas of feeding behavior such as food requirements and feeding activity have received even less attention.

The specific objective of this study was to determine patterns of feeding activity of young sandbar sharks in relation to the time of day, tidal cycle, and vertical positions within the water column. Because information on sandbar sharks in nursery areas is scarce, data concerning the food items, abundance, sex ratio, and age-class composition of this species in Chincoteague Bay are also presented.

METHODS

This study was conducted from early May through late August during 1977 and 1978 and on

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12 July 1979 in the lower portion of Chincoteague Bay, Va. (Figure 1). Located within the summer distribution of this species, the bay supports a relatively large number of young sandbar sharks from early June through September (pers. obs.). Average water depth of the bay is 2 m, but many areas with strong current flow have depths as great as 12 m. A tidal inlet connects the bay with the Atlantic Ocean and tidal range varies from 0.75 to 2.00 m. Salt marshes with numerous tidal creeks, brackish to seawater salinities, and other conditions which seem typical of the nursery grounds of this shark along the middle Atlantic coast also characterize the area.

A 4.9 m outboard motorboat was used as a fishing platform and sharks were caught using sport fishing rods with 3/0 Penn[4] reels. Terminal tackle consisted of a 0.3 m wire leader with a straight-shank, ball-eye fishing hook. To increase fishing effort, two leaders were attached (0.5 m apart) on each fishing line. To facilitate captures over the entire size range of sharks in the area, each line was rigged with a 3/0 and a 8/0 hook. A lead sinker or cork float was attached to adjust the lines to the desired fishing depth. Cut pieces of freshly frozen Atlantic menhaden, *Brevoortia tyrannus*, were used as bait and each hook was rebaited hourly. Nothing was thrown into the water to attract sharks except the bait. Upon capture each shark was brought into the boat where it was identified, sexed, and measured. The shark was then either tagged and released or sacrificed for stomach content analysis.

The type of fishing conducted fell into two categories. On 10 occasions, continuous fishing stations of approximately 24-h duration were completed (three in 1977, six in 1978, and one in 1979). These stations occurred at 10 different locations (Figure 1), each with a water depth >3 m. On all stations, the boat was anchored and three rods (rigged and baited as described above) were used with a rod fishing at the surface, middepth, and bottom. Fishing technique was standardized from station to station. After catching a shark, the rod was immediately replaced by another so that fishing effort was not interrupted. On 52 other occasions (20 in 1977 and 32 in 1978), shorter fishing periods were completed at randomly selected locations. The duration of these fishing periods and the time of day that they were conducted varied, but in a random fashion. The same fishing gear was employed at these times, but shallow as well as deep areas were fished. These shorter fishing periods are hereafter referred to as miscellaneous fishing stations. During both types of fishing, data concerning tidal current flow and water temperature were collected.

Strikes by fishes not captured were not included in the analysis of data. For each fishing station, catch per unit of effort (CPUE) was calculated by dividing the total number of sharks caught by the total number of hours spent fishing. CPUE is expressed as the number of sandbar sharks caught per hour of fishing using the three fishing rods previously described. CPUE was also calculated for various comparison categories within fishing stations such as day and night periods. For comparison categories involving fishing depth, CPUE at each depth was based on one fishing rod. Where mean CPUE is referred to in the results, the value is the arithmetic mean of CPUE values calculated for each fishing station. Because values of CPUE were not normally distributed, nonparametric methods of data analysis were employed. The tests used are described by Hollander and Wolfe (1973). Due to the large number of statistical comparisons made, many of the test names and probability values are given in tables rather than in the text of the results.

[4]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

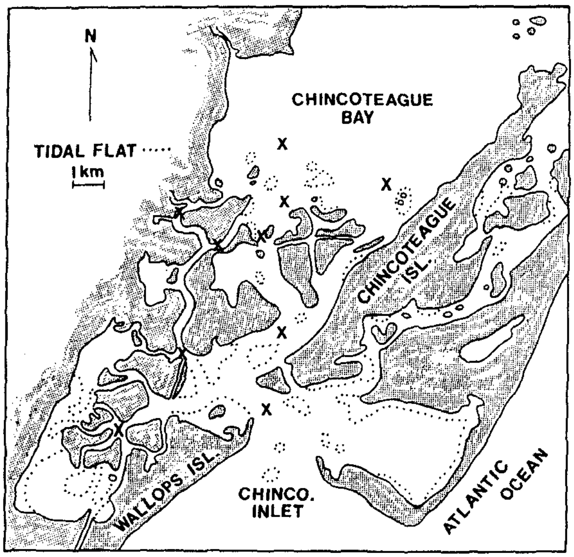

FIGURE 1.—Chart of the Chincoteague Bay study area (modified from National Ocean Survey Charts 12210 and 12211). x's give the locations of the 10 24-h fishing stations.

RESULTS

A total of 73 h from 17 fishing stations conducted in May 1977 and 1978 resulted in no catches. The first catch occurred on 6 June 1977 and on 1 June 1978 at water temperatures of 20.5° C and 21.0° C, respectively. After the initial catch, sandbar sharks were caught consistently and CPUE did not differ significantly among June, July, and August during either year (Table 1).

The number of catches and hours of fishing conducted after the arrival of sandbar sharks are summarized in Table 2. A total of 318 sharks were caught in 478 h of fishing. Mean CPUE for the 62 fishing stations was 1.02 sandbar sharks/h. CPUE varied among the 3 study yr (Table 3). CPUE in 1979 was 2.06 sandbar sharks/h, but was based on only one 24-h fishing station. In 1977 and 1978, CPUE was based on numerous fishing stations and was significantly higher in 1977.

Sandbar sharks were caught during all hours of the day and night. CPUE was calculated at 1-h intervals for each 24-h fishing station, but because of the relatively small sample size, numerous observations of zero CPUE, and great station-to-station variation in CPUE, these data were not sufficient for a statistical analysis of diel rhythmicity. Visual inspection did suggest a day-night difference in CPUE. On all but one 24-h station, CPUE was higher during the night than during the day. Grouping the data on this more general level and treating day and night observations (on CPUE) as samples paired on fishing station indicates CPUE was significantly higher during the night than during the day (Table 4).

CPUE did not differ significantly between flood and ebb tidal current periods (Table 4). During both current periods CPUE was higher during the night than during the day, but, because of multiple testing on the same data, the probability values given for the tests should be considered as only rough approximations (Table 4).

Catch data were grouped into four tidal current speed categories. Sandbar sharks were caught over the entire range of current speeds recorded during 24-h stations and CPUE was not significantly different among the four current speed categories (Table 5).

CPUE was calculated for the three fishing depths used during 24-h fishing stations. Although sandbar sharks were caught at all three depths, CPUE differed significantly among them (Friedman test, $P = 0.02$) and was higher at the bottom than at the surface or middepth. CPUE did not differ significantly between the surface and middepth (Table 6). The difference in CPUE among the depths was not the same for both day

TABLE 1.—Summary of fishing data for the 3 study mo of 1977 and 1978. The value given for "Mean rank" is the mean of the ranks assigned to the observations on CPUE in a Kruskal-Wallis test for differences in CPUE among months within the indicated year.

Year	Month	No. of fishing stations	Mean CPUE (sharks/h)	Mean rank	*P*-value
1977	June	13	1.46	16.1	
	July	5	1.63	13.4	0.46
	Aug.	5	.92	13.4	
1978	June	17	.63	17.3	
	July	12	.64	20.2	.47
	Aug.	9	1.21	22.8	

TABLE 2.—Summary of fishing data for 24-h stations, miscellaneous stations, and all stations combined.

Stations	Hours of fishing	No. of sharks caught	No. of stations	Mean CPUE (sharks/h)
24 h	232	160	10	0.67
Miscellaneous	246	158	52	1.07
Overall	478	318	62	1.02

TABLE 3.—Summary of fishing data for each study year. The value given for "Mean rank" is the mean of the ranks assigned to the observations on CPUE in a Mann-Whitney U-test.

Year	Hours of fishing	No. of sharks caught	No. of fishing stations	Mean CPUE (sharks/h)	Mean rank	*P*-value (2-tail test)
1977	128	119	23	1.39	39.2	0.005
1978	325	148	38	.76	26.0	
1979	25	51	1	2.06		

TABLE 4.—Summary of fishing data for various periods during 10 24-h fishing stations. The values given for "Rank sums" are the sums of the positive and negative differences of paired observations on CPUE in a Wilcoxon signed rank test. Differences for day-night and for day-night by current stage categories were for CPUE during the night minus CPUE during the day. Differences for the flood-ebb category were for CPUE during flood minus CPUE during ebb. Dusk and dawn periods were split equally between day and night categories.

Period	Hours of fishing	No. of sharks caught	Mean CPUE (shark/h)	Rank sums (+)	Rank sums (−)	*P*-value (2-tail test)
Day	143	85	0.56	48	7	0.04
Night	89	75	.86			
Flood	115	90	.75	39	16	.28
Ebb	117	70	.55			
Flood-day	76	49	.62	45	10	[1].08
Flood-night	38	41	.78			
Ebb-day	67	36	.41	47	8	[1].04
Ebb-night	51	34	.65			

[1]Probabilities should be considered as rough approximations because of multiple testing on the same data.

TABLE 5.—Summary of fishing data for tidal current speed categories during the eight 24-h fishing stations in which current speed was recorded. The value given for "Rank sum" is the sum of the ranks assigned to the observations on CPUE for that current speed category in a Friedman test.

Current speed (m/min)	Hours of fishing	No. of sharks caught	Mean CPUE (shark/h)	Rank sum	*P*-value
<10	36.5	25	0.65	24.0	$0.30<P<0.50$
10-20	42.5	20	.51	16.5	
20-30	52.0	35	.64	17.5	
>30	55.5	42	.63	22.0	

TABLE 6.—Summary of fishing data for the three fishing depths used during the 10 24-h fishing stations. The value for "Rank sum" is the sum of the ranks assigned to the observations on CPUE for that fishing depth in a Friedman test. Vertical lines are used to indicate significantly different CPUE (α = 0.05, multiple comparisons based on Friedman rank sums).

Fishing depth	Hours of fishing	No. of sharks caught	Mean CPUE (shark/h)	Rank sum
Surface	232	32	0.11	15.5
Middepth	232	42	.16	17.0
Bottom	232	85	.37	27.5

and night fishing periods. During the day, CPUE differed significantly among fishing depths and was highest at the bottom. In contrast, during the night no difference in CPUE was found among fishing depths (Table 7). At surface and middepth CPUE was substantially higher during the night than during the day on 9 out of 10 and 8 out of 10 fishing stations, respectively. In contrast, at the bottom CPUE differed little between day and night periods and was not consistently higher or lower during the night. These observations suggest that the above difference between day and night periods (i.e., depth differences in CPUE during the day but not during the night) was a result of increased CPUE at surface and middepth during the night rather than a decrease in CPUE at the bottom.

TABLE 7.—Summary of fishing data for time period-fishing depth categories during the 10 24-h fishing stations. The value given for "Rank sum" is the sum of the ranks assigned to the observations on CPUE for that category in a Friedman test. Vertical lines are used to indicate significantly different CPUE (α = 0.05, multiple comparisons based on Friedman rank sums).

Time period-fishing depth	Hours of fishing	No. of sharks caught	Mean CPUE (shark/h)	Rank sum
Day-surface	143	12	0.07	16.5
Day-middepth	143	21	.13	26.5
Day-bottom	143	52	.37	51.0
Night-surface	89	20	.22	32.5
Night-middepth	89	21	.23	38.5
Night-bottom	89	33	.36	48.5

The stomach contents of 80 sandbar sharks were examined to identify food items (Table 8). Items that could be identified included small crustaceans and fishes that are abundant in the study area (pers. obs.). The blue crab, *Callinectes sapidus*, of all sizes was found in 41% of the stomachs examined (and in over 52% of the stomachs not empty). Two or more different food items were found in 14 stomachs and several stomachs contained unidentifiable items but were very nearly empty. The proportion of empty or nearly empty stomachs (15 empty out of 27 examined) for sandbar sharks caught during the night was significantly greater than the proportion (16 empty out of 53 examined) for sharks caught during the day (2-tailed chi-square test for differences in probabilities, P = 0.04). Stomach contents were, in general, similar for the 3 study yr, both sexes, all sizes of sharks, and tidal current and capture depth categories.

The total number of male and female sharks caught (over all 3 yr) did not differ significantly, but yearly differences in sex ratio were found (Table 9). During 1978 and 1979 about equal numbers of male and female sandbar sharks were caught, but in 1977 significantly more females than males were caught. Sex ratios were consistent among the 3 study mo (June, July, and

TABLE 8.—Stomach contents of 80 young sandbar sharks.

Stomach contents	No. of stomachs found in	Percent of stomachs found in
Blue crab, *Callinectes sapidus*	33	41.3
Unidentified fish	9	11.3
Mantis shrimp, *Squilla* sp.	8	10.0
American eel, *Anguilla rostrata*	7	8.8
Calico crab, *Ovalipes ocellatus*	6	7.5
Puffer, *Tetraodon maculatus*	4	5.0
Atlantic menhaden, *Brevoortia tyrannus*	3	3.8
Rock crab, *Cancer irroratus*	3	3.8
Unidentifiable material	3	3.8
Unidentified crustacean	1	1.3
Unidentified crab	1	1.3
Unidentified shrimp	1	1.3
Bluefish, *Pomatomus saltatrix*	1	1.3
Spot, *Leiostomus xanthurus*	1	1.3
Mummichog, *Fundulus heteroclitus*	1	1.3
Empty stomachs	16	20.0

TABLE 9.—Number of male and female sandbar sharks caught and probabilities for chi-square goodness of fit test (2-tailed) for each year and the entire study.

Year	No. of males	No. of females	*P*-value
1977	24	48	<0.01
1978	60	58	$0.80<P<0.90$
1979	28	22	$.30<P<0.50$
Total	112	128	$.30<P<0.50$

August) both in 1977 and 1978, i.e., unbalanced in 1977 but balanced in 1978. For all study years taken together, the number of male sandbar sharks caught did not differ significantly from the number of females caught during day or night periods, during flood or ebb current periods, at any of the three fishing depths, or for any of the four current speed categories (2-tailed chi-square goodness of fit Test, α = 0.05).

With the exception of one sandbar shark (137.0 cm TL), the catch ranged from 60.0 to 112.5 cm TL. The length distributions for 1977 and 1978 are presented in Figure 2. Both distributions were based on relatively small numbers of sandbar sharks and are no doubt rough approximations of the actual size distributions. The fact that the distributions were not continuous and were characterized by several well-defined peaks does, however, suggest that in both years, the population of sandbar sharks consisted of relatively distinct size classes. Based on only visual inspection of the distributions, it appears that at least 3 and possibly as many as 5 different size classes may have been present. In general, similar size distributions were found for sex, light, tidal current stage and speed, and fishing depth categories.

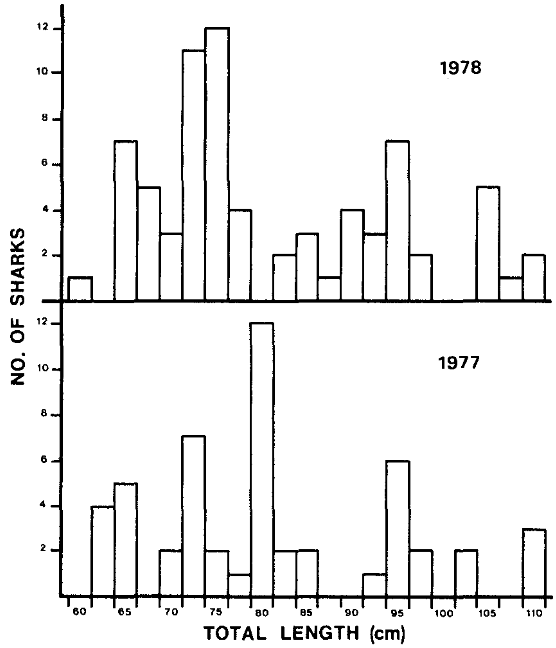

FIGURE 2.—Frequency distribution for total length of sandbar sharks caught and measured in 1977 and 1978. The total length given for each interval is the beginning length for that 2.5 cm wide interval.

DISCUSSION

Despite many hours of fishing, no sandbar sharks were caught before the first week of June either in 1977 or 1978, suggesting they were not present in the area during this time. Local fishermen who commonly catch numerous sharks in their gill nets also did not encounter sandbar sharks over this period; it appears that few, if any, sandbar sharks had migrated into the Chincoteague Bay area before the first week in June during these years. The consistency in CPUE among months within each year (Table 1) suggests that the abundance of sandbar sharks remained relatively constant in June, July, and August.

The mean CPUE of 1.02 sandbar sharks/h for the study indicates that the Chincoteague Bay area supports a large number of young sandbar sharks during the summer. The factors responsible for yearly differences in CPUE (Table 3) are unknown. Because fishing locations and times were selected in a random fashion and fishing technique was standardized over the entire study, it is unlikely that the differences were a result of the methods employed. Year-to-year changes in population numbers and/or shifts in distribution resulting in local differences in abundance may have been involved.

The significantly higher CPUE experienced during the night (Table 4) may relate to day-night differences in 1) the abundance of sandbar sharks in Chincoteague Bay, 2) the availability of prey, 3) the visual "attractiveness" of the bait, or 4) the feeding activity of young sandbar sharks.

Movements of sandbar sharks out of Chincoteague Bay to adjacent ocean waters during the day and back into the bay during the night could result in the observed differences. The movements of 23 sandbar sharks tracked in this area (Medved unpubl. data) were strongly oriented in the direction of tidal current flow and do not suggest a day-night pattern of movement into and out of the bay.

A decrease in the availability of various prey species could also account for increased CPUE during the night. Observations confirmed by local crab fishermen indicate that the blue crab (the most common food item found in the stomachs examined) is frequently found swimming near the water's surface during the night but rarely during the day. This difference in behavior would seem to make the blue crab more accessible and would probably tend to decrease rather than increase CPUE during the night.

Differences in the visual attractiveness of the bait used to catch sharks may have existed, but the limited visibility (<1 m) in the turbid waters of the area suggests that vision was probably of little importance in feeding behavior. Experiments conducted on various species (Hobson 1963; Hodgson and Mathewson 1978; Kalmijn 1978) have shown the ability of sharks to locate food by means other than vision and that feeding behavior is directed towards almost any object present in a high concentration of olfactory material. These experiments indicate that the importance of vision may be only to direct the final act of feeding. It appears doubtful that day-night differences in the visual attractiveness of the bait were responsible for increased CPUE during the night.

Finally, the night hours may simply be a period of increased feeding activity for young sandbar sharks in this area. The existence of such a diel pattern would not be surprising in that similar rhythmicity for various activities (including feeding) has been reported for several sharks (Springer 1963, see footnote 5; Randall 1967; Hobson 1968; Nelson and Johnson 1970; Myrberg and Gruber 1974; Finstad and Nelson 1975; Sciarrotta and Nelson 1977).

Numerous catches at surface and middepth (Table 6) suggest that the young of this species occur throughout the vertical range of the water column. This would appear to be in conflict with Springer's (1960) statement that sandbar sharks are properly considered "ground sharks," rarely seen at or near the surface. However, most of Springer's observations were apparently made on adult sandbar sharks. The conflict may simply indicate differences between the young and adults of this species. The increase in CPUE at surface and middepth at night (Table 7) suggests that the tendency of sandbar sharks to move into these areas may have been greater at night and possibly related to the movements of blue crabs discussed earlier.

In general, food items taken by this shark (Table 8) agree with those reported by other authors (Bigelow and Schroeder 1948; Springer 1960; Clark and von Schmidt 1965; Bass et al. 1973; Lawler 1977). The fact that the blue crab was by far the major prey item may simply reflect its abundance in the area rather than a specific food preference. Wass (1973) indicated that food is retained within the stomachs of sandbar sharks for periods of 2-4 d or more, depending on the consistency of the item. The relatively large proportion of empty stomachs observed in this study would then indicate that the young of this species may frequently go at least several days without feeding. Whether this is by choice or imposed by difficulties in capturing food is uncertain. The higher proportion of empty stomachs observed for sandbar sharks caught during the night than for those caught during the day may relate to the possible day-night difference in feeding activity previously mentioned.

Selectivity in the fishing method employed may account for the observed yearly differences in sex ratio (Table 9). Assuming equal numbers of both sexes in the area, the method must have been selective for females in 1977 but not in 1978 and 1979. Considering that the same methods were employed in all years, it appears that the proportion of male and female sharks utilizing the area may have varied among years.

It seems that sandbar sharks >112.5 cm TL rarely occurred in the study area (Figure 2). The failure to capture larger sharks was not felt to be related to the fishing method because this method has yielded numerous large sandbar sharks in offshore areas (pers. obs.). A period of approximately 9 mo separates successive year classes of sandbar sharks (Springer 1960), and age determinations using vertebral annuli indicate relatively rapid rates of growth for the first several year classes (Lawler 1977). Lawler's growth rates suggest that the relatively distinct size classes apparent in this study were probably a reflection of the various year classes of sandbar sharks present in the area. The impression of the existence of 3 to 5 different age-classes given by the size distributions also agrees with Casey's (1976) contention that young sandbar sharks may occupy nursery ground areas for up to 5 yr before moving farther offshore.

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