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Habitat Use and Movements of Shortnose and Atlantic Sturgeons in the Lower Cape Fear River, North Carolina

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Abstract.—We conducted a gill-net survey and used sonic tracking to document the distribution and movements of adult shortnose sturgeons *Acipenser brevirostrum* and juvenile Atlantic sturgeons *Acipenser oxyrhynchus* in the lower Cape Fear River, North Carolina. Shortnose sturgeons were rare; only eight fish were captured from 1990 to 1993. The five fish we tracked occupied river kilometer 16–96 from early January to May. The presence of gravid females and the rapid (11.5–27.0 km/d), directed upstream migrations we observed provided evidence that shortnose sturgeons may attempt to reproduce in this drainage. We also documented the disruption of spawning migrations by dams and incidental gill-net capture, which may prevent these fish from ever reaching their spawning grounds. Atlantic sturgeon juveniles were relatively common and preferred deep areas (>10 m) in the vicinity of the saltwater–freshwater interface (km 46). In summer they held position for extended periods and apparently fasted, but were more active (1.3 km/d) and ranged over a greater area during cooler water temperatures in fall, winter, and spring. Both species occupied regularly dredged areas and were present during dredging operations in the Wilmington Harbor.

Shortnose sturgeon *Acipenser brevirostrum* and Atlantic sturgeon *Acipenser oxyrhynchus* co-occur throughout most of their ranges (southeastern Canada to Florida). The shortnose sturgeon is found primarily in riverine and estuarine areas, whereas the Atlantic sturgeon occupies these habitats but also makes extensive coastal migrations (Gilbert 1989). Sturgeons historically supported a valuable commercial fishery in North Carolina. In the late 1800s the largest landings in the southeastern USA were recorded from the Cape Fear River (McDonald 1887). It is impossible to track landings of each species separately because their catch records were combined (Smith 1985). By the early 1900s the sturgeon fishery had declined dramatically in North Carolina (Smith 1907). Now the shortnose sturgeon is a federally listed endangered species, and the Atlantic sturgeon is considered threatened in North Carolina (Ross et al. 1988). Consequently, both recreational and commercial sturgeon fishing was banned in the state, starting in 1991.

Both sturgeon species have been extensively studied in the northern part of their range (Brundage and Meadows 1982; Dadswell et al. 1984; Lazzari et al. 1986; Kieffer and Kynard 1993; O'Herron et al. 1993) but very few studies have documented sturgeon habits in the southeastern USA (Dadswell et al. 1984; Hall et al. 1991). It was unclear that shortnose sturgeons even occurred in North Carolina until 1987, when a gravid adult was captured in the Brunswick River, a relatively undisturbed tributary of the lower Cape Fear River (Ross et al. 1988). Although Atlantic sturgeons are regularly caught in North Carolina, details of their distribution patterns and habitat preferences are unknown (Ross et al. 1988). Whether or not sturgeons are affected by dredging operations, low-elevation dams, and incidental capture is also unknown. In this study we documented the relative abundance, seasonal occurrence, habitat use, and movements of adult shortnose sturgeons and juvenile Atlantic sturgeons in the lower Cape Fear River. We also compared the two species' use of both routinely dredged and undisturbed areas, and noted the effects of a low-elevation dam and gill-net capture on migrating shortnose sturgeons.

Study Area

The Cape Fear River estuary is a drowned river valley, characterized by tidally driven currents,

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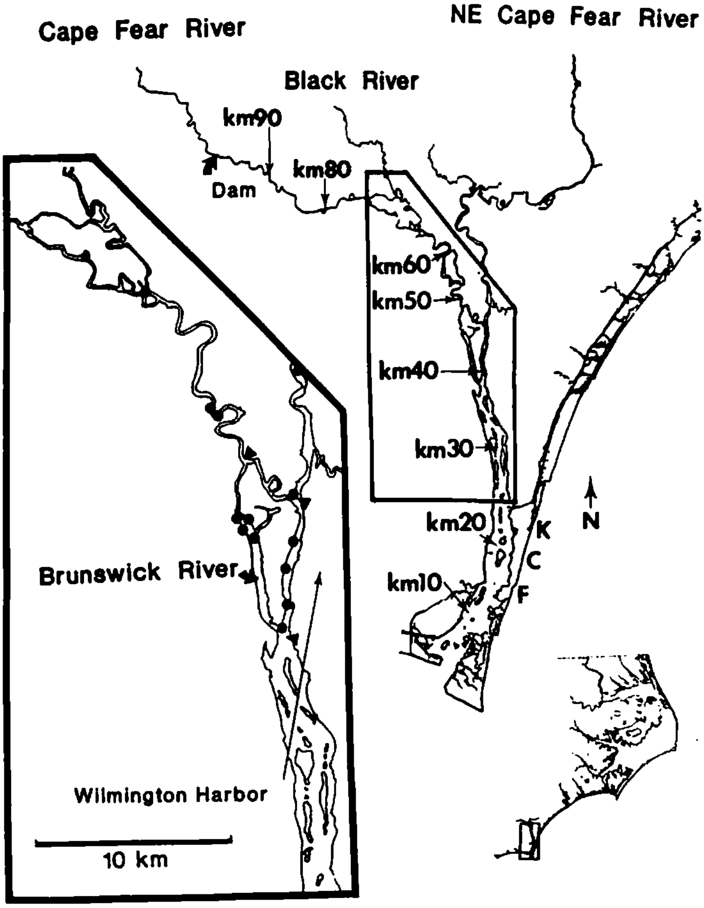

FIGURE 1.—Study area in the lower Cape Fear River, North Carolina, with the region from km 20 to 75 expanded (boxed area) and the North Carolina coastline in lower right corner. Remote receiving stations at km 37, 44, and 49 are indicated by triangles, and gill-net stations are shown with circles. The ocean beaches where Atlantic sturgeon were recaptured, Carolina, Kure, and Ft. Fisher, are denoted by C, K, and F, respectively.

high turbidity, and vertical salinity stratification. Sediment ranges from soft mud to sand. Mean bottom salinity at river km 21 in the lower estuary generally ranges from 9 to 25‰, varying with seasonal changes in river discharge (50–900 m^3/s). The Cape Fear River is influenced by diurnal tides within the entire study area (Figure 1), but tidal range decreases from 1.2 m at km 49 to 0.3 m at km 96. Profiles of vertical current velocity in the study area are typically uniform with depth to within 1.5–3.0 m of the bottom (Giese et al. 1979). The Brunswick River runs parallel to the main stem of the Cape Fear River from km 37 to 46 and has not been extensively dredged since the 1940s. In contrast, the Cape Fear River from km 37 to 46 (Wilmington Harbor) is dredged annually so that a depth of 12 m is maintained. The main stem of the Cape Fear River in the study area above km 49 is dredged to an average depth of 4 m, but there are numerous deep holes (>10 m) throughout. Lock and Dam 1, one of three navigational locks and dams built between 1915 and 1934, defines the upper limit of our study area (km 96). The maximum height of this dam is 4 m.

Methods

Gill-net survey.—We conducted a gill-net survey from May 1990 to May 1992. All sinking gill nets were 50 m long and 3.5 m deep. We used two sizes of monofilament mesh gill nets: 14-cm stretched mesh (year-round) and 5.1-cm stretched mesh (April–November). One trammel net (inside panel, 7.6-cm stretched mesh; outside panels, 20.3-cm stretched mesh) was also operated year-round. The gill nets were set perpendicular to the current, from 2 to 20 m deep. The trammel net was always set approximately 5 m deep and parallel to the current, due to the increased drag created by this gear.

We set gill-nets in three general areas (Figure 1): the Brunswick River (year-round), the Wilmington Harbor from km 37 to 46 (December–May), and the Cape Fear River from km 46 to 66 (April–November). Samples were taken weekly from December to May and every 2 weeks during the rest of the year. In each sampling week the nets were deployed for three days and two nights and checked daily. When water temperature exceeded 28°C, the nets were checked twice daily to reduce fish mortality. Surface and bottom salinity and temperature were recorded at each set on each sampling day.

Weights (nearest 25 g) and fork (FL) and total (TL) lengths (nearest mm) of all sturgeons were recorded. Catch per unit effort (CPUE) was defined as the number of fish caught in one 50-m net fished for 24 h (a net-day). Both Atlantic and shortnose sturgeons were tagged externally with Petersen disc tags (Floy model FTF-69) through the dorsal caudal fin. Stomachs of dead sturgeons were removed, wrapped in cheesecloth, and preserved in 10% formalin for later analysis. Stomach contents were identified to the lowest possible taxon, and frequency of occurrence of each item (number of fish with item/total number of fish) was calculated.

We also recorded commercial captures of shortnose sturgeons made in the study area that were voluntarily reported by 5–10 shad and striped bass fishermen. The commercial gill nets were all 50–100 m long with 13.3–14.0-cm stretched monofilament mesh. They were operated daily from late November to late May as both stationary and drifting nets set perpendicular to the current.

Sonic tracking.—Sturgeons in excellent condition were selected for sonic tagging and placed in a 1 × 1.5 × 1-m floating net pen. Large fish (>800 mm TL) were fitted with high-power transmitters (18 × 100 mm, 12 g in air) having an 18-month battery life (Sonotronics CHP-87-L). Sturgeons smaller than 800 mm TL received smaller high-power transmitters (18 × 65 mm, 8 g in air) having a 7-month battery life (Sonotronics CHP-87-S). Transmitters were usually attached externally (Buckley and Kynard 1985) and were surgically implanted only when water temperature was less than 28°C to minimize handling stress. For internal implantation, the sturgeons were lightly anesthetized with MS-222 (50 mg/L). The transmitter and surgical instruments were disinfected with chlorhexidine diacetate and rinsed with 0.9% sodium chloride. A 3-cm incision was made laterally through the body wall just above the fifth ventral scute. After the transmitter was inserted posterior to the incision, we closed the incision with five to six individual knotted sutures of 2-0 coated Vicryl (Ethicon). The entire operation took no longer than 10 min. Sterile technique was used throughout the procedure, and implanted fish received a 30-min prophylactic treatment of 0.2 g nitrofurazone/L (9.2%).

All transmitters used in this study were uniquely coded by frequency (68–80 kHz) and pulse interval so that individual fish could be identified. Sonically tagged fish were released at the site of capture and tracked continuously for at least 6 h immediately after release. Transmitter signals were located by a portable digital-readout receiver (Sonotronics USR-5B) and a directional hydrophone (Sonotronics DH-2). During periods of continuous tracking, fish positions (±20 m) were determined by a combination of triangulation and signal strength at least every 15 min. Current velocity (±1 cm/s) at 1-m depth was measured (Marsh–McBirney 201) at least every 30 min during continuous tracking, and surface and bottom temperatures and salinities were recorded frequently.

After the release date, sonically tagged fish were relocated during daily surveys with the portable receiver or whenever they passed one of three remote receiving stations (Sonotronics USR-90) at km 37, 44, and 49 (Figure 1). The remote receivers operated around the clock and provided a record of diel activity. Each passage event was defined by the median time of passage (halfway between the time of first and last recorded presence). We analyzed only cases in which fish passed the receiver in less than 30 min to eliminate cases when a fish was not actively moving. Individual passage events for the same fish were included if they were separated by at least 30 min. To determine whether or not Atlantic sturgeons exhibit diel activity patterns, we compared the frequency of passage events during six 4-h time periods using the χ^2 test (Zar 1984). Only fish that passed the monitors at least 24 different times were included in this analysis to assess individual variation and ensure a minimum expected frequency of four in each time period (Zar 1984).

Depth, temperature, and salinity were recorded at each relocation. We documented the depth distribution of juvenile Atlantic sturgeons by comparing depths at daily relocations to available depths using χ^2 analysis (White and Garrott 1990). Recent (1991) bathymetry maps were available for

TABLE 1.—Release date, fish size, duration of tracking, and gross travel rate (total distance travelled/total time tracked) of shortnose and Atlantic sturgeons. Transmitter placement (I = surgically implanted, E = externally attached) and approximate dates of tag loss (if known) are also given.

Fish number	Release date	Size (mm TL)	Days tracked (number of observations)	Gross travel rate (km/d)	Tag place-ment	Tag loss date
			Shortnose sturgeon			
1	16 Feb 1989	942	14.7 (20)	1.0	E	
2	9 Jan 1990	900	2.3 (13)	10.8	E	
3	4 May 1991	715	88.0 (112)	2.6	E	31 Jul 1991
4	14 Feb 1992	812	4.2 (47)	14.9	I	
5	26 Feb 1992	753	21.4 (87)	14.1	E	
			Atlantic sturgeon			
1	3 Jul 1990	910	2.1 (3)		I	
2	19 Oct 1990	760	15.2 (42)	2.4	I	3 Nov 1990
3	14 Dec 1990	1,220	229.0 (98)	0.5	E	31 Jul 1991
4	8 Jan 1991	752	364.0 (31)	0.3	I	
5	27 Jun 1991	716	93.1 (85)	1.7	E	27 Sep 1991
6	10 Jul 1991	705	72.0 (38)	0.5	E	20 Sep 1991
7	23 Jul 1991	689	87.2 (42)	0.2	E	18 Oct 1991
8	8 Aug 1991	723	71.0 (11)	0.2	E	18 Oct 1991
9	15 Aug 1991	735	36.0 (62)	1.1	E	20 Sep 1991
10	3 Sep 1991	1,202	34.2 (17)	0.4	E	
11	3 Sep 1991	838	90.1 (76)	0.8	E	2 Dec 1991
12	3 Dec 1991	719	222.0 (67)	1.1	I	
13	24 Mar 1992	746	161.0 (127)	1.7	I	
14	9 Apr 1992	833	156.3 (150)	1.8	I	

only km 46–59 of our study area in the Cape Fear River (Cape Fear Community College, unpublished data), so only sturgeons that were relocated in this mapped area were included in the analysis. The mapped area was divided into three depth zones: less than 5 m, from 5 to 10 m, and greater than 10 m. The proportional area of each depth zone was determined by the map-weighing method (White and Garrott 1990).

Gross travel rate (km/d) was defined as the total distance a fish traveled divided by the total time over which that fish was tracked or relocated. Percent holding time was defined as the number of days that a fish was relocated in the same position (± 1 km) divided by the total number of days the fish was tracked or relocated. For observations made during periods of continuous tracking, we estimated fishes' swimming speed in body lengths per second (BL/s) by subtracting speed of the current from fish ground speeds.

Results

Shortnose Sturgeon

Despite intensive gill-net sampling (893 net-days), we caught only three shortnose sturgeons in the lower Cape Fear River drainage during 1990–1992. One of these, a gravid female (870 mm FL, 990 mm TL), died during capture in the Brunswick River on 6 February 1991. Gut contents of this fish included two slender isopods (*Cyathura polita*), detritus, and sand grains. Five shortnose sturgeons were also caught and voluntarily reported by commercial fishermen from 1989 to 1993. Two of these five fish were captured in 1993 after our field work had ended and thus were not sonically tagged. The first (525 mm FL, 623 mm TL, 1,725 g) was captured on 1 February at Cape Fear River km 90 in a stationary gill net. The second fish (568 mm FL, 643 mm TL, 1,450 g) was captured in the same net on 4 February. This fish was recaptured and released at km 92 on 11 February 1993 by the same fisherman.

Five shortnose sturgeons were tagged with sonic transmitters and tracked for up to 3 months following their release (Table 1). Shortnose sturgeons 1, 2, and 4 were captured and released in the Brunswick River in January and February. Shortnose sturgeon 3 was captured and released at the mouth of the Black River in May and a fifth fish was captured at km 90 and released at km 92 in late February. Shortnose sturgeons 1 and 2 were obviously gravid females, but the sex of the other three fish is unknown. The fish occupied the entire study area from km 16 to 96 (Lock and Dam 1) from January to mid-July and moved through both the undredged Brunswick River and the regularly dredged Wilmington Harbor during dredging operations.

Shortnose sturgeons tended to move downstream in response to excessive handling or recapture. Fish 2 and 5 that were captured by commercial fishermen and subjected to increased handling both moved rapidly downstream at rates of 8.5–36.0 km/d after release. Shortnose sturgeon 1 was originally captured by a commercial fisherman and then recaptured twice in a stationary gill net in the Brunswick River. This fish moved rapidly downstream after the second recapture and did not move back upstream while we were monitoring its movements. Shortnose sturgeon 5 was also recaptured twice in the upper 2 m of drift nets set at km 62 and 63. We were tracking the fish as it moved upstream just before these captures, and in both cases it was released unharmed. Nevertheless, this fish moved downstream immediately after the second release and did not resume upstream movements while we tracked it. In contrast, shortnose sturgeons 3 and 4, which we captured, received minimal handling and both moved rapidly upstream following release.

We tracked shortnose sturgeons during rapid and directed upstream movements which were apparently obstructed by Lock and Dam 1. Shortnose sturgeons 3, 4, and 5 remained in midchannel while moving upstream and stemmed strong ebbing currents of up to 40 cm/s. Their mean estimated swimming speeds during continuous tracking ranged from 0.78 to 1.07 BL/s, and they maintained average ground speeds of 11.5–27.0 km/d. Both fish 3 and 5 exhibited rapid and directed upstream migration from the point of release to the dam base. Upon reaching the dam, they milled about at its base for 24 h and then moved back downstream. Shortnose sturgeon 3 did not resume upstream movement and was relocated periodically in the area km 37–79 during the next 2 months. Shortnose sturgeon 5 resumed upstream migration after falling 78 km downstream from the dam but was then recaptured in a drift net as described earlier. We tracked fish 4 to within 8 km of the dam, but the next day an anonymous caller reported that it had been captured and probably killed, so it is unclear whether or not upstream movement of this fish was affected by the dam.

Atlantic Sturgeon

We captured 100 juvenile Atlantic sturgeons. The highest CPUEs occurred in the Brunswick River from June through September when water temperatures were greater than 25°C (Figure 2). This area was near the head of the salt wedge where salinity did not exceed 10‰ (Figure 2). Brunswick River fish were generally captured over shoals (<7 m), even though the nets extended into deeper channel areas. In contrast, fish caught in the upper Cape Fear River were always in deep water (>10 m), away from the shoreline and low in the net webbing. In Wilmington Harbor, Atlantic sturgeons were caught primarily at stations located near the mouth of the Brunswick River (Figure 1) and in depths less than 7 m. Atlantic sturgeons ranged from 340 to 1,240 mm TL, but most were 600–800 mm TL (overall mean, 708 mm TL) due to the size selectivity of our gear.

Gill-net mortalities ($N = 24$) occurred from June through September when water temperatures exceeded 28°C (Figure 2), even though the nets were often checked after less than 4 h. Gut content analysis of these 24 dead fish plus one donated by a fisherman revealed that 12 had empty stomachs. There was generally very little food present in any of the other 13 fishes' stomachs, but the food items in highest frequency of occurrence were polychaete worms (fragments, 32%), slender isopods (*Cyathura polita*, 28%), and molluscs (shell fragments, 12%).

Seven Atlantic sturgeons had severe wounds or abnormalities. Four had large dorsal wounds consisting of a 10–15-cm-long gash, usually just anterior to the dorsal fin. These wounds were up to 3 cm deep and in all cases had healed, resulting in loss of two to four dorsal scutes. Otherwise these fish appeared to be healthy. Abnormalities exhibited by the other three fish included a deformed mouth, lesions of the buccal region, lesions around the eye, or some combination thereof. These fish were in poor condition, and two did not survive capture.

Seventy-seven Atlantic sturgeons were conventionally tagged and released. We recaptured 12 fish (16%), and commercial fishermen recaptured 5 (6%). The fish we recaptured were at large for varying periods during the summer (June to early September) and were recaptured within 1 km of their release sites in the Brunswick River (Table 2). These fish did not increase in TL or weight, and the weight of fish number 8760 decreased from 2,500 g to 2,300 g. Commercial gill-net fishermen recaptured fish in spring and fall but did not measure them, so we could not calculate growth rates for these fish. Four fish moved from the river into the ocean and were caught in gill nets set from shore at Carolina Beach (8788), Kure Beach (8793), and Ft. Fisher (8794, 8932) (Figure 1).

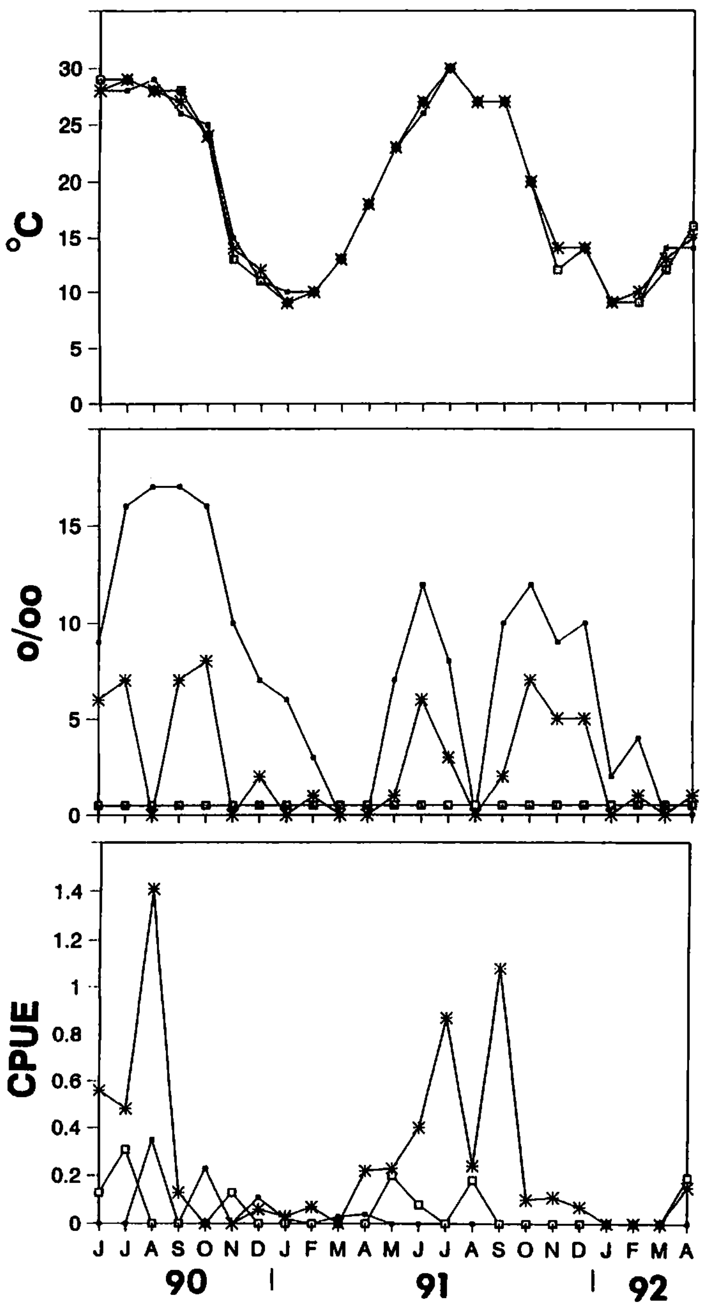

FIGURE 2.—Monthly mean bottom temperature (°C), salinity (‰), and CPUE (number of fish per net-day) at the gill net stations in the Brunswick River (stars), Wilmington Harbor (dots), and upper Cape Fear River (open squares).

Atlantic sturgeons did not retain sonic tags well. We tracked 14 juveniles (705–1,220 mm TL) between September 1990 and April 1992 using both externally attached and surgically implanted sonic transmitters (Table 1). The first fish in which we surgically implanted a tag was captured when water temperature exceeded 30°C, and it died within 2 d of release. Thereafter, all sturgeons captured in water temperature exceeding 28°C (fish 5–11) were tagged externally. In all but two cases (fish

TABLE 2.—Recaptures of Atlantic sturgeon tagged with Petersen discs, including days at large and distance between release and recapture sites (BR = Brunswick River km, CF = Cape Fear River km). Nine fish were recaptured within 48 h of the release date and were not included here.

Tag number	Fish size (mm TL)	Release date	Recapture date	Days at large	Release site	Recapture site	Distance (km)
8748	580	5 Jun 1990	12 Jun 1990	7	BR44.5	BR44.5	0.0
8759	750	6 Jun 1990	13 Jun 1990	7	BR45.5	BR44.5	1.0
8760	686	26 Jun 1991	3 Sep 1991	69	BR45.4	BR45.4	0.0
8788	719	3 Dec 1991	?? May 1992	>148	BR45.4	Ocean	75.0
8789	497	15 Jan 1991	2 Feb 1991	18	CF44.4	BR45.5	12.9
8793	840	6 Mar 1991	1 Oct 1991	209	CF42.0	Ocean	68.9
8794	698	26 Jul 1990	5 Apr 1992	618	BR44.5	Ocean	62.3
8932	817	16 Apr 1992	11 May 1992	26	CF61.1	Ocean	78.9

10 and 11, both very large individuals), the transmitters fell off within 3 months of the fishes' release, primarily during September and October. Two surgically implanted transmitters were also apparently expelled by the sturgeons, as was found by Kieffer and Kynard (1993). Retention of surgically implanted tags was improved when the transmitters were coated with a biologically inert polymer, Dupont Sylastic (fish 12–14, Table 1).

All of the Atlantic sturgeons released between June and September (fish 5–11) behaved similarly. Movements during this period were very slow (mean gross travel rate, 0.7 km/d, Table 1). The fish occupied both the Cape Fear and Brunswick rivers from km 35 to 61 (*N*, 180 observations; mean, km 46; SD, 5.4 km). During daily relocations these fish were found within 1 km of their previous location 80% of the time and often were found in exactly the same spot for several days (mean duration of holding, 12.1 d; SD, 5.5 d).

Holding areas were all deep (>10 m) and were often used by several different individuals; however, we never found more than one sonically tagged sturgeon in any site at the same time. The majority of the area from km 46 to 59 of the Cape Fear River was less than 10 m deep (Table 3). Seven fish tracked in this area during the day were found in deeper areas than expected on the basis of depth availability (Table 3). We pooled the results of the χ^2 analysis and found that as a group Atlantic sturgeon occupied depths greater than 10 m (Table 3). We compared the depth distributions of sturgeon tracked when temperature exceeded 25°C (warm) to those tracked during the rest of the year (cool), and found that sturgeons occupied deeper depths in both temperature regimes (warm: χ^2 = 138.3, df = 14; cool: χ^2 = 75.8, df = 8; both $P < 0.05$).

The Atlantic sturgeons we released in fall, winter, and spring (2, 3, 4, 12, 13, and 14, Table 1) were more active than those released in summer (mean gross travel rate, 1.3 km/d). During movements their mean estimated swimming speed was 0.44 BL/s (SD, 0.21). The center of Atlantic sturgeon distribution from October to May was the same as in summer, but a variance ratio test (Zar 1984) indicated that the fishes' range was significantly larger in winter (*N*, 215 observations, mean, km 46, SD, 10.5). Atlantic sturgeons 13 and 14 were both released in the Brunswick River in spring, immediately moved downstream to km 38 in Wilmington Harbor, and resided between km 36 and 41 for the month following release. Twice during this time, sturgeon 13 was tracked as it moved within 100 m of a hydraulic pipeline dredge operating at km 40, but there was no evidence that

TABLE 3.—Depth ranges of relocated juvenile Atlantic sturgeons in the Cape Fear River, km 46–59. Availability of each depth range, in parentheses, is expressed as a percent of the mapped area (km 46–59). Significant χ^2 test results ($P < 0.05$) are marked with an asterisk and indicate sturgeons that showed a depth bias. "Warm" indicates sturgeons that were tracked between June and September when water temperature was greater than 25°C. "Cool" indicates sturgeons tracked in water temperatures less than 25°C.

Sturgeon number	Water temperature	Number of observations <5 m (34%)	5–10 m (55%)	>10 m (11%)	χ^2
2	Cool	0	2	3	11.48*
3	Cool	0	3	8	43.73*
4	Cool	0	1	3	18.95*
5	Warm	1	3	4	12.21*
6	Warm	0	0	5	36.67*
7	Warm	1	3	12	65.20*
8	Warm	0	2	1	2.73
11	Warm	1	2	1	1.03
12	Cool	0	2	0	1.64
13	Warm	0	0	2	18.00*
14	Warm	0	3	0	2.52
Total		3	21	39	214.16*

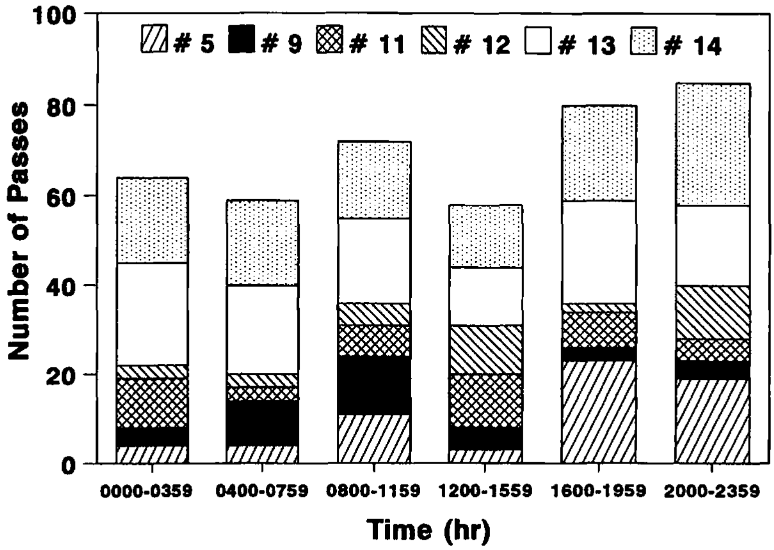

FIGURE 3.—Number of times individual Atlantic sturgeons (5, 9, 11, 12, 13, and 14) passed the remote receiving stations during different times of day.

the fish was affected by the dredge on either occasion. In late April, sturgeon 13 migrated steadily (1.1 km/h) upstream into the Northeast Cape Fear River and stayed between km 47 and 50 until 30 May. Atlantic sturgeon 14 moved up the Brunswick River on 21 May at a rate of 0.6 km/d and was relocated between km 37 and 54 until mid-September. Both fish were relocated in deep holes (>10 m) throughout the summer until tracking was terminated.

Six Atlantic sturgeons (5, 9, 11, 12, 13, 14) passed the remote receivers more than 24 times and were analyzed for diel activity patterns. Atlantic sturgeon 9 passed the monitor significantly (χ^2 = 12.54, df = 5, $P < 0.05$) more often than expected during the morning (0400–1200 hours) and sturgeon 12 passed the monitors significantly (χ^2 = 16.01, df = 5, $P < 0.05$) more often than expected in early afternoon (1200–1600 hours) and evening (2000–2400). The remaining four fish showed no significant diel activity pattern. We pooled the data for all fish and found that the observed times of passage occurred evenly throughout the day and night and were not significantly different from expected frequencies (χ^2 = 1.9, df = 25, $P > 0.05$; Figure 3).

Discussion

Shortnose sturgeons are very rare in the Cape Fear River drainage and are extremely susceptible to both set and drifting gill nets that target striped bass *Morone saxatilis* and American shad *Alosa sapidissima*. Several commercial fishermen reported capturing shortnose sturgeons regularly in the past, but always in small numbers. Some of these fishermen may have captured and released the same fish on several occasions, as occurred twice during this study. To reduce fishing mortality, a state law was passed in 1991 prohibiting the possession of any sturgeon in North Carolina. However, shortnose sturgeons may still suffer significant mortality from incidental capture.

Our gill-net sampling and sonic tracking data indicated a much wider distribution of shortnose sturgeon in the Cape Fear River basin than previously documented (Ross et al. 1988). Although previous captures were from only the Brunswick River in January, we found that shortnose sturgeons also occupied the main stem of the Cape Fear River from the lower estuary (km 16) to Lock and Dam 1 (km 96) and were caught from early January to early May. This corresponds with the timing of spawning migrations observed in other southeastern U.S. rivers (Dadswell et al. 1984; Hall et al. 1991). We observed directed upstream movements at rates similar to those reported for prespawning shortnose sturgeon in other systems (Buckley and Kynard 1985; Hall et al. 1991), indicating that shortnose sturgeons in the Cape Fear River drainage participate in spawning migrations. Moreover, both Cape Fear River specimens deposited at the North Carolina State Museum of Natural Sciences (NCSM 13827 and 17539) were gravid females, and two of the fish used for sonic tracking appeared to be gravid.

Our data suggested that the combined obstacles of high fishing pressure and dams may prevent shortnose sturgeons from reaching spawning areas, which, in other rivers, are 100–300 km upstream (Dadswell et al. 1984; Hall et al. 1991; O'Herron et al. 1993). Upstream migration of at least two of the shortnose sturgeons we tracked was apparently blocked by Lock and Dam 1. In addition, repeated capture or excessive handling of shortnose sturgeons by commercial fishermen appeared to interrupt or abort the spawning migration of four of the five fish we tracked. No juvenile shortnose sturgeons have been caught in this drainage, further indicating that the species may not be spawning successfully here.

Our data indicated that Atlantic sturgeons reproduce in the Cape Fear River drainage. Compared to shortnose sturgeons, Atlantic sturgeon juveniles were abundant. Historical records also indicate that Atlantic sturgeons occur regularly in the Cape Fear River drainage (McDonald 1887; Schwartz et al. 1981). Our CPUE of Atlantic sturgeon juveniles was most comparable to that of the Delaware River and estuary (Brundage and Meadows 1982; Lazzari et al. 1986). Based on age-to-fork-length relationships (Smith 1985; Lazzari et al. 1986), we estimated that most of the Atlantic sturgeons we caught were 3–7 years old, although the smallest individuals may have been 2-year-olds.

The center of juvenile Atlantic sturgeon distribution in the Cape Fear River was near the saltwater–freshwater interface, as in other southern rivers (Hall et al. 1991; G. Rogers, Georgia Department of Natural Resources, personal communication). In contrast, juvenile Atlantic sturgeons in northern rivers favor more saline areas (Kieffer and Kynard 1993). The fish we tracked occupied depths greater than 10 m year-round and in summer they moved infrequently and appeared to fast. These observations suggest that Atlantic sturgeons in the southern part of their range may be confined to a relatively small number of deep, freshwater holes which serve as thermal refuges. Mason and Clugston (1993) reported a similar pattern of reduced summer and fall feeding by Gulf sturgeons *Acipenser oxyrhynchus desotoi* in the Suwannee River, Florida, with increased feeding at estuarine overwintering sites. Some of the winter holding sites favored by the sturgeons we tracked in the lower Cape Fear River estuary also support very high levels of benthic infauna (M. Posey, University of North Carolina at Wilmington, personal communication) and may be important feeding stations.

We frequently caught deformed and previously injured Atlantic sturgeons in the Brunswick River. Common defects in the buccal region, like those we observed, have also been noted in shortnose sturgeons (Dadswell et al. 1984). Oral, buccal, and ventral lesions or ulcerations, often signs of poor water quality, were observed on several sturgeons and ictalurids we captured. Because sturgeons often move in the upper water column, the dorsal gashes we observed could have been caused by boat propellers. Further study is needed to determine the causes of such abnormalities and injuries and to what extent they affect these fishes.

Atlantic and shortnose sturgeons occupied both relatively undisturbed and regularly dredged areas and were tracked through the Wilmington Harbor during dredging operations. These fish appear to seek out deep areas and stay in midchannel, behaviors that would put them in the proximity of dredges. However, as did McCleave et al. (1977), we found some evidence that shortnose sturgeons remain within 2 m of the surface while moving, which would limit their entrainment in dredges. Although we obtained no evidence that dredges affected sturgeons, our results clearly indicated that both species are incidentally taken in commercial gill nets and that shortnose sturgeons may abort spawning migrations as a result of capture and release. Of even more concern is the observation that even low-elevation dams, such as Lock and Dam 1, block upstream migration of this endangered species.

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