ABSTRACT

ARMSTRONG, JAMES LELAND. Movement, Habitat Selection And Growth Of Early-Juvenile Atlantic Sturgeon In Albemarle Sound, North Carolina. (Under the direction of Joseph E. Hightower.)

We characterized habitat use, growth, and movement of early juvenile Atlantic sturgeon in Albemarle Sound, North Carolina through field work conducted in 1997 and 1998. Most of the Atlantic sturgeon encountered in the study were estimated to be age-1 fish. The presence of numerous age-1 Atlantic sturgeon near a historic spawning river (Roanoke River) suggests that these fish are likely native to the system. Recaptures of tagged Atlantic sturgeon allowed us to describe the growth of early juveniles using simultaneous analysis of length increment and length composition data. Growth of Atlantic sturgeon in Albemarle Sound was similar to growth rates observed in other systems, and suggests that Albemarle Sound serves as an adequate nursery habitat. Among telemetered individuals, we observed a preferred depth interval of 3.6 to 5.4 m. Additionally, the organic rich mud substrate type was used significantly more than expected under the null hypothesis of random movement. Site-constrained movement was demonstrated by some fish. Occasional large catches of Atlantic sturgeon in our survey gear suggested that these fish may aggregate in the sound. Bycatch of Atlantic sturgeon by a commercial flounder gillnetter in eastern Albemarle Sound was dominated by fish within the expected age-2 size range. The impact of local gillnet fisheries on the Atlantic sturgeon population in the Roanoke River/Albemarle Sound system remains an important and unanswered question.

MOVEMENT, HABITAT SELECTION AND GROWTH OF EARLY-JUVENILE ATLANTIC STURGEON IN ALBEMARLE SOUND, NORTH CAROLINA

by

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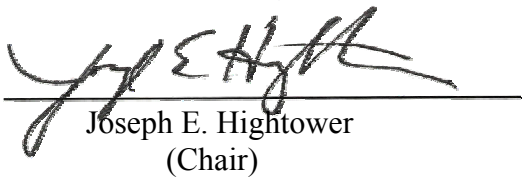
A Thesis submitted to North Carolina State University
In Partial Fulfillment of the Requirements for the Degree of
Master of Science
In Fisheries and Wildlife Science

Department of Zoology
North Carolina Cooperative Fish and Wildlife Research Unit

North Carolina State University

1999

Approved by
Advisory Committee



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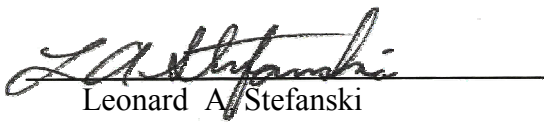

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Biography

Jim Armstrong was born in Addis Ababa, Ethiopia on June 22, 1966 to Joe and Mary Lou Armstrong. His family was in Ethiopia because Jim's father was a tropical disease researcher for the U.S. Navy; Jim's younger sister, Kerry, was also born in Ethiopia. Jim and his family moved to Silver Spring, Maryland in June of 1975 and Jim lived there until he joined the U.S. Navy in 1985. After serving four years in the Navy, Jim entered college. He graduated summa cum laude from UNC Wilmington in 1993 receiving a B.S. in marine biology with honors in biology. Jim worked as an assistant to fisheries researchers for a couple of years, married Alicia Henrikson in 1995 and, in 1996, persuaded Dr. Joseph Hightower to let him into the graduate program at NC State University. Before finishing his graduate work at NC State, Jim secured a position as a population dynamics analyst with the Division of Marine Fisheries in Morehead City, NC. Upon completion of this thesis, Jim and Alicia Armstrong are living in Morehead City, NC and are eagerly awaiting the arrival of their first child in late July 1999.

Acknowledgments

Many thanks to T. Mitchell, T. Galvan, T. Collins, and A. Armstrong for their help as field crew. Thanks also to commercial fishermen R. White, R. Bass, S. Keefe, and R. Davenport for their help in obtaining sturgeon. Thanks to H. Johnson, S. Winslow, S. Trowell, and the crew from the northern district office of the NC Division of Marine Fisheries, as well as E. Atstupenas, L. Harrell and others from the Edenton National Fish Hatchery for help with critical logistical needs. Many thanks to T. and M. Gaylord of Jamesville for allowing us to put our remote monitoring station at their boathouse. Thanks to the Albemarle Fisherman's Association including R. Williams. Thanks to Barry Smith for help in implementing the growth model. We thank Virginia Power and the U.S. Fish and Wildlife Service for funding this project.

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Introduction

The historically abundant Atlantic sturgeon (*Acipenser oxyrinchus*) once occurred in over 17 rivers along the East Coast of North America ranging from Hamilton Inlet, Labrador, Canada in the north to St. John's River, in eastern Florida, USA in the south (Vladykov and Greeley 1963; ASMFC 1998). Populations of Atlantic sturgeon are believed to be severely depleted throughout the species' range and to have been extirpated in the Connecticut River, most Chesapeake Bay tributaries, and the St. John's River, Florida (ASMFC 1998; Wirgin and Waldman 1998). For systems in which reproduction is still occurring, successful restoration of Atlantic sturgeon is thought to be constrained by three major factors: 1) directed or incidental fishing mortality, 2) impeded access to historic spawning sites, and 3) diminished habitat quality (Smith 1985; Waldman and Wirgin 1998).

Estimating the relative importance of these obstacles presents a variety of challenges to fisheries biologists. While fishing mortality is considered the historically predominant influence on sturgeon numbers, the current impact is unknown, occurring mostly through incidental captures (Collins et al. 1996; Kahnle et al. 1998). Estimating the impact of bycatch on Atlantic sturgeon populations would entail surveying multiple fisheries within the geographic range of each population. Impassable dams currently prevent Atlantic sturgeon from reaching upstream waters of many large coastal rivers that once provided spawning habitat (Smith 1985). While technologically feasible means of transporting Atlantic sturgeon above dams exist, the value of implementing these is unclear in those cases where historic

spawning sites are inundated by lentic reservoir waters. Finally, habitat quality is perhaps the most ecologically complex factor to be addressed, in that Atlantic sturgeon alternately occupy several habitat types (riverine, estuarine, and offshore marine) throughout their lives. Relatively more is known about riverine and estuarine habitat use because of the difficulty of studying the offshore ecology of the adult stage (Borodin 1925; Vladykov and Greeley 1963; Murawski and Pacheco 1977; Yelverton and Holland 1977; Dovel 1979; Brundage and Meadows 1982; Dovel and Berggren 1983; Smith et al. 1982; Smith et al. 1984; Van Den Avyle 1984; Lazzari et al. 1986; Gilbert 1989; Moser and Ross 1995, Bain 1997). Additionally, capturing Atlantic sturgeon, regardless of the scope of the research, can be difficult, especially in systems with reduced numbers and where distributional data are lacking.

The focus of this report is on early-juvenile Atlantic sturgeon movement, habitat selection and growth in Albemarle Sound, North Carolina. The Albemarle Sound estuarine system may provide important habitat for juvenile Atlantic sturgeon. Juveniles occur occasionally as bycatch in commercial fishing operations and in a North Carolina Division of Marine Fisheries (NCDMF) survey of striped bass. No studies directed at sturgeon in Albemarle Sound have been conducted to date. Examination of movement, growth and habitat use of early-juvenile Atlantic sturgeon in Albemarle Sound should contribute to a more complete understanding of the species and offer insights into how we can aid in its recovery.

Historic Fishery Accounts from the colonial period of United States history indicate that Atlantic sturgeon were once numerous in eastern inland and coastal

waters (Yarrow 1874; Tower 1908). With the establishment of a market for sturgeon in the mid-1800s, sturgeon fisheries began to emerge along the East Coast. These fisheries concentrated harvest effort on adult sturgeon migrating into large coastal rivers to spawn. Female sturgeon were particularly valuable for their roe (caviar). Localized sturgeon fisheries of the late 19th century typically returned profits for about ten years after they had begun, and were abandoned after local sturgeon stocks had been exhausted (see Tower 1908).

In 1889, the first sturgeon fishery in North Carolina began at Avoca in western Albemarle Sound (Leary 1915). Four years later, sturgeon were still being harvested, but catches were reported to be "much less numerous than formerly" (see Leary 1915). Sturgeon were fished so aggressively in the sound that "the species was almost wiped out in a short time and has never been able to reestablish itself" (Smith 1907). By 1915, Leary foresaw the need for "legislation protecting the young [sturgeon] and for their propagation". Atlantic sturgeon continued to be harvested at low levels in North Carolina until possession of the species was outlawed in 1991 (Moser and Ross 1995). Since that time, however, there has been no indication of increasing adult abundance in Albemarle Sound or the Roanoke River.

In 1998, the Atlantic States Marine Fisheries Commission (ASMFC) released an interstate fishery management plan (FMP) for Atlantic sturgeon. The goal of the FMP was "…to restore Atlantic sturgeon spawning stocks to population levels which will provide for the sustainable fisheries, and ensure viable spawning populations" (ASMFC 1998). Additionally, the Commission recommended localized assessments of obstacles to the recovery of Atlantic sturgeon.

Barriers to migration Man-made impediments to historic spawning sites exist throughout the range of Atlantic sturgeon (Smith 1985). When dams eliminate important spawning or juvenile habitat, they ultimately contribute to the decline of Atlantic sturgeon populations (Smith 1985). In North Carolina, a number of barriers have been constructed on the Roanoke River. Manipulation of the river near historic spawning sites began when a system of canals and locks was built to allow navigation past Roanoke Rapids during the late 18th century (Robinson 1997). In 1889, hydroelectric power generation began at Roanoke Rapids, and the dam present today was built in 1950 (Zarzecki and Hightower 1997). From 1952 to 1964, five mainstem reservoirs were built on the Roanoke River (Zarzecki and Hightower 1997). None of the dams provide for fish passage; consequently sturgeon and other anadromous species are restricted to the river downstream of the Roanoke Rapids dam (river km 221).

Habitat requirements Atlantic sturgeon are anadromous benthic omnivores. After hatching at the riverine spawning grounds, larvae establish benthic behavior within nine to ten days (Bath et al. 1981). Detailed information on the ecology of age-0 Atlantic sturgeon is generally lacking, and this has been attributed to difficulty in sampling (Van Den Avyle 1984; Gilbert 1989; Smith 1997). Larger juveniles (age one to six) are commonly caught in commercial gear and tagging studies have shown that they typically remain near their natal system in fresh (<0.5 ‰) to oligohaline (0.5 to 3.0 ‰) waters (Smith and Dingley 1984). As these juveniles get older, they move progressively toward more saline waters (Smith 1985) and are sometimes found

around the saltwater-freshwater interface of the lower estuary (Moser and Ross 1995). The degree to which juvenile Atlantic sturgeon enter saline waters may vary latitudinally, with northern fish reportedly associating with higher salinities earlier in their life history (Kieffer and Kynard 1993). Generalized juvenile movement over the course of a year consists of movement into upstream areas in the spring, followed by movement downstream after midsummer; these movements appear to be influenced by water temperature (Smith et al. 1982; Van Den Avyle 1984; Gilbert 1989; Moser and Ross 1995; Bain 1997).

At the end of the juvenile phase, subadult Atlantic sturgeon migrate to the offshore marine habitat where they mature at eight to eleven years of age (Smith and Dingley 1984). Mature adults migrate into rivers to spawn in the spring, usually when water temperatures are 13 to 19°C (Smith 1985). Spawning habitat typically consists of main channel sites with rubble, cobble, or bedrock substrate (Vladykov and Greeley 1963). After spawning, adult Atlantic sturgeon return to saline waters and may not spawn again for four to six years (Smith and Dingley 1984).

Throughout their lives, Atlantic sturgeon appear to be opportunistic benthic omnivores (Van Den Avyle 1984; Gilbert 1989). Using sensitive barbels to detect food, they root in the sand with their shovel-like snouts and suck organisms and substrate into their mouths (Van Den Avyle 1984). Mollusks, polychaetes, gastropods, crustaceans and small benthic fishes typically make up the diet of individuals in the marine habitat, while juveniles in freshwater consume aquatic insects, crustaceans and oligochaetes (Vladykov and Greeley 1963). Pre-spawning adults apparently do not feed (Scott and Crossman 1973).

Growth Growth rates for Atlantic sturgeon appear to vary among river systems, with slower growth reported for individuals taken in northern latitudes (Greeley 1937; Magnin 1964; Murawski and Pacheco 1977; Smith et al. 1982). Atlantic sturgeon generally demonstrate fastest growth during the first 2 years (early-juvenile phase - Bain 1997) ranging from an average of 0.47 mm/day in the St. Lawrence River, Canada (Murawski and Pacheco 1977) to 0.91 mm/day in South Carolina (Smith et al. 1982). Age at first spawning is reported for South Carolina Atlantic sturgeon at 5-13 years for males and 7-19 years for females (Smith et al. 1982). The maximum reported length for Atlantic sturgeon is 4267 mm (Vladykov and Greeley 1963), although they suggest that reports of Atlantic sturgeon reaching 5486 mm may be valid.

Atlantic sturgeon in the Albemarle Sound - Roanoke River system The Roanoke River is one of nine tributaries to Albemarle Sound, but contributes more than 80% of the freshwater input (Wells 1989). Historical reports indicate that sturgeon were more common in the Roanoke River than in the Chowan River, the other major tributary to the sound (Smith 1891). The Roanoke River has historically yielded adult Atlantic sturgeon during the time of their spring (February to April) spawning migration (Smith 1907). Considerable numbers of Atlantic sturgeon were caught at the fall line in the mid-1800s (Yarrow 1874; Moseley et al. 1877; Williamson 1878). Robinson (1997) provides a photograph of a large Atlantic sturgeon (estimated to have been 1525-1830 mm in length) captured from the Roanoke River around the turn of the century although the date and capture site are not given. An adult Atlantic sturgeon measuring 2692 mm total length was captured

in a Weldon fish slide in May 1908 (The Roanoke News 1908). Worth (1904) reported a sturgeon spawning site in the "falls" of the Roanoke River near Weldon and Roanoke Rapids. He also noted the collection of a 51 mm (2 in) young-of-the-year sturgeon on May 26, 1904 and past captures of juvenile sturgeon (of "hand's length") during apparent autumn outmigrations. Those fish were captured on inclined "fish slides" constructed primarily to harvest striped bass (*Morone saxatilis*). It is not known to what extent areas upstream of the current Roanoke Rapids dam site functioned as spawning sites. Reports of large, spawning-size Atlantic sturgeon (greater than 1500 mm) in the river since the early 20th century are generally lacking. The Roanoke River may still support a reproducing population (FERC 1995), but no directed surveys for Atlantic sturgeon have been done.

Gillnetting surveys by the NCDMF research crews, as well as incidental catches by commercial fishermen, indicate that juvenile Atlantic sturgeon occur within Albemarle Sound throughout the year. These fish are typically less than 500mm FL. Atlantic sturgeon this size should be age-2 or younger (Smith et al. 1982; Dovel and Bergrenn 1983) and would therefore fall into Bain's (1997) "early-juvenile" category. Given that early-juvenile Atlantic sturgeon typically remain near their natal system (Smith 1985; Bain 1997), evidence of Atlantic sturgeon this young in the sound suggests that local spawning may be occurring.

The potential for Albemarle Sound to function as a productive nursery ground for Atlantic sturgeon may be limited by habitat quality. The U.S. Environmental Protection Agency (EPA), through their Environmental Monitoring and Assessment Program (EMAP), has measured chemical and biological indicators of estuarine

health in Albemarle Sound and other estuarine sites in the Carolinian Province since 1994. The results of these assays suggest that Albemarle Sound is among the most contaminated regions covered by the study (Hackney et al. 1998).

Objectives In this investigation, we set out to: 1) evaluate habitat selection of Atlantic sturgeon in Albemarle Sound with regard to benthic habitat and depth; 2) determine growth rates of early-juvenile Atlantic sturgeon in Albemarle Sound and relate these growth rates to rates observed in other systems; and 3) describe movement of telemetered Atlantic sturgeon within Albemarle Sound.

Methods

Atlantic sturgeon captures Field methodologies adopted for this project were devised for the purpose of capturing and gathering data from as many Atlantic sturgeon as possible in Albemarle Sound. Juvenile Atlantic sturgeon consistently occur as bycatch of the flounder gillnet industry in Albemarle Sound; however, current regulations require fishermen to return sturgeon to the water as soon as they are removed from nets (NCDMF 1998). Therefore, in 1997, we went aboard vessels of cooperating commercial fishermen and collected data from any incidentally captured Atlantic sturgeon. We recorded capture locations using Global Positioning System (GPS), and returned to these sites later in our own vessel to characterize temporally stable habitat parameters (depth, substrate type) associated with those captures. Atlantic sturgeon obtained in this manner were captured with monofilament gillnets ranging from 12.7 to 15.4 cm stretch mesh (5.0 to 6.5 inch stretch mesh [ISM]). Each net was 91.4 m (100 yds) in length and 30 nets were strung end to end making a total set 2.74 km (3000 yds) long. Gillnets were typically set parallel to shore on either sand or organic rich mud (ORM). Nets were pulled in using hydraulic net reels. Six fishermen allowed us to observe their fishing operations during this project.

In September 1998, commercial fisherman R. White received a Marine Fisheries Commission (MFC) Fishery Resource Grant to perform a tagging study on Atlantic sturgeon in the northeastern region of Albemarle Sound. Initial results from his captures are also included in this report.

Although cooperation with fishermen was an integral part of early capture success, there were limits to the information that could be obtained aboard commercial vessels. It was not possible to measure dynamic habitat parameters (temperature, salinity, dissolved oxygen) at the time of capture, because the limited amount of gear we could bring aboard commercial vessels. In addition, these fishermen were not targeting Atlantic sturgeon, so we felt that higher catch rates might be possible through directed survey effort.

Cooperation with NCDMF yielded data on Albemarle Sound Atlantic sturgeon for this project as well. NCDMF has conducted a striped bass gillnet survey in Albemarle Sound since 1990 using gillnets ranging from 7.6 to 20.3 cm stretch mesh size in both sinking and floating arrays and a stratified random sampling protocol. Atlantic sturgeon captured incidentally in NCDMF nets were delivered to us as we boated alongside in our own vessels. An advantage to this approach was that, besides morphometrics and locational data, more extensive habitat data could be recorded at time of capture. Disadvantages included the low frequency of Atlantic sturgeon captures in NCDMF nets.

In 1998, we obtained our own gillnets in order to target areas of the sound where Atlantic sturgeon reportedly occur regularly. Mesh size of our monofilament gillnets was 10.2 cm and each net measured 91.4 m with five nets strung end to end for a total of 457 m. Mesh size was chosen because the incidence of NCDMF early-juvenile Atlantic sturgeon captures was greatest for this mesh size (Figure 1). Our nets measured 2.4 m from leadline to topline but had 46 cm lines every 9.1 m connecting the leadline to the topline ("tie-downs"). This arrangement is used by

commercial fishermen in Albemarle Sound to reduce bycatch of striped bass. It also causes the webbing to bag, potentially increasing capture efficiency for demersal species like Atlantic sturgeon. Our gillnets were tied end to end with mud anchors tied to the toplines of the first and last nets. We limited fishing effort to the area of Albemarle Sound west of the Hwy. 32 bridge (76°30.00W Long.) and east of the Chowan River (Hwy. 17) bridge (76°43.00W Long.) which was judged to be a manageable area for telemetry work and was immediately outside the mouth of the Roanoke River. Nets were not set in a randomized array, but instead with the expressed intent of capturing as many Atlantic sturgeon as possible. Anecdotal reports by commercial gillnetters indicated that a likely area for Atlantic sturgeon was the southern nearshore area of the sound (less than 3.6 m deep) east of about 76°35.00W Long. These observations by commercial fishermen were consistent with the distribution of NCDMF Atlantic sturgeon captures, which were greatest in the southwestern sound (Figure 2).

Processing Atlantic sturgeon captures For each Atlantic sturgeon captured in either field season, we recorded date and time of capture, latitude, longitude, mesh size of net, source of capture, as well as fork length (mm), weight (g), and presence of any injuries or lesions on the fish. Additional morphometrics including interorbital width (mm), snout length (mm), mouth width (mm), and presence or absence of plates between anal fin and lateral scutes were recorded. The ratio of mouth width to intraorbital width is generally less than 55% for Atlantic sturgeon and greater than 62% for shortnose sturgeon (*Acipenser brevirostrum*) (Dadswell et al. 1984). Plates

are present between the anal fin and lateral scutes of Atlantic sturgeon but not for shortnose sturgeon (Dadswell et al. 1984). To provide additional documentation of species identification, we photographed some individuals' underside of snout and side near the anal fin.

Each captured Atlantic sturgeon was tagged with a passive integrated transponder (PIT) tag (Biomark Inc.) that was injected subcutaneously to the left of and posterior to the fourth dorsal scute. This location has been used by other Atlantic sturgeon researchers making it likely that captured, tagged fish could be detected by research crews in other systems if between-system movement occurs. Tissue samples (left pectoral fin clips) for mitochondrial DNA analysis were taken from most Atlantic sturgeon encountered during the project. Fin clips were stored in 90% isopropyl alcohol and were sent to genetics researcher Isaac Wirgin (Nelson Institute of Environmental Medicine). Waldman and Wirgin (In Press) are identifying genetically distinct populations of Atlantic sturgeon on the East Coast.

Telemetry Telemetry has been shown to be an effective technique for monitoring Atlantic sturgeon distribution and habitat associations over time (Kieffer and Kynard 1993; Moser and Ross 1995). For our study, Atlantic sturgeon weighing more than 700 g and which appeared active and healthy were considered candidates for telemetry tagging with 8 g (in-air weight) ultrasonic transmitters. These were coded transmitters with no off-time, having frequencies of 30 to 40kHz and an 18 month battery life (Sonotronics CHP87-S). Transmitters were coded by frequency and pinger pattern so that individual fish could be identified.

Transmitters were attached externally to Atlantic sturgeon using 100 lb. test stainless steel trolling wire in a technique used by other researchers (pers. comm., Frank Paruka, U.S. Fish and Wildlife Service; Bain et al. 1995), with the exception of location of placement. Whereas protocol used in other current Atlantic sturgeon projects calls for transmitters to be attached at the base of the dorsal fin, we judged this technique inappropriate for early-juvenile Atlantic sturgeon because of the small size of the caudal peduncle at young ages. Our transmitters were, therefore, attached just anterior to the dorsal fin. The need to limit handling time of Atlantic sturgeon during the summer field season when water temperatures can exceed 30°C obviated field-surgical implantation of transmitters (maximum water temperature during 1998 field season was 32.1°C).

When possible, water quality parameters (temperature, dissolved oxygen, salinity) were recorded at each capture or relocation site using a Hydrolab scout or YSI water quality meter. Water depth was measured with a SONAR depth finder. A bottom sediment sample was obtained with a PONAR grab sampler and visually inspected to assess sediment type and benthic macroinvertebrates. Two sediment types were considered (sand and organic rich mud [ORM]), according to Wells (1989).

In order to detect movement of fish from Albemarle Sound into the Roanoke River, a data-logging receiver was positioned at Jamesville (approximately rkm 30).

Movement Demonstration of site-constrained movement by Atlantic sturgeon in Albemarle Sound may indicate preference for patchily distributed habitat. To test

the null hypothesis that movement demonstrated by telemetered Atlantic sturgeon in our study was random (as opposed to the alternative hypothesis that observed movement by Atlantic sturgeon was site-constrained), relocation data for telemetered fish from the 1998 field season were tested using the Animal Movement program (Hooge and Eichenlaub 1997) through ArcView 3.1 GIS software (Environmental Systems Research Institute, Inc.). In this program, random walk tests using Monte Carlo simulation of net movement paths is used to test whether observed movement shows more site fidelity or is more dispersed than would be expected under the null hypothesis. Simulated movement paths are equivalent to observed paths in length, number of nodes, and distance between nodes. By randomizing the angle of new movement at each node over 500 simulated movement paths, the simulation approximates a distribution of potential dispersal values. Rejection of the null hypothesis occurs when a significantly small proportion of simulated movements shows equal or lower dispersal than the observed movement path. Dispersal is measured as the mean squared distance (MSD) from the center of activity.

Statistical Analyses Individually-based Chi-square tests were used to assess whether Atlantic sturgeon were randomly distributed in the sound with respect to depth and sediment type (Neu et al. 1974; Byers et al. 1984; White and Garrott 1990). Under the null hypothesis, relocations of an individual Atlantic sturgeon with respect to a given habitat parameter would be expected to be in proportion to the relative availability of that habitat type. The Chi-square test requires that observations of an animal's location be independent (White and Garrott 1990). Therefore, when a

telemetered fish was relocated twice a day, only the first relocation was used in the analysis to reduce the potential for dependence among observations. In order for the Chi-square test to be reliable at the α=0.05 level, the average expected value within each habitat category should be four or greater (Roscoe and Byars 1971).

Depths were divided into four 1.8 m intervals (<1.8, 1.8-3.6, 3.6-5.4, >5.4). Sediment types available in Albemarle Sound consisted of two types: sand (30%) and organic rich mud (70%; Riggs 1996). Other water quality parameters (e.g. temperature, salinity) are reported to influence juvenile Atlantic sturgeon distribution in other systems (Smith et al. 1982; Van Den Avyle 1984; Gilbert 1989; Moser and Ross 1995; Bain 1997). However, it was not feasible to characterize available habitat for these temporally varying habitat parameters.

Growth Analyses Our characterization of growth of Albemarle Sound Atlantic sturgeon was based on von Bertalanffy's (1957) growth equation:

$$L_t = L_\infty(1 - e^{-K(t - t_0)})$$

where L_t is length at age t, L_∞ is asymptotic maximum length, K is the instantaneous growth rate, and t_0 is the hypothetical age when length is 0. Although the von Bertalanffy growth model is typically applied to length-at-age data, we fitted the model to length increment data (growth data from mark-recaptures) as well as to length frequency data (change in length composition for a single cohort) for Atlantic sturgeon captured during the 1998 field season. The model that we used was developed by Sainsbury (1980), and extended by Smith and McFarlane (1990). These authors considered that variation in growth rates within a population of fish resulted

from each fish following an individual von Bertalanffy growth pattern. Thus, the jth individual would have maximum length (L_j) and instantaneous growth rate (K_j). The population of individual maximum length values is assumed to be normally distributed with mean L_∞ and $V[L_\infty]$. The population of individual growth rates is assumed to have a gamma distribution with mean K and variance V[K]. The gamma distribution was chosen by Sainsbury (1980) because it can take on a variety of forms but does not permit negative values.

The expected value for a length increment (I_j) for fish j, conditional on length at release (l_j) and time at large (t_j) is

$$E[I_j \mid l_j, t_j] = (L_\infty - l_j)(1 - E[e^{-K_j t_j}])$$

where $$E[e^{-K_j t_j}] = \left(1 + \frac{t_j V[K]}{K}\right)^{-\left(\frac{K^2}{V[K]}\right)}$$

(Sainsbury 1980; Smith and McFarlane 1990). The increment variance is

$$V[I_j \mid l_j, t_j] = k_1 V[L_\infty]^2 + k_2 (E[L_\infty] - l_j)^2$$

where $$k_1 = 1 - 2\left(1 + \frac{t_j V[K]}{K}\right)^{\left(\frac{K^2}{V[K]}\right)} + \left(1 + \frac{2t_j V[K]}{K}\right)^{-\left(\frac{K^2}{V[K]}\right)}$$

and $$V[e^{-K t_j}] = \left(1 + \frac{2 t_j V[K]}{K}\right)^{-\left(\frac{K^2}{V[K]}\right)} - \left(1 + \frac{t_j V[K]}{K}\right)^{-\left(\frac{K^2}{V[K]}\right)}$$

(Sainsbury 1980).

L_∞, K, $V[L_\infty]$, and V[K] were treated as model parameters and estimated using log likelihood methods.

Following Smith and McFarlane's (1990) approach for estimating change in length frequency within a cohort, length frequency distributions were treated as normally distributed increment data where time at large (t) was equal to the difference between age of the cohort at time of capture and t_0. The predicted length distribution for the cohort at time t, then, was a normal distribution with mean (E[I | 0, t]), sample size, and variance (V[I | 0, t]).

Atlantic sturgeon length data used for estimating model parameters came from captures made in July, September, October and November of 1998. Based on inspection of the length distributions, these data were assumed to demonstrate growth of a single (age-one) cohort, with all individuals hatched January 1, 1997. The length range for Atlantic sturgeon included in this data set was 286 to 532 mm FL. These lengths are consistent with expected lengths of age-1 Atlantic sturgeon from nearby systems (e.g., Smith et al. 1985). Length data for Atlantic sturgeon caught within a given month were grouped so that monthly length frequencies were estimated with all fish treated as being captured on the 12th of the month. The average date of capture in

July was the 11th and fall captures were limited to the 11th and 12th of September, the 12th of October and the 14th of November.

Mean monthly weight was analyzed as a function of assumed age. Increase in monthly mean weight should provide indirect evidence that juvenile Atlantic sturgeon are foraging. Larger juveniles reportedly fast during the summer (Moser and Ross 1995).

In addition to growth modeling, we conducted least squares fitting of the length - weight relationship for Atlantic sturgeon captured during this investigation. Weight was treated as the dependent variable and predicted by the formula:

$$W = aL^b$$

where parameters a and b were estimated using non-linear regression by minimizing squared residuals on both untransformed and log-transformed scales. Length-weight analyses are commonly done using log-transformed variables because the variance of weight tends to increase with length. Estimates of parameters a and b from the length-weight analysis were compared to published estimates from other systems (Magnin 1964; Holland and Yelverton 1973), in order to examine the relative robustness of Albemarle Sound Atlantic sturgeon at a given length. Using the above formula, if parameter $b > 3$, then fish are becoming more robust with increasing length; when $b < 3$, fish are becoming less robust with length.

Results

1997 captures A total of 22 Atlantic sturgeon were captured in 1997, ranging in length from 320 to 1422 mm FL (mean = 563, SD = 278) and in weight from 227 to 29,484 g (mean = 3,638, SD=8,031; Table 1, Figure 3). The two largest Atlantic sturgeon obtained in either year were captured in 1997. On August 9, an individual measuring 1,422 mm FL was caught in a flounder gillnet in northeastern Albemarle Sound. On September 2, an Atlantic sturgeon measuring 1,340 mm FL was captured in a pound net (the only Atlantic sturgeon to come from this gear) in the southeastern area of the sound. Both of these Atlantic sturgeon were tagged with ultrasonic transmitters.

No shortnose sturgeon were identified among the 1997 captures. One fish with a intraorbital/mouth width ratio of 0.81 (Figure 4) was determined from photographs to have been an Atlantic sturgeon. The high ratio is considered to be a measurement or recording error. Two other intraorbital/mouth width ratios fell within the lower range of values expected for shortnose sturgeon (Figure 4); however, we attribute this to inadequate measurement technique in 1997. Mean intraorbital/mouth width ratio was significantly higher in 1997 than in 1998 ($mean_{1997} = 0.53$, $mean_{1998} = 0.46$, $t = 4.680$, $p<0.001$, Figure 4).

Atlantic sturgeon captures in 1997 occurred over both mud (64%) and sand (32%) substrates (Table 1). Salinities ranged from 0.4 to 3.4 ‰. Captures were distributed throughout the sound, however most were made relatively nearshore (Figure 3). No growth data for 1997 Atlantic sturgeon were obtained because none of these Atlantic sturgeon were recaptured.

Telemetry of 1997 Atlantic sturgeon Of the nine Atlantic sturgeon tagged with ultrasonic transmitters in 1997, five were never relocated, and two (Atlantic sturgeons 357 and 456) apparently either shed their tags or died shortly after release (Figure 5). Of the two remaining telemetered fish, Atlantic sturgeon 555 was relocated three times, and Atlantic sturgeon 447 was relocated two times (Figure 5). The longest time between release and relocation for either field season (55 days) occurred in 1997 with Atlantic sturgeon 447. Because of the limited number of relocations, no habitat selection analysis was conducted for telemetered fish from 1997. No movement into the Roanoke River was detected, based on the Jamesville station at rkm 30.

1998 captures There were 85 Atlantic sturgeon captured in 1998, with lengths ranging from 286 to 659 mm FL (mean = 429, SD = 48; Table 1, Figure 3) and weights from 150 to 1948 g (mean = 479, SD = 180). Of these fish, nine were recaptured including one individual caught three times. The smallest Atlantic sturgeon captured in either field season (FL = 286 mm) was captured in 1998 near the southern shoreline of the study area. Atlantic sturgeon captured in 1998 were smaller on average than those caught in 1997 ($t = 4.361$, $p<0.001$). Two Atlantic sturgeon mortalities occurred in our nets in 1998. Lesions (sores that did not appear to be recent injuries) were observed on 13.8% (n = 13) of Atlantic sturgeon captured by NCSU crews in 1998.

A single shortnose sturgeon capture from the Batchelor Bay region of Albemarle Sound occurred just prior to the start of the 1998 field season (18 April 1998). This individual was captured by NCDMF survey crews, judged unlikely to survive and was placed in a storage freezer (Steve Trowell, NCDMF pers. comm.). The North Carolina State Museum of Natural Sciences currently holds this specimen and a record of its capture. Morphometrics for sturgeon captured by NCSU crews in 1998 did not indicate any shortnose sturgeon captures (Figure 4).

Mean soak time for net sets in 1998 was 11.2 hrs (SD = 5.9). Both daytime (total sets = 21, net hours = 116.1) and nighttime (total sets = 23, net hours = 377.3) sets were conducted. Captures of Atlantic sturgeon in 1998 occurred over both sand (63.8%) and ORM (36.2%). Salinities ranged from 0.0 to 2.2‰ and water surface temperatures ranged from 12.9°C in November to 32.1°C in late July. Most Atlantic sturgeon were captured nearshore, although captures from sets made in deeper water occurred as well (Figure 6).

Because our intent was to obtain as many Atlantic sturgeon as possible, areas that produced Atlantic sturgeon were subjected to relatively greater netting effort than less productive areas. A particularly productive site was located in July 1998 that yielded over 60% of the 1998 catch. This site consisted of an approximately 1 km square area in the shallow (<3.6 m), nearshore, southeastern region of the study area (Figure 7). All nets set in September through November occurred in this area. In September, two consecutive overnight sets at this site yielded 21 Atlantic sturgeon. A single overnight set in October produced 20 Atlantic sturgeon, although only two were caught in an overnight set in November. Another productive site located 2.5 km

outside of the mouth of the Roanoke River produced 20 Atlantic sturgeon on June 2 and 3 (Figure 7). Subsequent netting at this site, however, yielded only three more Atlantic sturgeon.

Telemetry of 1998 Atlantic sturgeon Seven Atlantic sturgeon were released with ultrasonic transmitters in 1998. Of these, all were relocated at least once, three provided sufficient data for habitat selection analysis, and three for movement analysis. The total number of relocations was 100 (Appendix Table 1) excluding those relocations assumed to be from shed tags or fish that died after release. Although searches were conducted throughout the sound (as conditions permitted), all relocations of telemetered Atlantic sturgeon in 1998 occurred within the delimited study area in the western part of the sound. Most fish were relocated at sites that were 1.8 to 5.4 m in depth, although fish 2336 was relocated several times over ORM in the deepest sections of the study area (Figure 8). Relocation patterns of individual fish appeared to demonstrate short-range movement within discrete areas. No movement up into the Roanoke River was detected by the Jamesville monitoring station.

Three of seven Atlantic sturgeon either shed their transmitter or died during the period when telemetry searches were conducted (Table 2). Fish 294 was relocated at only one position after release, so it may have died due to capture or handling. Fish 2237 and 384 were relocated at several sites over periods of 10 and 31 days respectively, then repeatedly relocated at the same sites. This pattern probably

indicates a shed transmitter. The maximum time at large for which discernible movement by an Atlantic sturgeon was detected was 34 days by fish 276.

Atlantic sturgeon sometimes move long distances after release. Fish 384 moved about 5 km northeast initially, but subsequent relocations indicated short-range movement in the western half of the study area (Figure 9). Most relocations for fish 384 occurred over the 3.6 to 5.4 m depth interval. After 31 days at large, relocations for this fish were at a fixed site (Figure 9) and the transmitter was assumed to have been shed. Fish 465 was captured in the southeastern region of the study area and relocated about 10 km away the following day (Figure 10). All subsequent relocations of this fish revealed short-range movement in the northeastern region. Fish 2345 was tagged in the Bachelor Bay area and relocated at widely separated sites during the final 10 days of tracking (Figure 11). All relocations of this fish occurred in relatively shallow water.

Only one fish was relocated in a tributary to Albemarle Sound. Fish 2237 was released on 2 June, then relocated at the confluence of the Middle and Cashie rivers from 3 June to 9 June, after which this fish moved approximately 5 km upstream into the Middle River (Figure 8). The fish stayed at this new location from 10 June through 12 June, then returned to the area where it was originally relocated. All subsequent relocations of this fish occurred at this site and the tag was assumed to have been shed.

Fish 276 demonstrated short-range movement within two discrete areas of western Albemarle Sound (Figure 12). It was found in the southwestern region of the study area from the date of release (18 June) through 30 June, then relocated in the

north-central part of the study area until the end of the field season (Figure 12). This fish, which was caught in our nets on 22 July, was the only telemetered fish to be recaptured. Examination of the pre-dorsal fin area revealed ulcers where the transmitter had been in contact with the fish's skin. This fish grew relatively little compared to other recaptured fish without transmitters. Because of a possible transmitter effect on growth, this fish was not included in growth analysis.

We found evidence of non-random movement patterns (site fidelity) for three of the four cases for which we had sufficient data (Table 3, Figure 13) at $\alpha = 0.10$. Because relocations for fish 276 occurred in two discrete zones, they were tested separately as 276N (north) and 276S (south). Fish 465 showed significantly constrained movement, while fish 384 showed marginally constrained movement (Table 3). Fish 276 showed significantly constrained movement in the northern set of relocations, but not in the south, or when both northern and southern relocations were analyzed together. Observed dispersal for fish 2345, which was only relocated 5 times and appeared to range more widely than other Atlantic sturgeon, was not significantly different from dispersal for random walk simulations.

1998 MFC Fishery Resource Grant Project Sixty-nine Atlantic sturgeon were captured and tagged by R. White from September through December 1998 through the MFC Fishery Resource Grant Program (Table 5). Six individuals were recaptured, resulting in a total of 75 Atlantic sturgeon capture occurrences. Mr. White did not report encountering any Atlantic sturgeon mortalities or any shortnose sturgeon captures. Consistent with the distribution of fishing effort, captures were

primarily along the northern shore of the sound at depths of 1.8 - 5.4 m near the Little and Pasquotank Rivers, (Figure 14) although some offshore sets also produced Atlantic sturgeon. Captures occurred over ORM (66.2%) sand (7.0%) and mixed ORM and sand (26.8%)(Table 5).

Habitat selection Sample sizes for examining habitat selection were adequate for Atlantic sturgeon 384, 276, and 465. All three of those telemetered Atlantic sturgeon demonstrated statistically significant depth preferences (384: Chi squared=63.13, $p<0.001$; 276: Chi squared=11.71, $p<0.01$; 465: Chi squared=10.85, $p<0.01$; Figure 15). Patterns of depth association varied among individuals, but generally, the shallowest (<1.8 m) and deepest (>5.4 m) depth intervals were used less than expected under the null hypothesis. The 3.6-5.4 m depth interval was the preferred depth range for fish 384 and 465 (Figure 15).

Two of three fish demonstrated a significant substrate preference (384: Chi squared=12.00, $p<0.01$; 276: Chi squared=1.65, $p< 0.10$; 465: Chi squared= 5.12, $p<0.05$). Relocations over ORM for fishes 384 and 465 were more frequent than could be expected under the null hypothesis (Figure 16).

Length distributions Length distributions from NCSU 1997 - 1998 survey netting were roughly similar to the pooled distribution from the 1990 - 1995 NCDMF fishery-independent survey (Figure 17). Atlantic sturgeon captured by NCSU were larger on average in 1997 than 1998 ($t = 4.36$, $p<0.001$) (Figure 3). Atlantic sturgeon captured in 1998 by R. White using larger mesh gillnets and fishing in eastern

Albemarle Sound were larger than those caught in 1998 by NCSU ($t = 12.76$, $p<0.001$). Atlantic sturgeon captured by NCSU during May - June 1998 varied widely in size (Figure 18). Length compositions for July - November were assumed to apply to a single cohort of age-1 fish that was used for growth modeling.

Growth The estimated relationship between fork length (mm) and weight (g) for Atlantic sturgeon captured by NCSU crews in 1998 was:

$$\text{Weight} = 9.10 \times 10^{-6} (\text{Length})^{2.944}$$

Non-linear regression analysis indicated significant dependence of Weight on Length ($F = 486.15$, $p<0.001$, $R^2 = 0.933$, SE = 64.3; Figure 19).

A linear model fitted to mean length from monthly July, September, October, and November 1998 sampling provided a good fit (mean length = 206.65(age in years) + 63.55; $R^2=0.99$). This is equivalent to a daily growth rate of 0.57mm/day. Mean monthly weight increased exponentially with increasing assumed age (mean weight = 72.169(age in years)$^{3.6}$; $R^2=0.77$).

Log-likelihood estimation of von Bertalanffy model parameters from observed length increment and length frequency data initially produced unacceptable values for mean maximum length (L_∞) and instantaneous growth rate (K):

$$\text{Length} = 422.8(1 - e^{-0.836 (\text{Age} - [-0.281])}).$$

Estimated L_∞ was well below biologically reasonable values, due to the lack of length increment data from either larger fish or from longer time at large periods (Figure 20). Because the estimates of L_∞ and K were highly inversely correlated, the underestimate of L_∞ also produced an overestimate of K. By fixing L_∞ at the

maximum length reported for Atlantic sturgeon from the Roanoke River (2,692 mm; Roanoke News 1908), more realistic von Bertalanffy parameter estimates were obtained:

$$\text{Length} = 2692(1 - e^{-0.0903(\text{Age} - [-0.148])}).$$

This model produced good agreement between predicted and observed length increments (Figures 20 and 21). Predicted and observed length frequencies agreed reasonably well except in November, where the sample size was n=2 fish (Figure 21).

An alternative value for L_∞ (2,179mm) was obtained by averaging mean lengths reported for age-21+ Atlantic sturgeon from other river systems. River systems for which these data could be obtained for Atlantic sturgeon included the St. Lawrence River (Magnin 1964), Hudson River (Dovel and Bergrenn 1983), and the Waccamaw, Black, Pee Dee, South Santee, and South Edisto rivers in South Carolina (Smith et al. 1982). Using this lower estimate of L_∞ produced an increase in K:

$$L_t = 2179(1 - e^{-0.1172(t - [-0.102])}).$$

but provided a similarly good fit to the length increment and length frequency data. The growth curve with L_∞ based on the single large fish from 1908 produced predicted values that were generally higher than observed lengths at age from other systems (Figure 22). The growth curve with L_∞ based on mean lengths of age-21+ fish was in close agreement with observed sizes at ages 1-20 from South Carolina rivers. Both curves generally overestimated size at ages 1-20 from the Hudson and St. Lawrence systems.

Relationship of Atlantic sturgeon captures to EMAP measurements EMAP sampling in western Albemarle Sound detected two sites with high toxicity levels in the Roanoke River and mouth of the Cashie River and one in deep water in the northeastern region of the study area (Figure 23). There was no clear relationship between 1998 capture locations of Atlantic sturgeon with visible lesions and their proximity to sites showing high sediment toxicity (Figure 23).

Species Composition of NCSU Gillnet Captures In terms of numbers of individuals caught, Atlantic sturgeon was the ninth most abundant species (Figure 24), representing 3.1% of the total catch, with the monthly percentage ranging from 1.4% in November to 5.3% in October (Figure 25). The most common species in 1998 NCSU gillnet sets were gizzard shad (*Dorosoma cepedianum*), redhorse (*Moxostoma sp.*), and blue crab (*Callinectes sapidus*), particularly in summer samples (Appendix Table 2, Figures 24-25). A large catch of Atlantic menhaden (n = 254) occurred in a single overnight set in October, causing it to be the fourth most abundant bycatch species.

Discussion

Although spawning has not been directly observed, there is strong evidence to indicate that Atlantic sturgeon are reproducing in the Albemarle Sound drainage. Through mitochondrial DNA analysis of tissue samples provided through this project, Wirgin and Waldman (unpublished data) have identified a genetically distinct Albemarle Sound strain among East Coast populations of Atlantic sturgeon. Additionally, growth data for Atlantic sturgeon from other systems (Dovel and Bergrenn 1983, Smith et al. 1982) indicate that observed lengths for fish we captured in 1998 are consistent with observed lengths for early-juveniles (age two or younger; Bain 1997). Atlantic sturgeon of this age are typically found within their natal system (Smith and Dingley 1984; Smith et al. 1985; Bain 1997). This evidence of an extant native population suggests that the current prohibition of harvest, coupled with efforts to minimize bycatch should allow the Albemarle Sound Atlantic sturgeon population to increase naturally without the need for stocking.

Captures of occasionally large numbers of juvenile Atlantic sturgeon in Albemarle Sound suggest that these fish may be aggregating. Gillnet capture rates are a function of both fish density and swimming activity, so it is difficult to establish that a patchy distribution explains variability in catch. Moser and Ross (1995) observed increased swimming activity of Atlantic sturgeon during months with cooler (<25°C) water temperatures. Anecdotal reports by Albemarle Sound commercial fishermen describe relatively greater fall and winter bycatch of Atlantic sturgeon. Increased catch during fall and spring may also be a function of increased migratory behavior during those seasons (Smith et al. 1985; Moser and Ross 1995;

Bain 1997). Aggregational behavior may also results from patchy distribution of forage species. EMAP benthic diversity assessments (Hackney et al. 1998) suggest that the abundance of infaunal forage species varies spatially. Gut content analyses and more extensive benthic surveys are needed to address this possibility. Because capture methodology was contrived to maximize catch, rather than randomized to test capture variability, statistical analysis of 1998 NCSU capture variability would be complicated by multiple confounding variables and was not conducted.

Depth selection by early-juvenile Atlantic sturgeon was demonstrated by some individuals, although it was not consistently shown. Problems with shed transmitters reduced sample sizes, limiting our ability to address this question. Researchers working in other systems have observed depth selection of juvenile Atlantic sturgeon with deeper waters being occupied during summer months (Smith et al. 1982; Moser and Ross 1995; Bain 1997). Albemarle Sound is a relatively shallow system, however, with a lack of cool oxygenated refugia during summer. Interestingly, the majority of our July captures occurred along the southern shoreline in less than 3m when bottom water temperatures approached 30°C. Given their long history of association with Albemarle Sound, these Atlantic sturgeon may be especially adapted to withstand the stresses of summer water quality constraints.

Preference for the ORM substrate-type was demonstrated statistically for two telemetered Atlantic sturgeon in Albemarle Sound while capture of juvenile Atlantic sturgeon by commercial gillnetters is reportedly more frequent over sand. This conflict may come from our small sample size or may be due to the relatively greater commercial fishing effort on sandy shoals than on the ORM basin in Albemarle

Sound. R. White set nets over both bottom types and most of his Atlantic sturgeon captures occurred over ORM. Most likely, sediment type is of secondary influence on Atlantic sturgeon distribution compared to the distribution of forage species. Further investigation into Atlantic sturgeon food habits and the distribution of benthic invertebrates in the sound may be the most productive follow up for addressing substrate associations.

Estimated length-weight model parameters for Atlantic sturgeon in Albemarle Sound are similar to estimated values for other systems (Magnin 1964; Holland and Yelverton 1973; Figure 19). Additionally, increase in monthly mean weight of juveniles captured during the study period suggests that these Atlantic sturgeon may be feeding during the summer. This result, coupled with the consistency of our growth curves with growth curve estimates for other systems, indicates relatively typical growth of early-juvenile Atlantic sturgeon in Albemarle Sound. The reliability of both length-weight and size-at-age models could be improved with the addition of data from larger size classes. Gut content analysis is necessary to confirm that these juveniles are foraging in the summer. The current results however are consistent with the function of Albemarle Sound as an adequate nursery habitat.

A somewhat more pessimistic view of the quality of fish habitat in Albemarle Sound was put forth by Hackney et al. (1998). They reported visible pathologies on 15% of finfish obtained at uncontaminated sites in Albemarle Sound during EMAP demersal trawl sampling, and 50% occurrence at contaminated sites. These researchers did not offer an etiological explanation for observed finfish pathologies in their study (Hackney et al. 1998). We observed lesions on 13.8% of Atlantic

sturgeon captured during 1998 NCSU sampling, but we also observed movement of telemetered and tagged Atlantic sturgeon throughout western Albemarle Sound. Thus it does not seem possible to link site-specific sediment toxicity data to the presence of lesions on individual Atlantic sturgeon. Further research is necessary, of course, to establish a causative basis for the observed pathologies.

Site fidelity analysis of telemetered Atlantic sturgeon suggests that movement of early-juvenile Atlantic sturgeon can be site constrained, at least for temporary periods. This is consistent with Atlantic sturgeon movement observed in the Cape Fear River by Moser and Ross (1995). Whether site constraint is a function of temperature, oxygen, forage availability, or some other factor is unknown. Further telemetry studies, possibly using surgically implanted transmitters to increase tracking time, may help to address these questions.

Most Atlantic sturgeon captured in 1997, and by commercial gillnetter R. White in 1998 were within the expected size range for age-2 fish, whereas Atlantic sturgeon captured in NCSU nets in 1998 were estimated to be age one. Although predicting ages of individuals from lengths should be approached cautiously, modal lengths of early-juvenile Atlantic sturgeon cohorts should be well separated because of an abbreviated spring spawning season, and fast juvenile growth (Dadswell 1979).

The impact of bycatch on Atlantic sturgeon remains unevaluated in Albemarle Sound. Juvenile Atlantic sturgeon occur as bycatch predominately in monofilament gillnets set for flounder. Collins et al. (1996) reported 20% injuries and 16% mortality for sturgeons captured in American shad gillnets in South Carolina. Bycatch of Atlantic sturgeon in Albemarle Sound may reveal different trends,

however, due to their comparatively smaller size as well as differences in the fishery. Limited availability of Atlantic sturgeon habitat in the sound may increase likelihood of incidental capture where the distribution of required habitat coincides with the distribution of fishing effort.

Although the morphology of early-juvenile Atlantic sturgeon appears to make them vulnerable to capture in monofilament gillnets of any mesh size (Moser pers.comm., Armstrong pers. obs.), size-selectivity of NCDMF gear was demonstrated (Figure 1; L(mm) = 273.9 + 18.4[mesh size (cm)], $F = 78.75$, $p<0.001$). Mesh sizes used by flounder gillnetters in Albemarle Sound typically range from 14.0 to 17.1cm, so Atlantic sturgeon of 532-589 mm in length would be expected to have highest vulnerability to that fishery. Observed length frequency data from R. White's 1998 catches (Figure 17) are consistent with that prediction.

It is difficult to assess the degree to which flounder gillnet bycatch might impact the Atlantic sturgeon population in Albemarle Sound. NCDMF captured only 15 Atlantic sturgeon in mesh sizes used by commercial gillnetters (14.0-17.8 cm) from 1990 to 1995 (Figure 1). One interpretation for this low catch would be high mortality prior to recruitment to these mesh sizes. Alternatively, if Atlantic sturgeon distribution in the sound is size-structured east to west, larger fish may avoid NCDMF gear since sampling occurs mostly in the western Albemarle Sound (Figure 2). Salinities are typically higher in the eastern sound and migration of larger juveniles into higher salinity waters has been reported in other systems (Smith 1985, Bain 1997). R. White captured 71 Atlantic sturgeon in only four months, using 14.0-15.2 cm mesh gillnets in northeastern Albemarle Sound. Migration into coastal ocean

waters could also account for our inability to locate some telemetered fish. One of the two largest fish (FL=1422 mm) was relocated on three occasions in the first three days after release; the second (FL=1340 mm) was never relocated after release.

Conclusions

The early-juvenile Atlantic sturgeon captured in Albemarle Sound through this project are likely to have been spawned within the Albemarle Sound drainage system. Management implications of this finding include maintaining the current prohibition of harvest and minimization of bycatch to allow the Albemarle Sound population to increase naturally, without the need for stocking. The impact of bycatch on the Atlantic sturgeon population in Albemarle Sound remains unevaluated.

Relatively normal growth rates of juvenile Atlantic sturgeon in the sound suggest that the sound may function as an adequate nursery ground for this species. Sediment contamination in Albemarle Sound is of unknown consequence to resident sturgeon. Additionally, the relative importance of various habitats available in the sound remains unclear, however, the aggregational behavior of early-juveniles suggested by occasionally large catches indicates the need for further study of this issue.

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Table 1. Summary data for 1997 and 1998 Atlantic sturgeon captures. Latitude and longitude are expressed in decimal degrees. Captures are presented in chronological order. A recapture is denoted by the individual number plus a letter indicating first recapture (a), second recapture (b), etc.

Capture Sequence	Individual	Tag ID	Date	Fork Length (mm)	Weight (g)	Latitude	Longitude	Transmitter	Substrate	Depth (m)	Source	Gear	Mesh Size (in)
1	1	115536792A	28-Jun-97	320	227	nr	nr		nr	nr	S. Keefe	gillnet	nr
2	2	116153735A	14-Jul-97	397	397	35.954067	-76.561117		sand	3.0	R.White	gillnet	6.5
3	3	116175513A	16-Jul-97	404	510	36.127800	-76.101750		sand	3.0	R.White	gillnet	nr
4	4	115962614A	16-Jul-97	587	1417	36.127800	-76.101750	357 37kHz	sand	3.0	R.White	gillnet	nr
5	5	115625553A	21-Jul-97	515	907	36.017200	-76.593100	456 40kHz	sand	2.6	R. Bass	gillnet	nr
6	6	116249390A	21-Jul-97	390	283	36.017200	-76.593100		sand	2.6	R. Bass	gillnet	nr
7	7	116269696A	21-Jul-97	409	454	35.943817	-76.573333		sand	1.5	NCSU	gillnet	3.0
8	8	116115324A	29-Jul-97	385	454	36.202617	-76.060133		sand	1.5	R.White	gillnet	nr
9	9	115526252A	9-Aug-97	1422	29484	36.119467	-76.085833	555 40kHz	ORM	5.5	R.White	gillnet	nr
10	10	115615235A	9-Aug-97	595	1724	36.119467	-76.085833	447 38kHz	ORM	5.5	R.White	gillnet	nr
11	11	no tag	9-Aug-97	602	1996	36.119467	-76.085833	366 38kHz	ORM	5.5	R.White	gillnet	nr
12	12	116162447A	11-Aug-97	425	510	36.101167	-76.057600		ORM	4.0	R.White	gillnet	5.5
13	13	115624455A	11-Aug-97	427	510	36.101567	-76.058817		ORM	4.0	R.White	gillnet	5.5
14	14	115619491A	11-Aug-97	410	454	36.101867	-76.053267		ORM	4.9	R.White	gillnet	5.5
15	15	115617244A	13-Aug-97	570	1270	36.115300	-76.085583	249 32kHz	ORM	4.3	S. Keefe	gillnet	nr
16	16	115623120A	2-Sep-97	1340	19278	36.000883	-76.066650	258 33kHz	ORM	4.9	R. Davenport	pound net	N/A
17	17	115544597A	14-Nov-97	504	nr	36.057433	-76.413567		ORM	4.2	S. Keefe	gillnet	4.5
18	18	115673350A	14-Nov-97	528	nr	35.996883	-76.410117		ORM, clay mix	3.0	S. Keefe	gillnet	nr
19	19	115666743A	14-Nov-97	585	nr	35.994300	-76.411617	348 36kHz	ORM, clay mix	2.6	S. Keefe	gillnet	nr
20	20	116161315A	14-Nov-97	474	nr	35.989783	-76.418233		ORM, clay mix	2.3	S. Keefe	gillnet	nr
21	21	115548535A	18-Dec-97	580	1355	36.099733	-76.702433	285 34kHz	ORM	5.2	NCDMF	gillnet	2.5
22	22	116169730A	18-Dec-97	510	1129	36.100350	-76.704333		ORM	5.2	NCDMF	gillnet	4.0
23	23	116215140A	7-May-98	420	508	35.947000	-76.633667		ORM	4.0	NCDMF	gillnet	3.00
24	24	115939331A	13-May-98	424	508	35.943667	-76.663833		sand	3.1	NCDMF	gillnet	5.00
25	25	114926370A	14-May-98	431	565	35.944833	-76.663833		sand	4.0	NCDMF	gillnet	4.50
26	26	116165395A	14-May-98	420	508	35.944833	-76.663833		sand	4.0	NCDMF	gillnet	nr
27	27	115551391A	15-May-98	625	1524	35.937833	-76.608333	384 40 kHz	ORM	nr	R. Bass	gillnet	5.75
28	28	2217764817	15-May-98	412	508	35.937833	-76.608333		ORM	nr	R. Bass	gillnet	5.75
29	29	221757286E	15-May-98	420	452	35.937833	-76.608333		ORM	nr	R. Bass	gillnet	5.75
30	30	114524391A	29-May-98	585	960	35.946833	-76.580833		sand	1.5	NCSU	gillnet	4.00
31	31	114933186A	2-Jun-98	425	508	35.962000	-76.677833		ORM	3.0	NCSU	gillnet	4.00
32	32	114552465A	2-Jun-98	422	536	35.963167	-76.677333		ORM	3.0	NCSU	gillnet	4.00
33	33	114534245A	2-Jun-98	659	1948	35.963167	-76.677333	2237 37khz	ORM	3.0	NCSU	gillnet	4.00
34	34	115146361A	2-Jun-98	421	452	35.963167	-76.677333		ORM	3.0	NCSU	gillnet	4.00
35	35	114551597A	2-Jun-98	415	423	35.962667	-76.676833		ORM	3.0	NCSU	gillnet	4.00
36	36	1435114352	2-Jun-98	560	1044	35.963000	-76.675667	294 35khz	ORM	3.0	NCSU	gillnet	4.00
37	37	1435314354	2-Jun-98	585	1327	35.963500	-76.674500	2336 38khz	ORM	3.0	NCSU	gillnet	4.00

Capture Sequence	Individual	Tag ID	Date	Fork Length (mm)	Weight (g)	Latitude	Longitude	Transmitter	Substrate	Depth (m)	Source	Gear	Mesh Size (in)
38	29a	221757286E	2-Jun-98	434	536	35.963333	-76.674333		ORM	3.0	NCSU	gillnet	4.00
39	38	1435714358	2-Jun-98	402	423	35.964000	-76.674000		ORM	3.0	NCSU	gillnet	4.00
40	39	1435914360	2-Jun-98	474	706	35.966333	-76.674333		ORM	3.0	NCSU	gillnet	4.00
41	40	(mortality)	2-Jun-98	454	595	35.984833	-76.674667		ORM	3.0	NCSU	gillnet	4.00
42	41	114527790A	3-Jun-98	454	678	35.963167	-76.673333		ORM	3.0	NCSU	gillnet	4.00
43	42	114924467A	3-Jun-98	450	649	35.963167	-76.673333		ORM	3.0	NCSU	gillnet	4.00
44	43	116165395A	3-Jun-98	439	593	35.962833	-76.675167		ORM	3.0	NCSU	gillnet	4.00
45	44	114922146A	3-Jun-98	467	706	35.962833	-76.675500		ORM	3.0	NCSU	gillnet	4.00
46	45	114752533A	3-Jun-98	479	790	35.962833	-76.675333		ORM	3.0	NCSU	gillnet	4.00
47	35a	114551597A	3-Jun-98	410	423	35.962500	-76.676000		ORM	3.0	NCSU	gillnet	4.00
48	46	115179445A	3-Jun-98	409	480	35.962500	-76.676667		ORM	3.0	NCSU	gillnet	4.00
49	47	115612255A	3-Jun-98	434	508	35.961667	-76.677500		ORM	3.0	NCSU	gillnet	4.00
50	48	114673245A	3-Jun-98	433	536	35.961833	-76.677667		ORM	3.0	NCSU	gillnet	4.00
51	49	0A00100044	10-Jun-98	372	450	35.962500	-76.672667		ORM	3.0	NCSU	gillnet	4.00
52	42a	114924467A	11-Jun-98	462	700	35.962333	-76.672833		ORM	3.0	NCSU	gillnet	4.00
53	41a	114527790A	11-Jun-98	466	650	35.960000	-76.672333		ORM	3.0	NCSU	gillnet	4.00
54	50	0A00100850	18-Jun-98	472	800	35.949333	-76.631500	276 33kHz	ORM	4.3	NCSU	gillnet	4.00
55	51	0A00101560	23-Jun-98	476	700	35.948500	-76.620667		ORM	5.5	NCSU	gillnet	4.00
56	52	0A00101278	1-Jul-98	391	450	36.003333	-76.586333		sand	5.5	NCSU	gillnet	4.00
57	53	0A00101549	2-Jul-98	313	170	35.950667	-76.539000		sand	1.8	NCSU	gillnet	4.00
58	54	0A00100178	2-Jul-98	329	275	35.950667	-76.539167		sand	1.8	NCSU	gillnet	4.00
59	55	0A00096843	3-Jul-98	471	700	35.950667	-76.539333	465 39kHz	sand	2.4	NCSU	gillnet	4.00
60	56	0A00101704	7-Jul-98	349	350	35.949667	-76.540833		sand	2.1	NCSU	gillnet	4.00
61	57	0A00100154	7-Jul-98	341	300	35.949333	-76.540833		sand	2.1	NCSU	gillnet	4.00
62	58	0A00100404	7-Jul-98	369	400	35.949000	-76.541500		sand	2.1	NCSU	gillnet	4.00
63	59	0A00100913	7-Jul-98	334	350	35.947833	-76.542667		sand	2.1	NCSU	gillnet	4.00
64	60	0A00101921	8-Jul-98	369	350	35.948667	-76.542833		sand	2.1	NCSU	gillnet	4.00
65	61	115621173A	8-Jul-98	328	200	35.948667	-76.542500		sand	2.1	NCSU	gillnet	4.00
66	62	0A00101216	8-Jul-98	335	200	35.949000	-76.542833		sand	2.1	NCSU	gillnet	4.00
67	63	0A00096907	8-Jul-98	455	650	35.949333	-76.542000		sand	2.1	NCSU	gillnet	4.00
68	64	0A00096729	8-Jul-98	326	250	35.949833	-76.539833		sand	2.1	NCSU	gillnet	4.00
69	65	0A00100829	8-Jul-98	286	150	35.949333	-76.540000		sand	2.4	NCSU	gillnet	4.00
70	66	114658186A	8-Jul-98	325	250	35.948000	-76.542833		sand	2.4	NCSU	gillnet	4.00
71	67	114659291A	16-Jul-98	382	400	35.950833	-76.537500		sand	2.7	NCSU	gillnet	4.00
72	68	114536551A	16-Jul-98	345	250	35.951000	-76.536500		sand	2.7	NCSU	gillnet	4.00
73	69	115623194A	16-Jul-98	331	250	35.951000	-76.534167		sand	2.7	NCSU	gillnet	4.00
74	70	115623391A	17-Jul-98	363	425	35.952167	-76.536333		sand	2.1	NCSU	gillnet	4.00
75	71	114919274A	17-Jul-98	344	200	35.951333	-76.538000		sand	2.1	NCSU	gillnet	4.00
76	42b	114924467A	20-Jul-98	485	800	35.979500	-76.683000	2345 38kHz	ORM	3.0	NCSU	gillnet	4.00

Capture Sequence	Individual	Tag ID	Date	Fork Length (mm)	Weight (g)	Latitude	Longitude	Transmitter	Substrate	Depth (m)	Source	Gear	Mesh Size (in)
77	72	0A00105152	21-Jul-98	447	500	35.970500	-76.671500		ORM	3.7	NCSU	gillnet	4.00
78	73	0A00100643	22-Jul-98	400	425	36.005167	-76.568833		ORM, grass	4.6	NCSU	gillnet	4.00
79	74	0A00103800	22-Jul-98	415	425	36.003833	-76.572333		ORM, grass	4.6	NCSU	gillnet	4.00
80	50a	0A00100850	22-Jul-98	480	700	36.003833	-76.572333	375 40kHz	ORM, grass	4.6	NCSU	gillnet	4.00
81	75	0A00100842	11-Sep-98	410	450	35.947000	-76.539167		sand	1.4	NCSU	gillnet	4.00
82	76	0A00102008	11-Sep-98	378	300	35.947000	-76.539333		sand	1.4	NCSU	gillnet	4.00
83	77	0A00103259	11-Sep-98	385	350	35.946667	-76.539500		sand	1.4	NCSU	gillnet	4.00
84	78	0A00101222	11-Sep-98	532	1100	35.947000	-76.539833		sand	1.4	NCSU	gillnet	4.00
85	79	0A00096941	11-Sep-98	377	300	35.947500	-76.539167		sand	1.4	NCSU	gillnet	4.00
86	80	0A00101538	11-Sep-98	425	500	35.946833	-76.542000		sand	1.4	NCSU	gillnet	4.00
87	81	0A00096977	11-Sep-98	431	500	35.947167	-76.541333		sand	1.4	NCSU	gillnet	4.00
88	82	0A00101114	11-Sep-98	365	300	35.946667	-76.542500		sand	1.4	NCSU	gillnet	4.00
89	69a	115623194A	12-Sep-98	370	300	35.948333	-76.544667		sand	1.4	NCSU	gillnet	4.00
90	83	0A00105425	12-Sep-98	395	400	35.948167	-76.545167		sand	1.4	NCSU	gillnet	4.00
91	84	0A00100649	12-Sep-98	405	350	35.948333	-76.546500		sand	1.4	NCSU	gillnet	4.00
92	85	0A00102033	12-Sep-98	404	450	35.947167	-76.548167		sand	1.4	NCSU	gillnet	4.00
93	86	0A00097219	12-Sep-98	386	300	35.946833	-76.548167		sand	1.4	NCSU	gillnet	4.00
94	82a	0A00101114	12-Sep-98	366	250	35.946667	-76.548667		sand	1.4	NCSU	gillnet	4.00
95	87	0A00103520	12-Oct-98	482	750	35.949333	-76.536000		sand	1.8	NCSU	gillnet	4.00
96	88	0A00097741	12-Oct-98	402	350	35.949333	-76.535833		sand	1.8	NCSU	gillnet	4.00
97	89	0A00101237	12-Oct-98	404	400	35.949500	-76.536167		sand	1.8	NCSU	gillnet	4.00
98	90	0A00101600	12-Oct-98	468	700	35.949000	-76.536167		sand	1.8	NCSU	gillnet	4.00
99	91	0A00105371	12-Oct-98	479	750	35.948667	-76.536000		sand	1.8	NCSU	gillnet	4.00
100	92	0A00100212	12-Oct-98	447	450	35.949167	-76.536500		sand	1.8	NCSU	gillnet	4.00
101	93	114536643A	12-Oct-98	426	450	35.949167	-76.536000		sand	1.8	NCSU	gillnet	4.00
102	94	0A00101656	12-Oct-98	458	600	35.949000	-76.536500		sand	1.8	NCSU	gillnet	4.00
103	95	0A00097266	12-Oct-98	449	500	35.949333	-76.536500		sand	1.8	NCSU	gillnet	4.00
104	96	0A00100274	12-Oct-98	394	400	35.949167	-76.536333		sand	1.8	NCSU	gillnet	4.00
105	97	0A00105367	12-Oct-98	444	450	35.949500	-76.537333		sand	1.8	NCSU	gillnet	4.00
106	98	0A00101959	12-Oct-98	432	450	35.949500	-76.537167		sand	1.8	NCSU	gillnet	4.00
107	99	0A00100654	12-Oct-98	458	600	35.948667	-76.538000		sand	1.8	NCSU	gillnet	4.00
108	100	0A00100438	12-Oct-98	426	450	35.949000	-76.537833		sand	1.8	NCSU	gillnet	4.00
109	101	0A00097034	12-Oct-98	444	500	35.949167	-76.538000		sand	1.8	NCSU	gillnet	4.00
110	102	0A00101004	12-Oct-98	484	650	35.949333	-76.538667		sand	1.8	NCSU	gillnet	4.00
111	103	0A00101362	12-Oct-98	467	750	35.949000	-76.538333		sand	1.8	NCSU	gillnet	4.00
112	53a	0A00101549	12-Oct-98	374	250	35.949000	-76.538833		sand	1.8	NCSU	gillnet	4.00
113	104	0A00101558	12-Oct-98	418	400	35.948500	-76.540167		sand	1.8	NCSU	gillnet	4.00
114	105	0A00101351	12-Oct-98	462	600	35.949167	-76.539833		sand	1.8	NCSU	gillnet	4.00
115	106	4163271E6F	14-Nov-98	492	700	35.949333	-76.543000		sand	1.8	NCSU	gillnet	4.00
116	107	416346713C	14-Nov-98	510	950	36.949000	-76.542000		sand	1.8	NCSU	gillnet	4.00

Table 2. Summary of results for telemetered Atlantic sturgeon released in 1998 in Albema

Transmitter/fish number	Attachment date	Date of last relocation	Days tracked	Number of relocations	Comment
384	15-May-98	16-Jun-98	31	41	probable tag loss
2336	2-Jun-98	6-Jun-98	4	5	
294	2-Jun-98	4-Jun-98	2	3	probable mortality
2237	2-Jun-98	12-Jun-98	10	13	probable tag loss
276	18-Jun-98	22-Jul-98	34	29	
465	3-Jul-98	30-Jul-98	27	21	
2345	20-Jul-98	30-Jul-98	10	5	

Table 3. Site fidelity analysis for telemetered Atlantic sturgeon 384, 276, 465, and 2345. Northern and southern relocations of fish 276 were analyzed separately (276N, 276S), and together (276).

Fish/Transmitter number	Number of relocations included in analysis	Minimum convex polygon area (km2)	Length of net movement path (km)	Proportion of simulated random walks with equal or less dispersal
384	27	14.16	30.33	0.109
276	29	38.51	38.13	0.701
276N	17	2.35	13.29	0.020
276S	12	9.68	17.54	0.346
465	21	17.11	37.55	0.066
2345	5	38.63	27.6	0.381

Table 4. Summary of September - December 1998 capture data for Atlantic sturgeon by R. White under NC Marine Fisheries Commission Fishery Resource Grant Number 98FEG-39.

Capture Sequence	Individual	Pect Tag	Dorsal Tag	FL (mm)	Latitude	Longitude	Time set	Time checked	Soak Time	Mesh size (ISM)	Depth (m)	Water temp (C)	Substrate
1	1	ATS001	ATS002	521	36.118117	-76.088033	9/10/98 5:00 PM	9/11/98 6:00 AM	13.00	5.50	4.4	24.4	mud
2	2	ATS003	ATS004	533	36.127733	-76.091750	9/24/98 5:30 PM	9/25/98 6:30 AM	13.00	5.50	3.1	23.3	mud and sand
3	3	ATS005	ATS006	552	36.125000	-76.089533	9/30/98 5:30 PM	10/1/98 6:30 AM	13.00	5.75	1.6	24.4	sand
4	4	ATS007	ATS008	756	36.126317	-76.109817	10/8/98 5:00 PM	10/9/98 7:00 AM	14.00	5.50	1.7	21.7	mud and sand
5	5	ATS009	ATS010		36.124350	-76.122200	10/11/98 5:00 PM	10/12/98 6:30 AM	13.50	5.50	1.6	21.7	sand
6	6	ATS011	ATS012	730	36.010600	-76.067233	10/12/98 5:00 PM	10/13/98 7:00 AM	14.00	5.50	5.1	20.6	mud
7	7	ATS013	ATS014	622	36.112367	-76.086867	10/15/98 4:00 PM	10/16/98 7:00 AM	15.00	5.50	4.5	20.0	mud and sand
8	8	ATS015	ATS016	686	36.114067	-76.083800	10/15/98 4:00 PM	10/16/98 7:00 AM	15.00	5.50	4.6	20.0	mud and sand
9	9	ATS017	ATS018	591	36.113800	-76.091067	10/15/98 4:00 PM	10/16/98 7:00 AM	15.00	5.50	4.5	20.0	mud and sand
10	10	ATS019	ATS020	705	36.113967	-76.090817	10/15/98 4:00 PM	10/16/98 7:00 AM	15.00	5.50	4.6	20.0	mud and sand
11	11	ATS021	ATS022	572	36.116233	-76.084050	10/15/98 4:00 PM	10/16/98 7:00 AM	15.00	5.50	4.5	20.0	mud and sand
12	12	ATS023	ATS024	622	36.150217	-76.001983	10/23/98 5:00 PM	10/24/98 7:00 AM	14.00	5.50	4.0	17.8	mud and sand
13	13	ATS025	ATS026	622	36.150217	-76.001983	10/23/98 5:00 PM	10/24/98 7:00 AM	14.00	5.50	4.0	17.8	mud and sand
14	14	ATS027	ATS028	584	36.108567	-75.869050	10/24/98 5:00 PM	10/25/98 7:00 AM	14.00	5.50	5.3	16.7	mud
15	15	ATS029	ATS030	572	36.033817	-75.860617	10/25/98 5:00 PM	10/26/98 7:00 AM	14.00	5.50	5.8	17.8	mud
16	16	ATS031	ATS032	540	36.047833	-75.872183	10/25/98 5:00 PM	10/26/98 7:00 AM	14.00	5.50	5.8	17.8	mud
17	17	ATS033	ATS034	591	36.098050	-75.986717	10/26/98 11:00 AM	10/27/98 7:00 AM	20.00	5.50	6.4	17.2	mud
18	18	ATS035	ATS036	648	36.129983	-76.066550	10/29/98 2:00 PM	10/30/98 7:00 AM	17.00	5.50	3.7	17.8	sand
19	19	ATS037	ATS038	464	36.101467	-76.045533	10/30/98 2:00 PM	10/31/98 7:00 AM	17.00	5.50	3.7	16.7	mud
20	20	ATS039	ATS040	724	36.142450	-76.025217	10/30/98 2:00 PM	10/31/98 7:00 AM	17.00	5.75	4.3	16.7	mud
21	21	ATS041	ATS042	514	36.129950	-76.058033	11/1/98 12:00 PM	11/2/98 8:00 AM	20.00	5.50	3.0	17.2	mud and sand
22	22	ATS043	ATS044	559	36.117633	-76.127917	11/2/98 12:00 PM	11/3/98 8:00 AM	20.00	5.50	3.8	16.7	mud and sand
23	10a	ATS019	ATS020					11/4/1998					
24	23	ATS045	ATS046	724	36.115750	-76.129183	11/3/98 2:00 PM	11/5/98 8:00 AM	42.00	5.75	4.6	15.6	mud

Capture Sequence	Individual	Pect Tag	Dorsal Tag	FL (mm)	Latitude	Longitude	Time set	Time checked	Soak Time	Mesh size (ISM)	Depth (m)	Water temp (C)	Substrate
25	24	ATS047	ATS048	1105	36.121683	-76.112917	11/5/98 12:00 PM	11/6/98 8:00 AM	20.00	5.75	3.7	14.4	mud and sand
26	25	ATS049	ATS050	521	36.118350	-76.136083	11/6/98 12:00 PM	11/8/98 8:00 AM	44.00	5.75	4.3	14.4	mud
27	26	ATS051	ATS052	610	36.117933	-76.165100	11/8/98 11:00 AM	11/10/98 8:00 AM	45.00	5.75	3.7	12.2	mud and sand
28	27	ATS053	ATS054	603	36.118467	-76.155500	11/8/98 11:00 AM	11/10/98 10:00 AM	47.00	5.50	3.7	12.2	mud and sand
29	28	ATS055	ATS056	533	36.118533	-76.148233	11/10/98 12:00 PM	11/12/98 8:00 AM	44.00	5.50	3.7	13.3	mud and sand
30	29	ATS057	ATS058	660	36.117483	-76.132133	11/10/98 12:00 PM	11/12/98 8:00 AM	44.00	5.50	3.7	13.3	mud
31	30	ATS059	ATS060	502	36.116317	-76.128783	11/12/98 10:00 AM	11/13/98 8:00 AM	22.00	5.75	5.2	13.3	mud
32	31	ATS061	ATS062	540	36.109867	-76.148767	11/12/98 10:00 AM	11/13/98 8:00 AM	22.00	5.50	5.5	13.3	mud
33	32	ATS063	ATS064	476	36.078450	-76.206600	11/13/98 12:00 PM	11/14/98 8:00 AM	20.00	5.50	4.9	13.3	mud
34	33	ATS065	ATS066	508	36.077667	-76.207667	11/13/98 12:00 PM	11/14/98 8:00 AM	20.00	5.50	6.1	13.3	mud
35	8a	ATS015	ATS106		36.008407	-76.198783		11/14/1998			4.9	13.3	mud
36	34	ATS067	ATS068	514	36.077850	-76.207433	11/14/98 12:00 PM	11/16/98 8:00 AM	44.00	5.75	4.9	14.4	mud
37	35	ATS069	ATS070	584	36.079450	-76.207517	11/14/98 12:00 PM	11/16/98 8:00 AM	44.00	5.50	4.9	14.4	mud
38	36	ATS071	ATS072	749	36.127383	-76.056367	11/16/98 12:00 PM	11/17/98 8:00 AM	20.00	5.50	4.9	13.9	mud
39	37	ATS073	ATS074	648	36.120050	-76.144883	11/16/98 12:00 PM	11/17/98 8:00 AM	20.00	5.25	3.0	13.9	mud and sand
40	27a	ATS053	ATS054					11/17/1998					
41	38	ATS075	ATS076	565	36.079950	-76.207483	11/17/98 12:00 PM	11/18/98 8:00 AM	20.00	5.50	4.9	12.8	mud
42	39	ATS077	ATS078	483	36.079983	-76.207533	11/17/98 12:00 PM	11/18/98 8:00 AM	20.00	5.50	4.9	12.8	mud
43	40	ATS079	ATS080	572	36.126067	-76.060367	11/18/98 12:00 PM	11/20/98 8:00 AM	44.00	5.50	5.8	12.8	mud
44	41	ATS081	ATS082	641	36.130217	-76.058550	11/20/98 12:00 PM	11/23/98 8:00 AM	68.00	5.50	2.4	13.3	sand
45	42	ATS083	ATS084	559	36.115017	-76.126783	11/23/98 12:00 PM	11/24/98 8:00 AM	20.00	5.75	4.3	13.3	mud
46	43	ATS085	ATS086	483	36.107833	-76.127200	11/24/98 12:00 PM	11/25/98 8:00 AM	20.00	5.50	4.6	13.3	mud
47	44	ATS087	ATS088	597	36.095283	-76.175017	11/25/98 12:00 PM	11/28/98 8:00 AM	68.00	5.75	4.3	13.3	mud
48	45	ATS089	ATS090	603	36.089833	-76.195600	11/28/98 12:00 PM	11/29/98 8:00 AM	20.00	5.50	4.0	14.4	mud and sand
49	46	ATS091	ATS092	483	36.130950	-76.086417	11/29/98 12:00 PM	11/30/98 8:00 AM	20.00	5.50	1.2	12.2	sand
50	47	ATS093	ATS094	648	36.128350	-76.055400	11/30/98 12:00 PM	12/3/98 8:00 AM	68.00	5.50	3.4	14.4	mud and sand

Capture Sequence	Individual	Pect Tag	Dorsal Tag	FL (mm)	Latitude	Longitude	Time set	Time checked	Soak Time	Mesh size (ISM)	Depth (m)	Water temp (C)	Substrate
51	48	ATS096	ATS095	603	36.128517	-76.057000	11/30/98 12:00 PM	12/3/98 8:00 AM	68.00	5.50	3.4	14.4	mud and sand
52	49	ATS097	ATS098	419	36.071150	-76.104033	12/3/98 12:00 PM	12/7/98 8:00 AM	92.00	5.50	5.8	15.6	mud
53	50	ATS099	ATS100	610	36.071017	-76.103967	12/3/98 12:00 PM	12/7/98 8:00 AM	92.00	5.50	6.1	15.6	mud
54	35a	ATS069	ATS070	578	36.107100	-76.054100	12/7/98 12:00 PM	12/12/98 8:00 AM	116.00	5.50	4.9	13.3	mud
55	51	ATS101	ATS102	483	36.102000	-76.064800	12/7/98 12:00 PM	12/12/98 8:00 AM	116.00	5.50	4.9	13.3	mud
56	52	ATS103	ATS104	584	36.102483	-76.063500	12/7/98 12:00 PM	12/12/98 8:00 AM	116.00	5.50	4.9	13.3	mud
57	53	ATS105	ATS106	552	36.103000	-76.057533	12/7/98 12:00 PM	12/12/98 8:00 AM	116.00	5.50	4.9	13.3	mud
58	54	ATS107	ATS109	546	36.103433	-76.055550	12/7/98 12:00 PM	12/12/98 8:00 AM	116.00	5.50	4.9	13.3	mud
59	55	ATS110	ATS112	483	36.103533	-76.056000	12/7/98 12:00 PM	12/12/98 8:00 AM	116.00	5.50	4.9	13.3	mud
60	50a	ATS099	ATS100					12/12/1998					
61	21a	ATS041	ATS042	528				12/18/98					
62	56	ATS113	ATS114	565	36.107283	-76.066383	12/12/98 12:00 PM	12/19/98 8:00 AM	164.00	5.50	4.9	11.1	mud
63	57	ATS115	ATS116	597	36.107017	-76.060550	12/12/98 12:00 PM	12/19/98 8:00 AM	164.00	5.50	4.9	11.1	mud
64	58	ATS117	ATS118	527	36.107450	-76.055783	12/12/98 12:00 PM	12/19/98 8:00 AM	164.00	5.50	4.9	11.1	mud
65	59	ATS119	ATS120	584	36.107033	-76.055133	12/12/98 12:00 PM	12/19/98 8:00 AM	164.00	5.50	4.9	11.1	mud
66	60	ATS121	ATS122	648	36.098967	-76.069617	12/19/98 12:00 PM	12/28/98 8:00 AM	212.00	5.50	5.5	8.9	mud
67	61	ATS123	ATS124	622	36.099717	-76.068400	12/19/98 12:00 PM	12/28/98 8:00 AM	212.00	5.50	5.5	8.9	mud
68	62	ATS125	ATS126	616	36.102867	-76.060717	12/19/98 12:00 PM	12/28/98 8:00 AM	212.00	5.50	5.5	8.9	mud
69	63	ATS127	ATS128	527	36.102750	-76.059983	12/19/98 12:00 PM	12/28/98 8:00 AM	212.00	5.50	5.5	8.9	mud
70	64	ATS129	ATS130	603	36.103033	-76.057733	12/19/98 12:00 PM	12/28/98 8:00 AM	212.00	5.50	5.5	8.9	mud
71	65	ATS131	ATS132	578	36.104083	-76.056283	12/19/98 12:00 PM	12/28/98 8:00 AM	212.00	5.50	5.5	8.9	mud
72	66	ATS133	ATS134	552	36.104217	-76.055833	12/19/98 12:00 PM	12/28/98 8:00 AM	212.00	5.50	5.5	8.9	mud
73	67	ATS135	ATS136	425	36.104967	-76.055733	12/19/98 12:00 PM	12/28/98 8:00 AM	212.00	5.50	5.5	8.9	mud
74	68	ATS137	ATS138	559	36.106783	-76.047700	12/19/98 12:00 PM	12/28/98 8:00 AM	212.00	5.50	5.5	8.9	mud
75	69	ATS139	ATS140	718	36.106950	-76.046833	12/19/98 12:00 PM	12/28/98 8:00 AM	212.00	5.50	5.5	8.9	mud

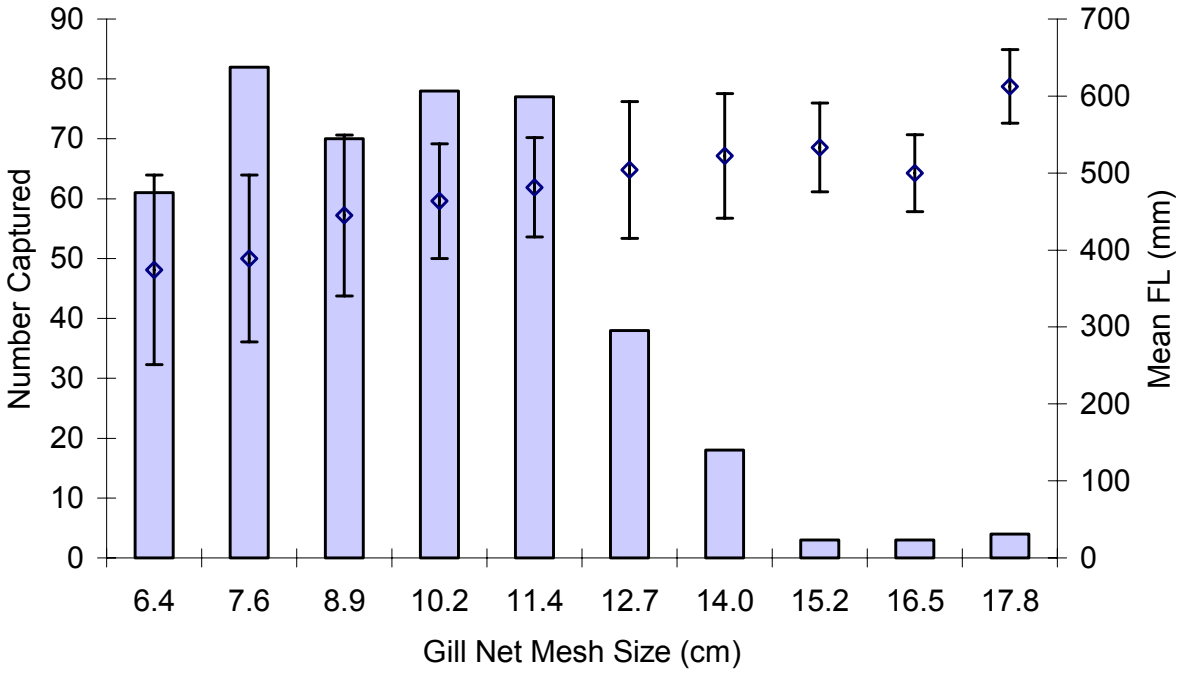

Figure 1. Catch and mean lengths by gillnet mesh size for Atlantic sturgeon captured by NCDMF from 1990 - 1995 (NCDMF unpublished data). Mesh size is measured as stretch mesh in cm. Error bars for mean lengths represent one standard error.

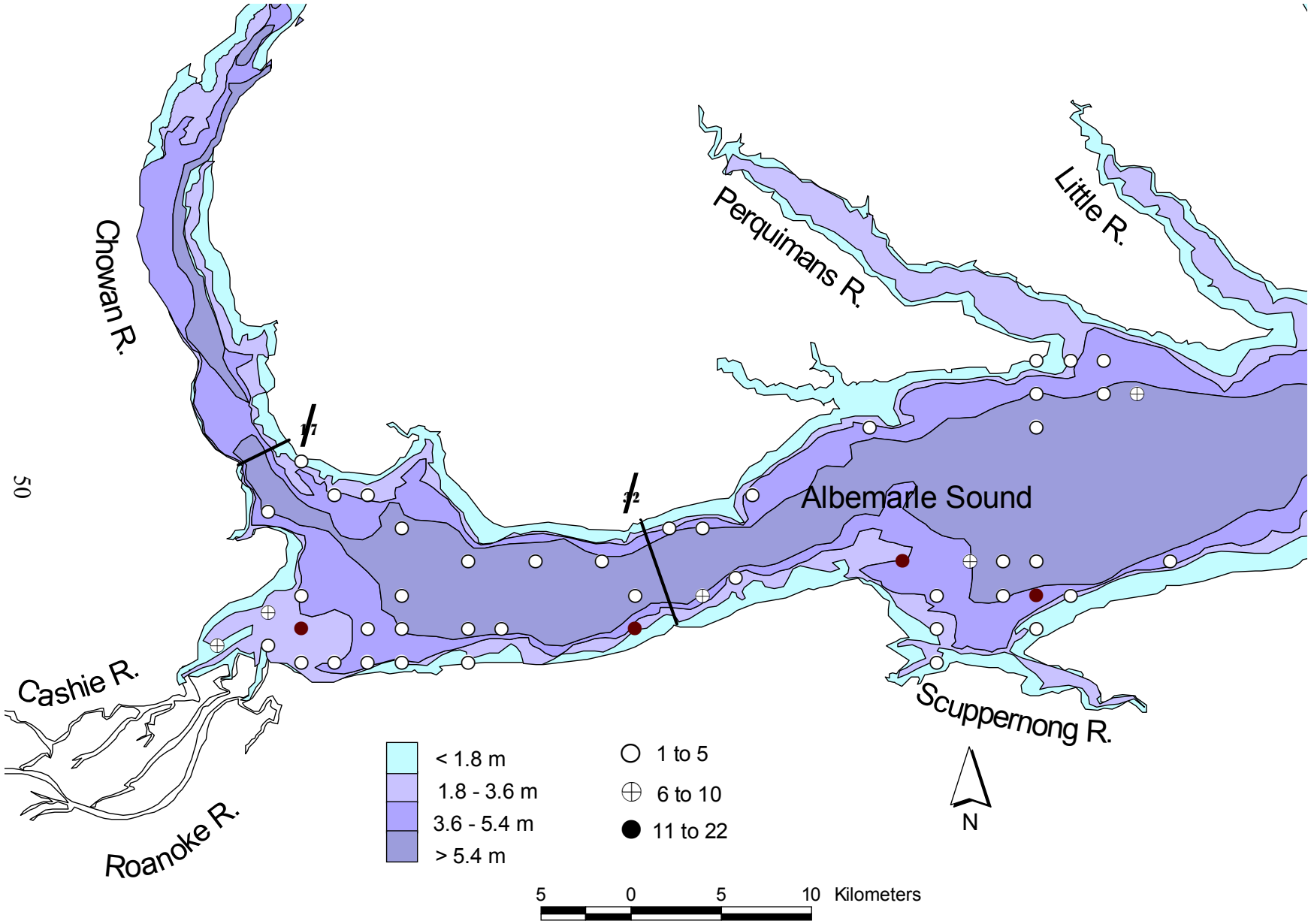

Figure 2. Distribution of Atlantic sturgeon captures by NCDMF survey crews in Albemarle Sound from 1990-1995.

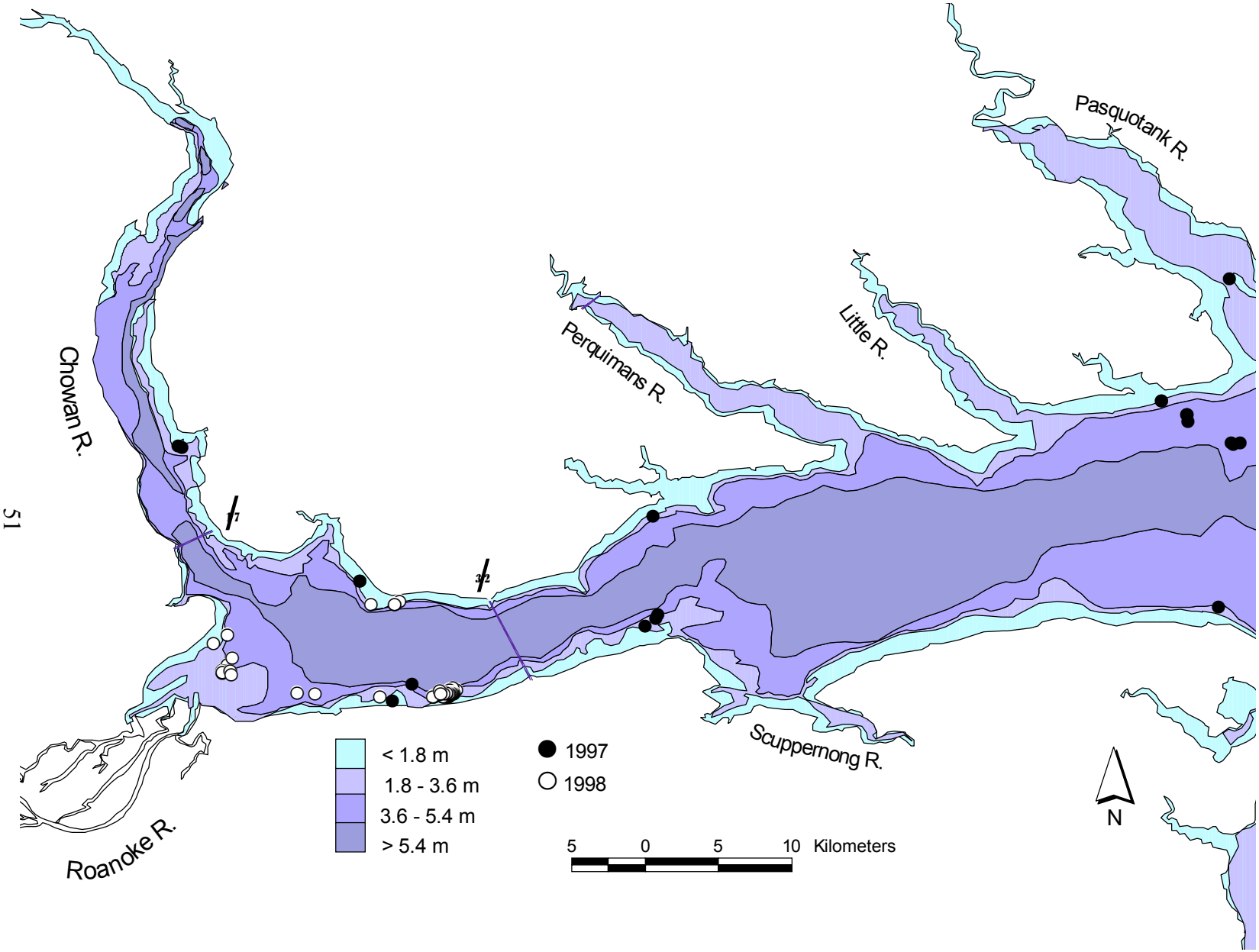

Figure 3. Capture locations for Atlantic sturgeon captured in 1997 (solid circles) and 1998 (open circles. Shaded regions represent 1.8 m depth intervals.

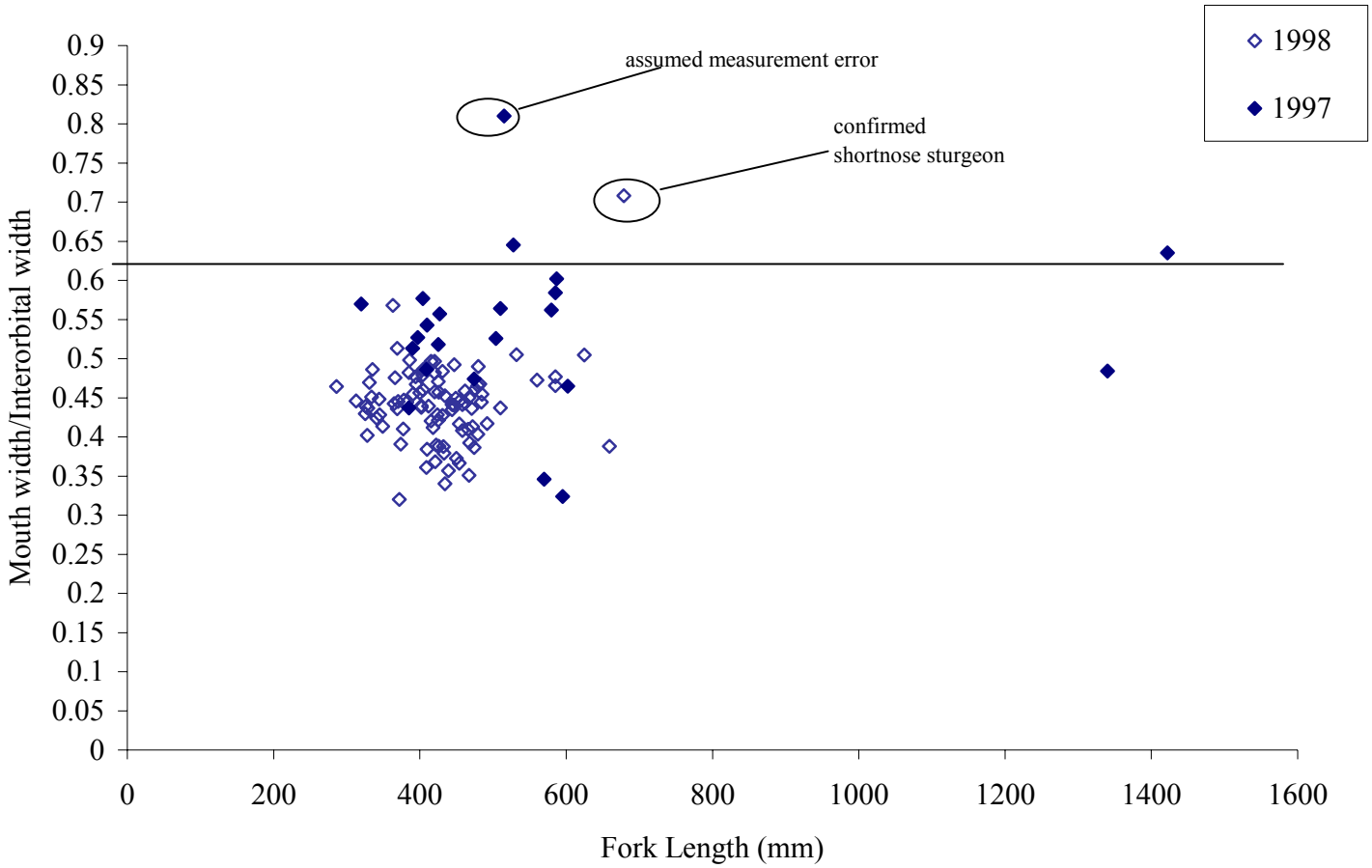

Figure 4. Mouth width / interorbital width ratios for sturgeon captured in Albemarle Sound in 1997 and 1998. The horizontal line at 0.62 represents the value above which ratios usually correspond to shortnose sturgeon (Dadswell 1984).

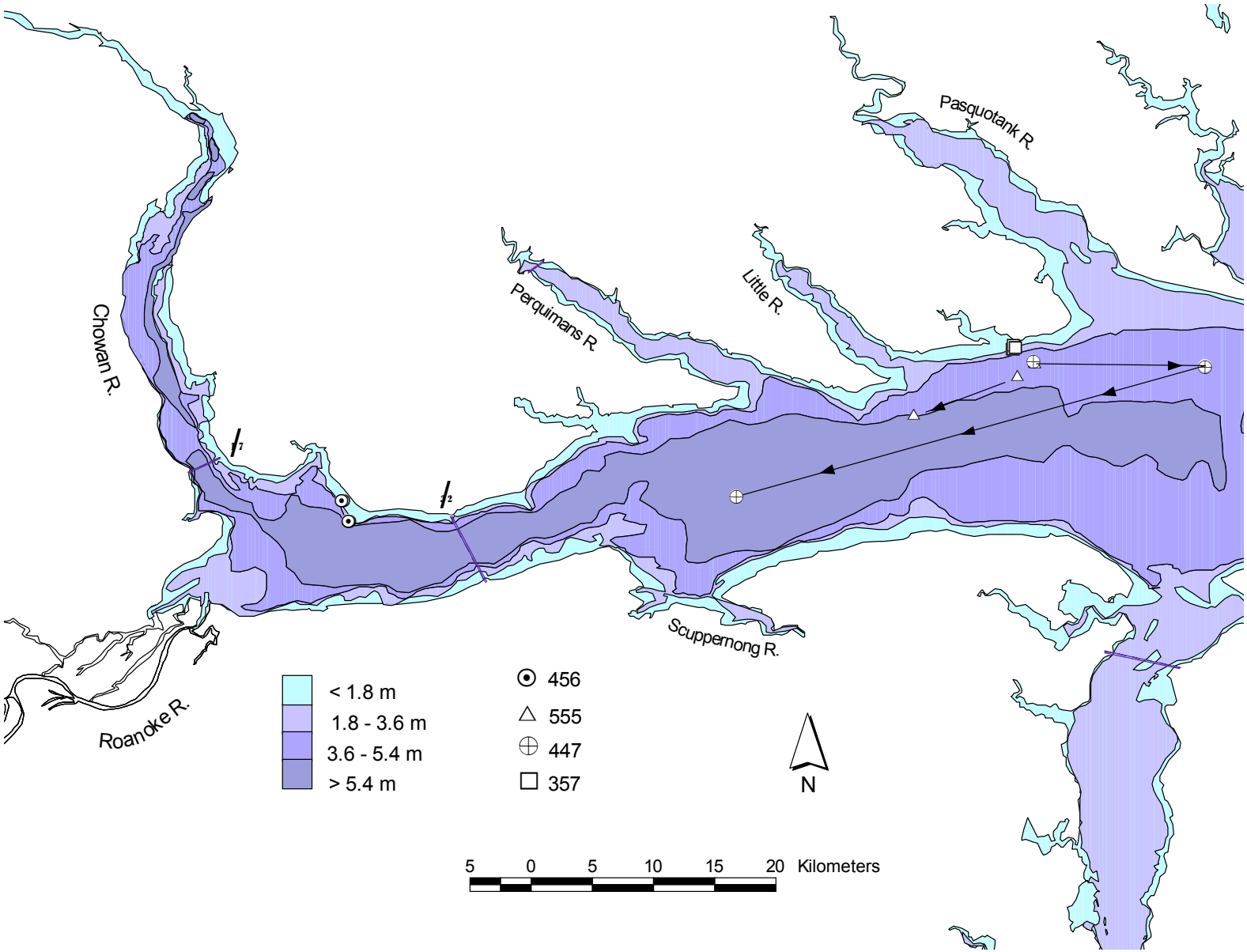

Figure 5. Distribution of telemetry relocations for sonically tagged Atlantic sturgeon during the 1997 field season. Each fish had a unique transmitter code. All relocations of Atlantic sturgeon 357 were made in the same location indicating a shed tag or mortality.

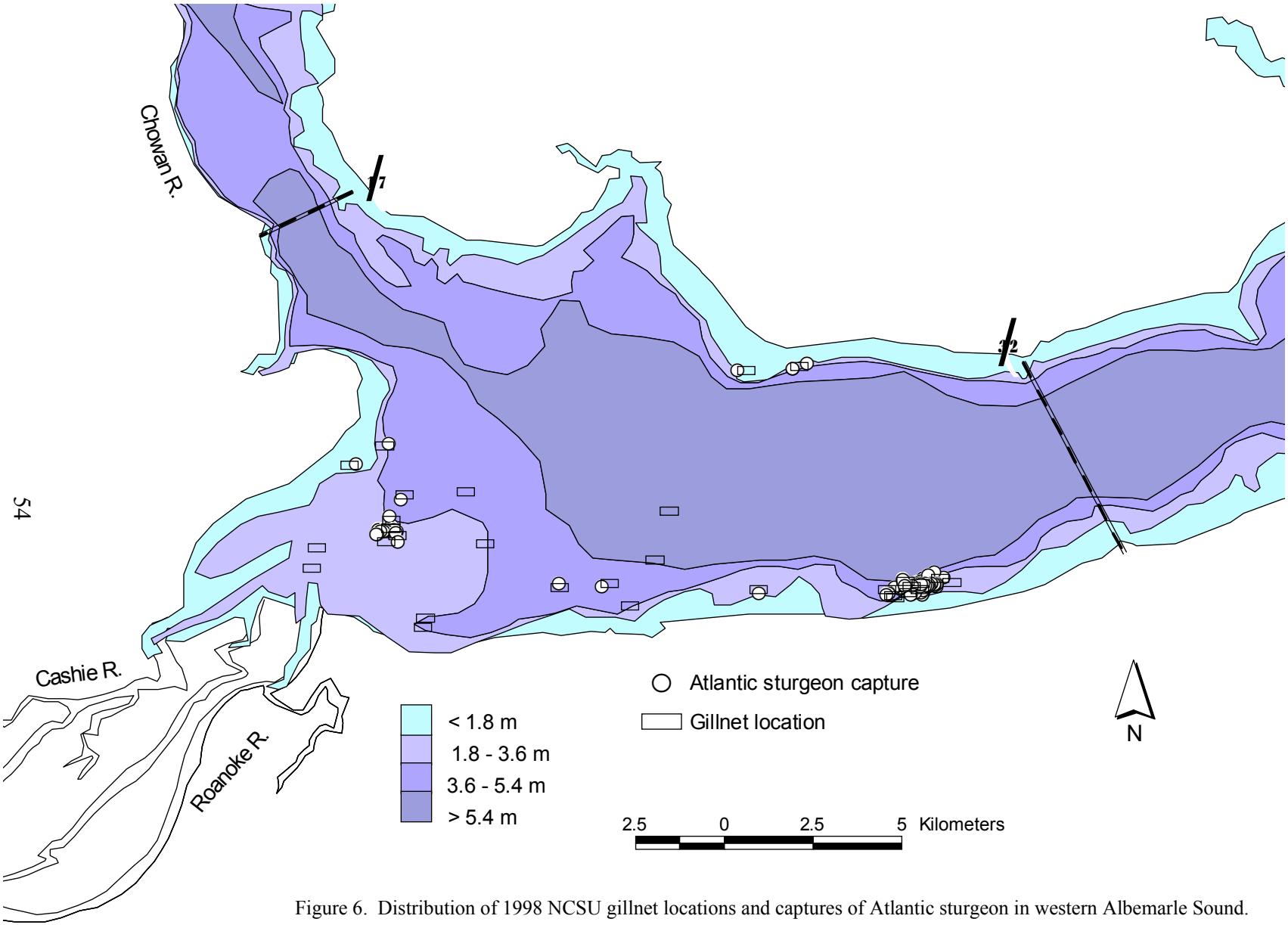

Figure 6. Distribution of 1998 NCSU gillnet locations and captures of Atlantic sturgeon in western Albemarle Sound.

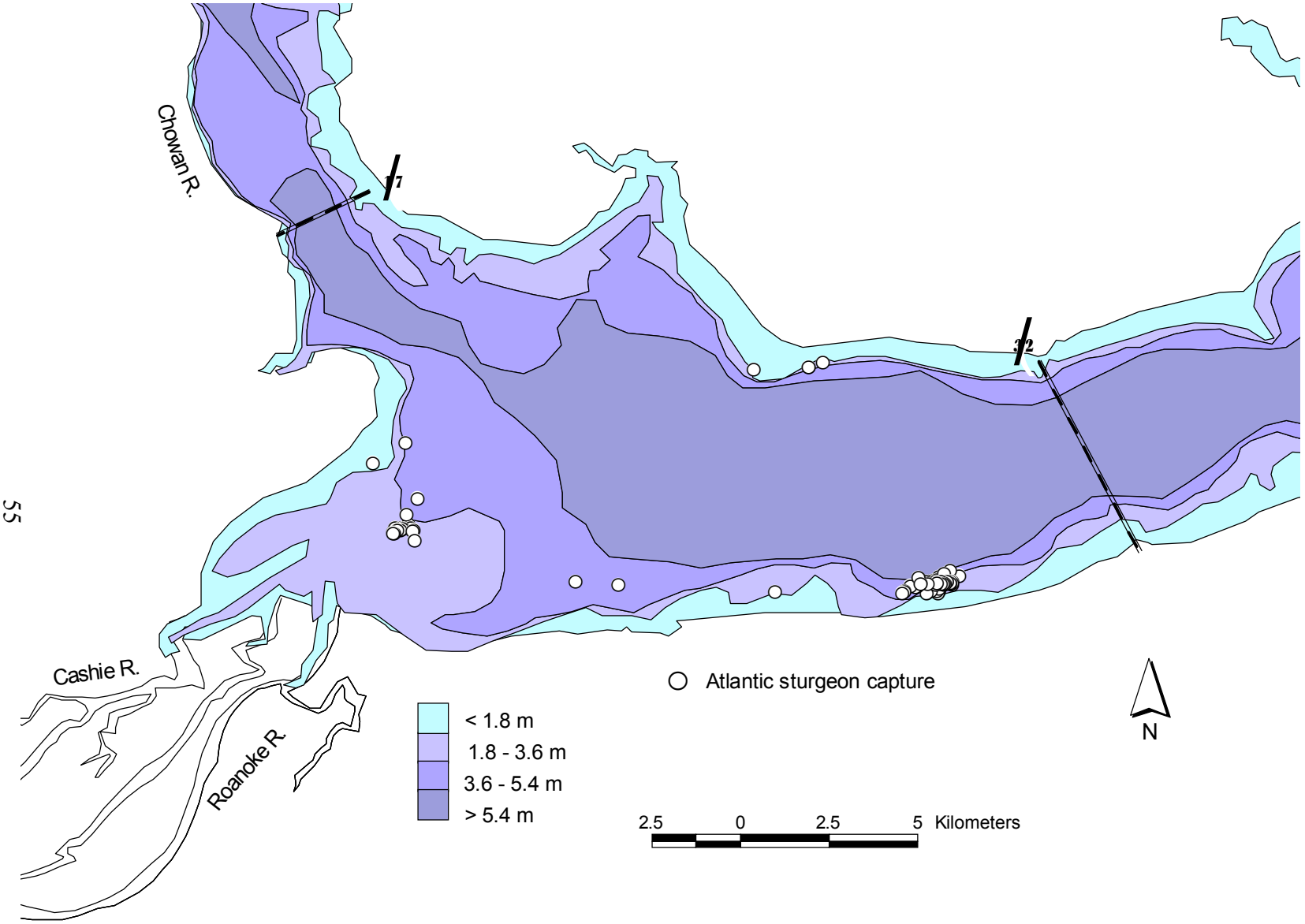

Figure 7. Distribution of 1998 Atlantic sturgeon captures by NCSU in western Albemarle Sound.

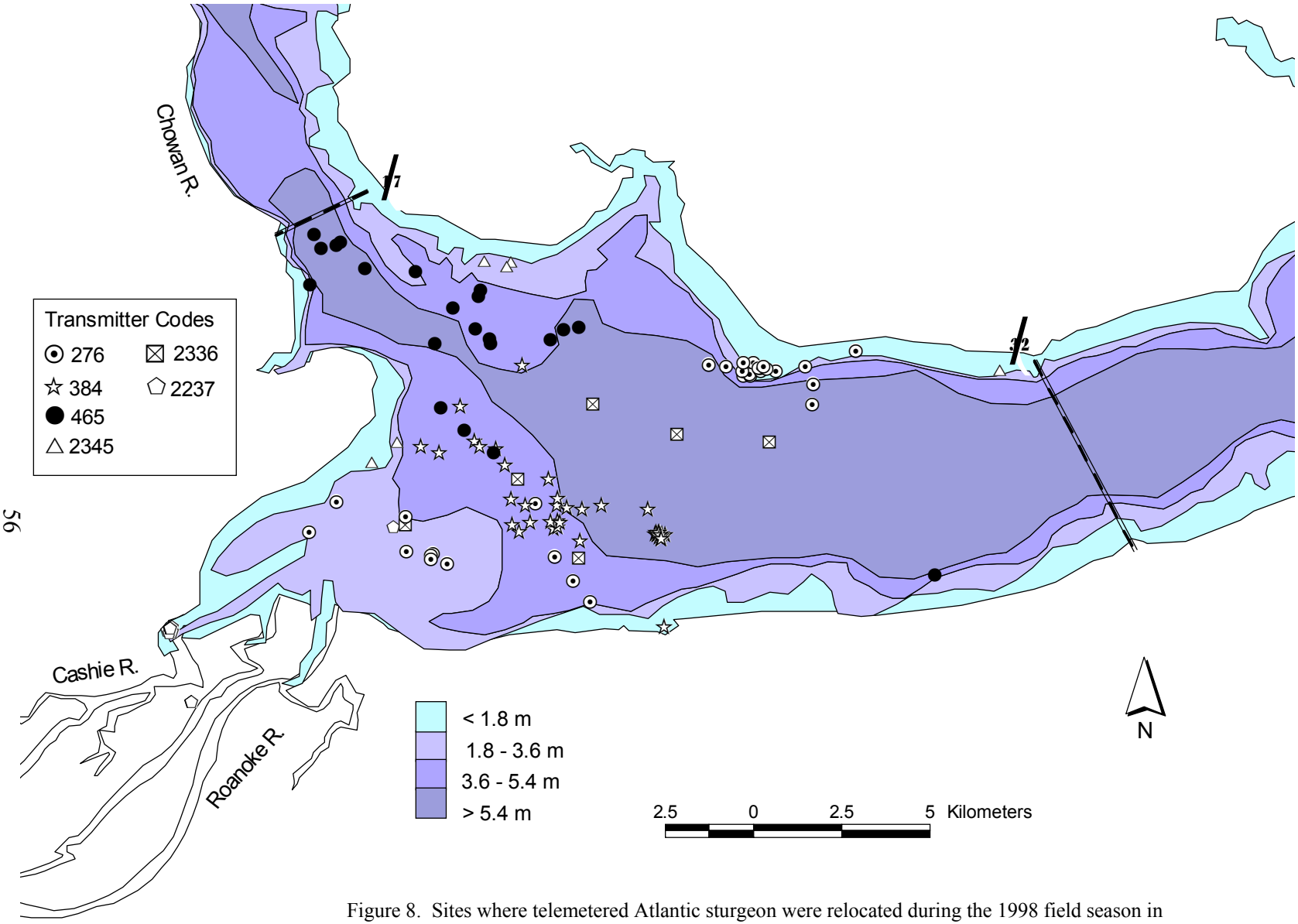

Figure 8. Sites where telemetered Atlantic sturgeon were relocated during the 1998 field season in Albemarle Sound. Symbols represent transmitter codes for individual fish.

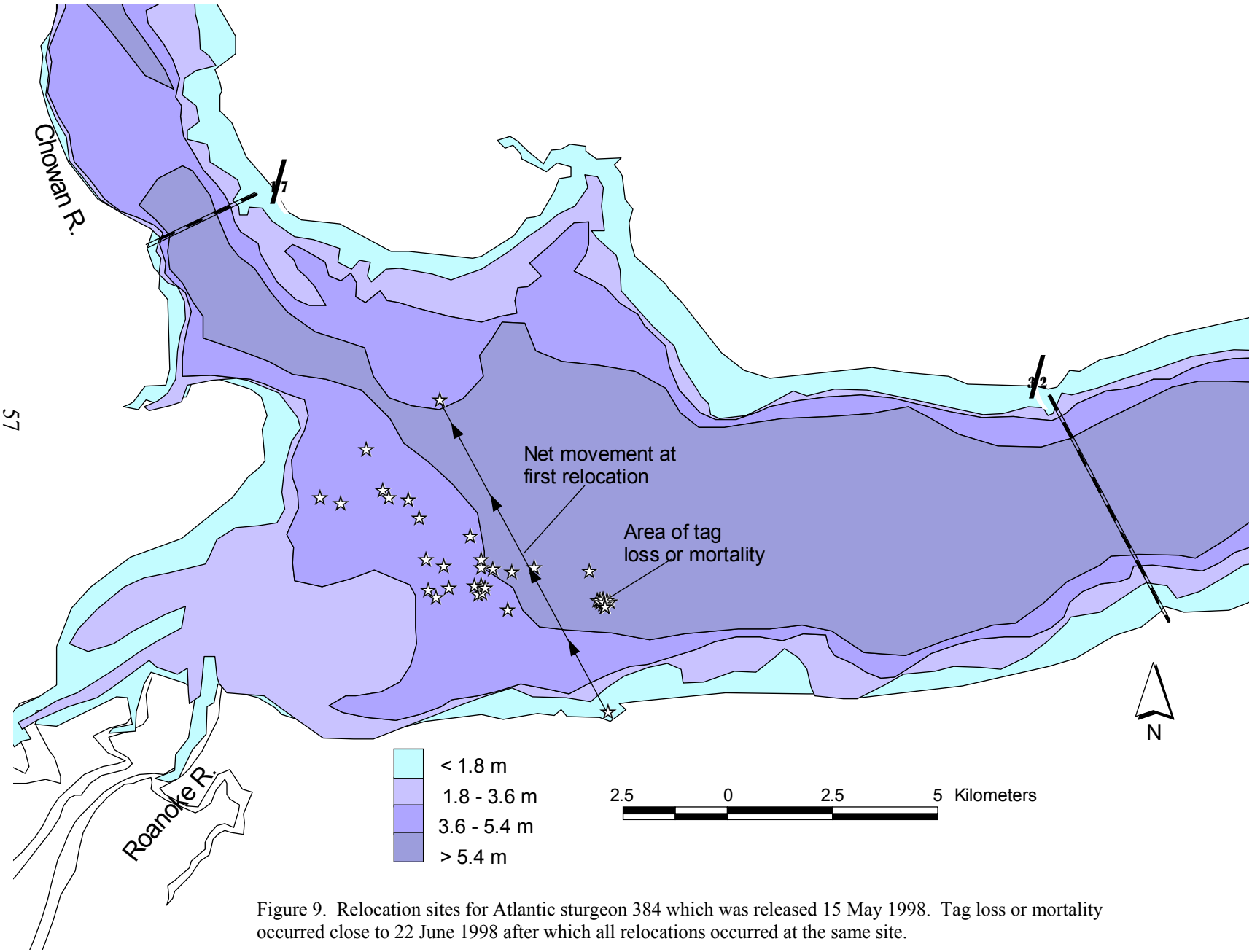

Figure 9. Relocation sites for Atlantic sturgeon 384 which was released 15 May 1998. Tag loss or mortality occurred close to 22 June 1998 after which all relocations occurred at the same site.

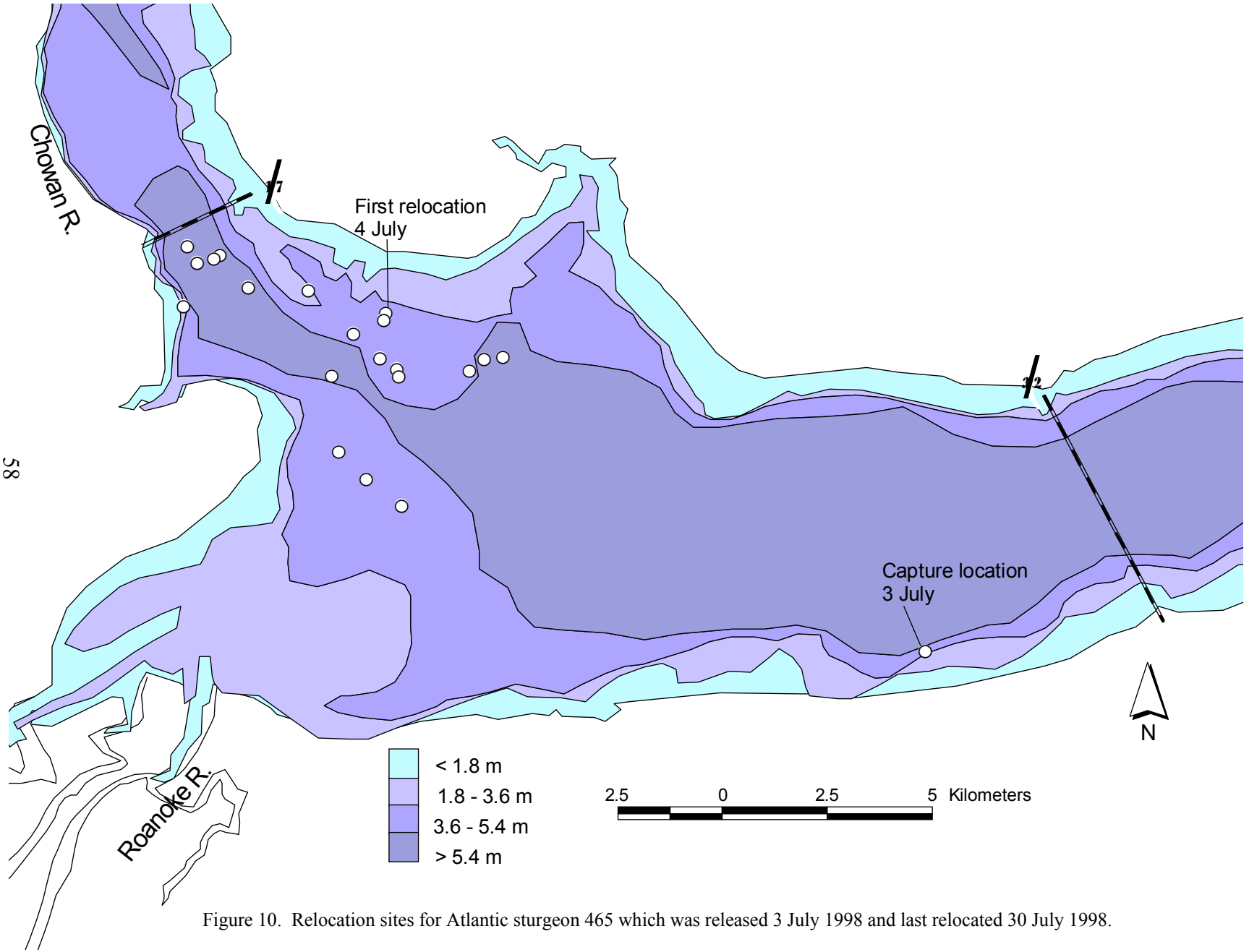

Figure 10. Relocation sites for Atlantic sturgeon 465 which was released 3 July 1998 and last relocated 30 July 1998.

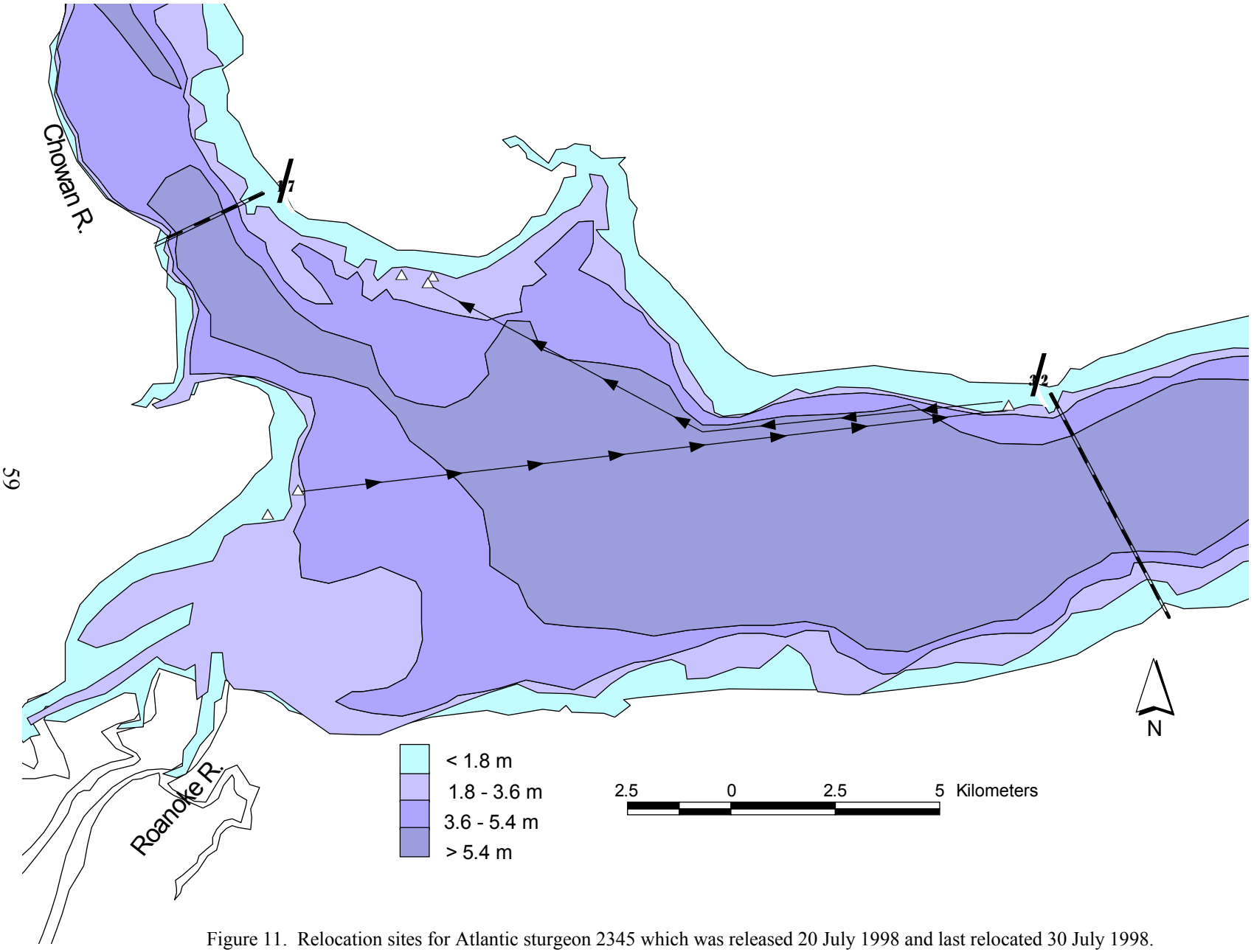

Figure 11. Relocation sites for Atlantic sturgeon 2345 which was released 20 July 1998 and last relocated 30 July 1998.

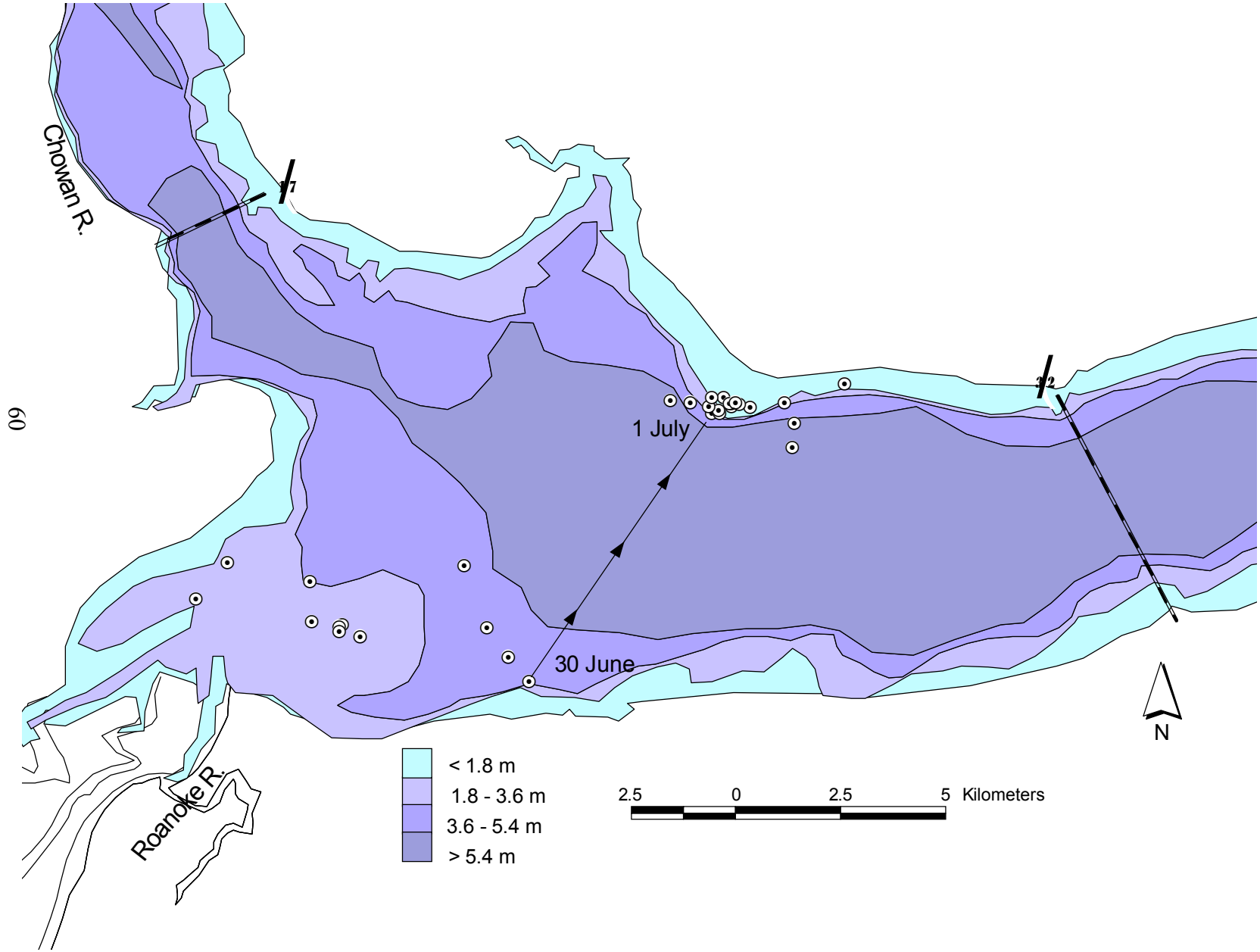

Figure 12. Relocation sites for Atlantic sturgeon 276 which was released 18 June 1998 and last relocated 22 July 1998.

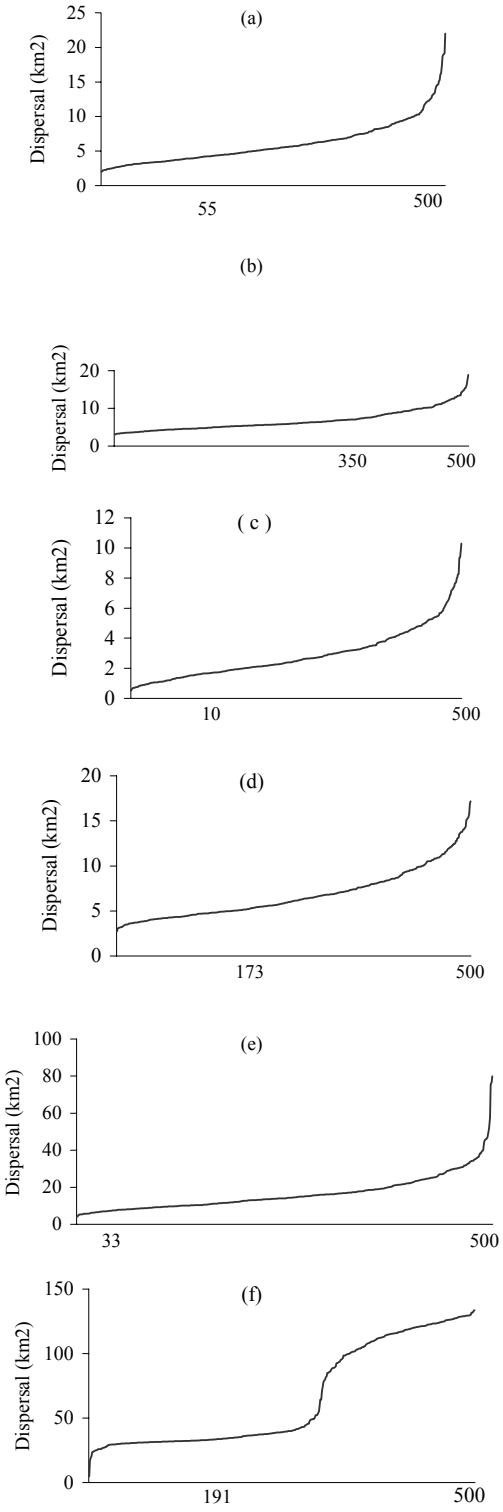

Figure 13. Distribution of dispersal values for random walk simulations using data from four telemetered Atlantic sturgeon. Graphs correspond to individual fish: 384 (a), 276 (b), 276 north (c) 276 south (d), 465 (e), and 2345 (f). Rank (out of 500) of observed dispersal is indicated on the x axis. Random walk simulations were constructed using Animal Movement program by Hooge and Eichenlaub (1997).

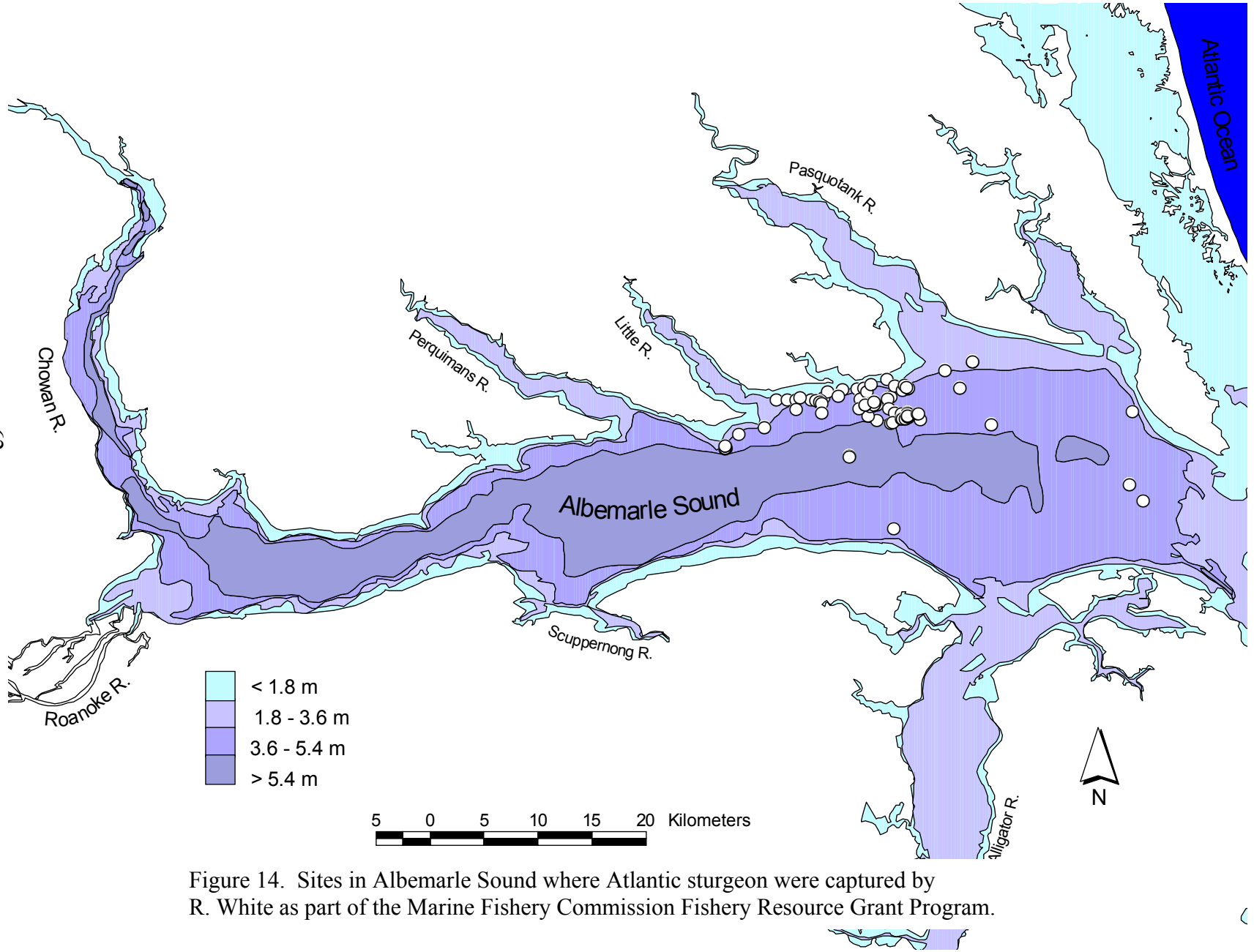

Figure 14. Sites in Albemarle Sound where Atlantic sturgeon were captured by R. White as part of the Marine Fishery Commission Fishery Resource Grant Program.

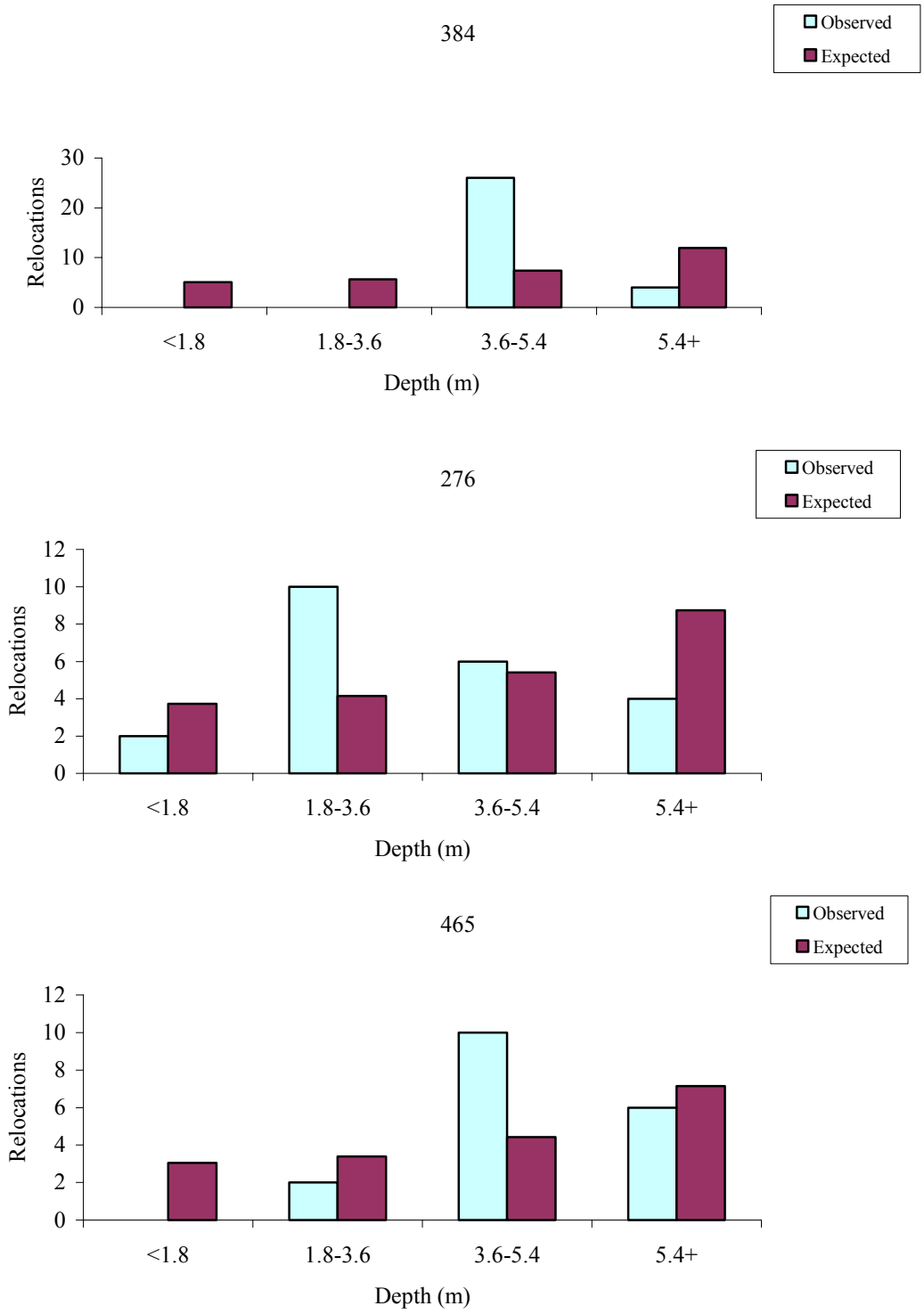

Figure 15. Depth selection by telemetered Atlantic sturgeon in 1998.

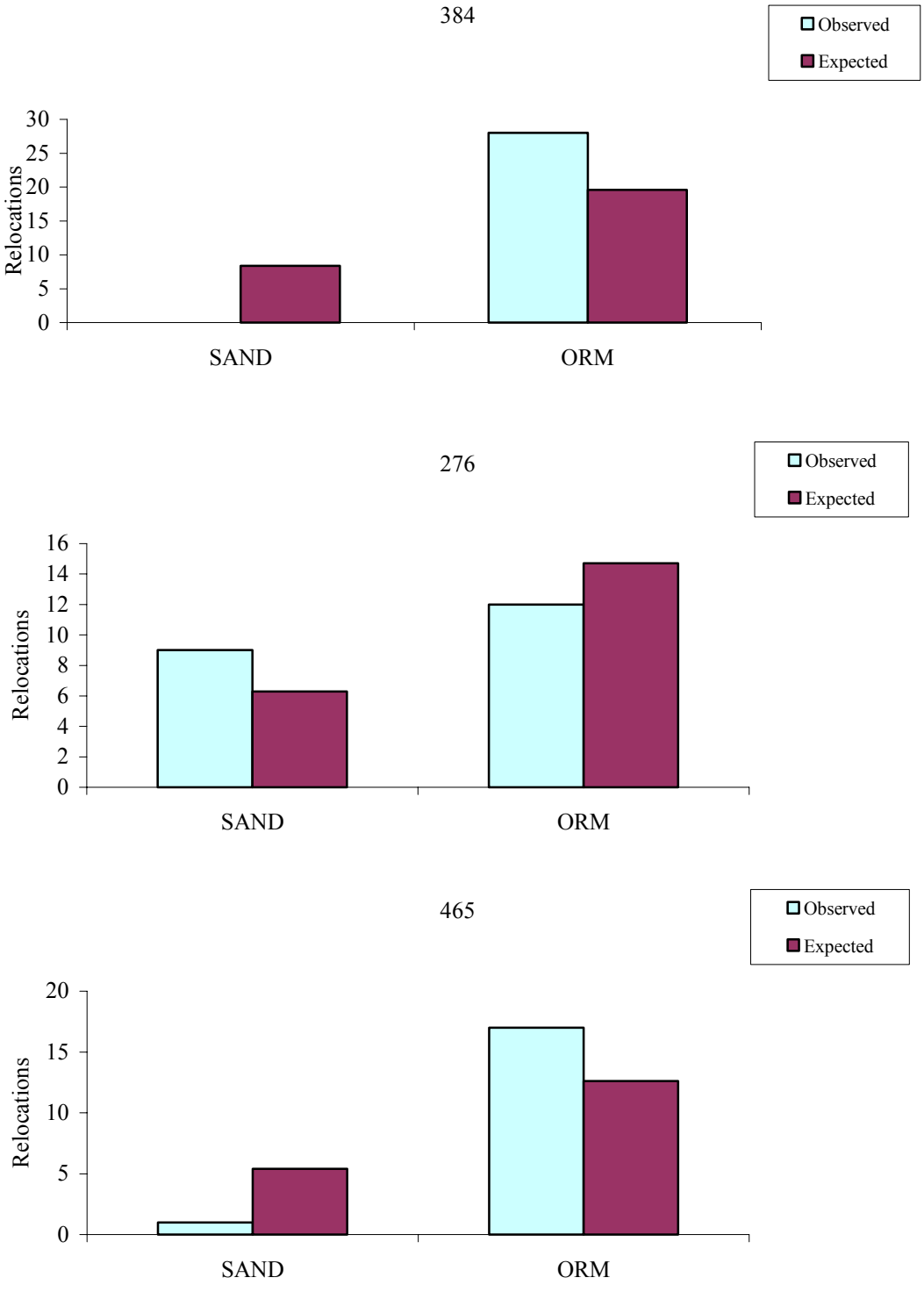

Figure 16. Substrate selection by telemetered Atlantic sturgeon in 1998.

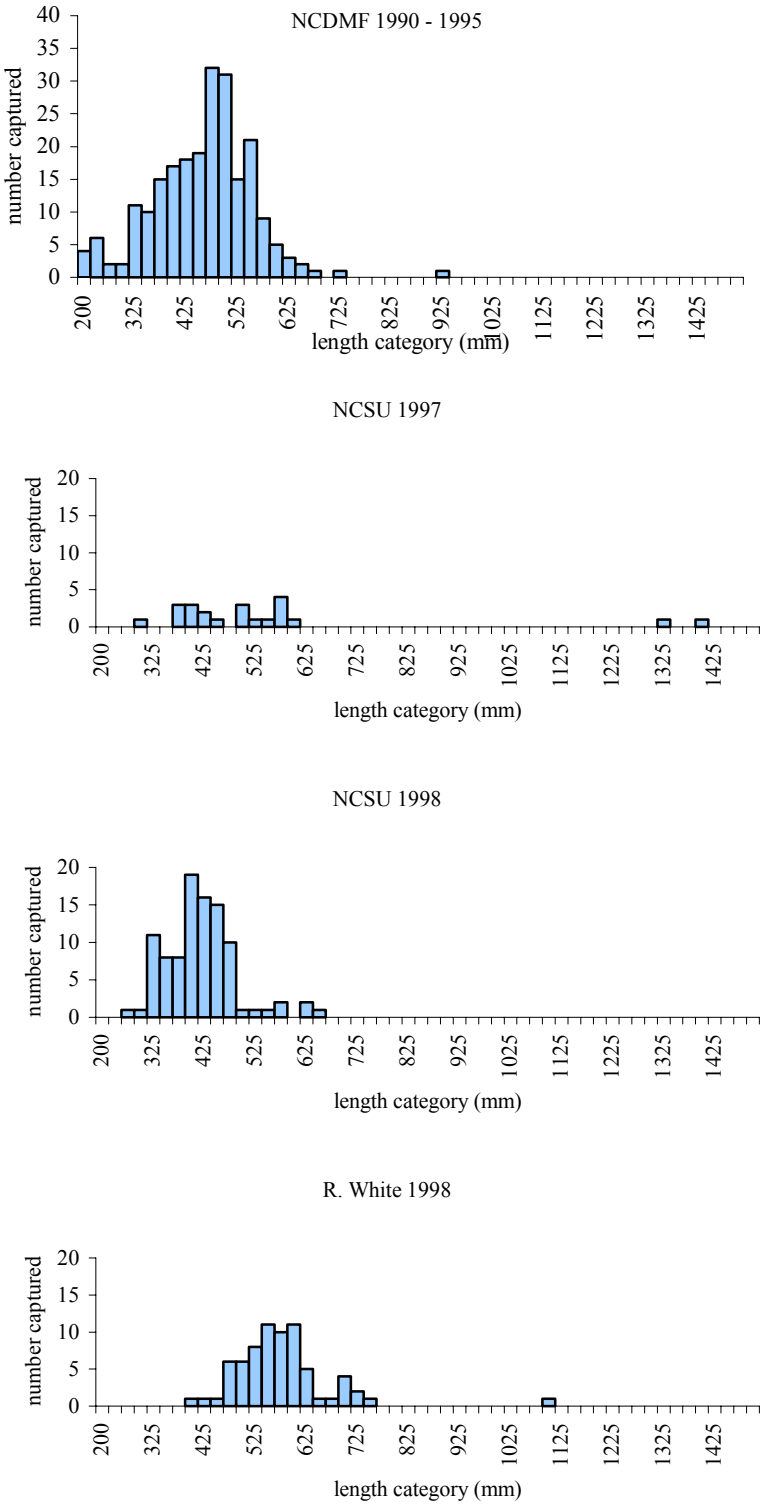

Figure 17. Length composition of Atlantic sturgeon catches for NCDMF (1990-1995, N = 217), NC (1997, N = 22; 1998, N = 94) and R. White (1998, N = 75).

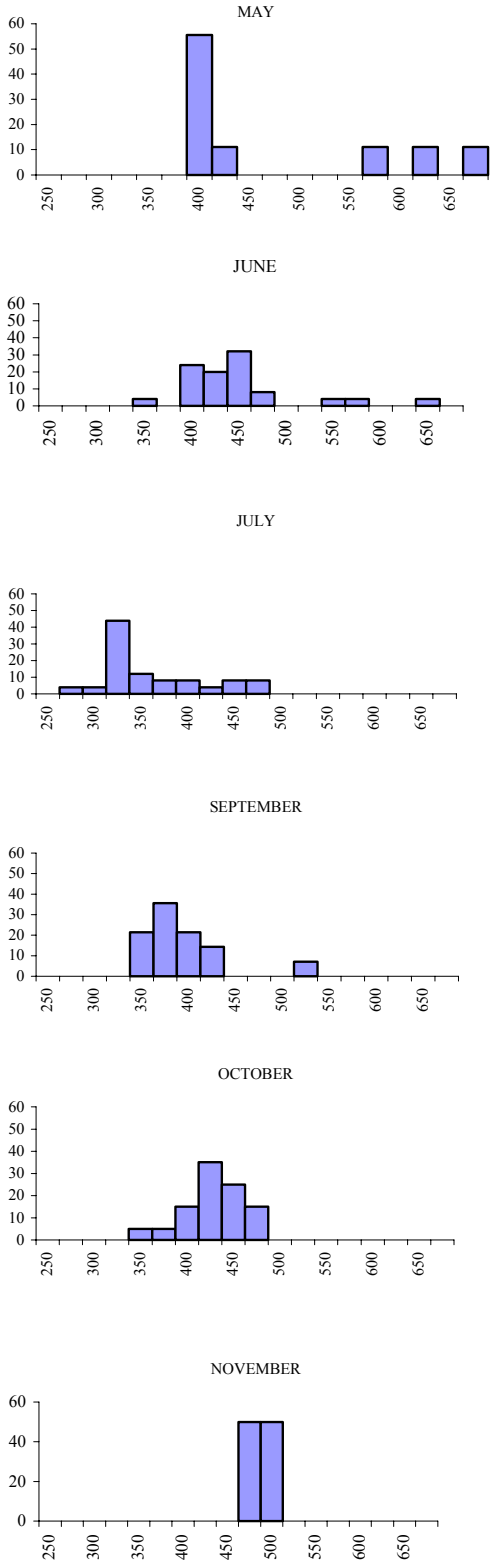

Figure 18. Monthly length composition for NCSU captures of Atlantic sturgeon from western Albemarle Sound in 1998.

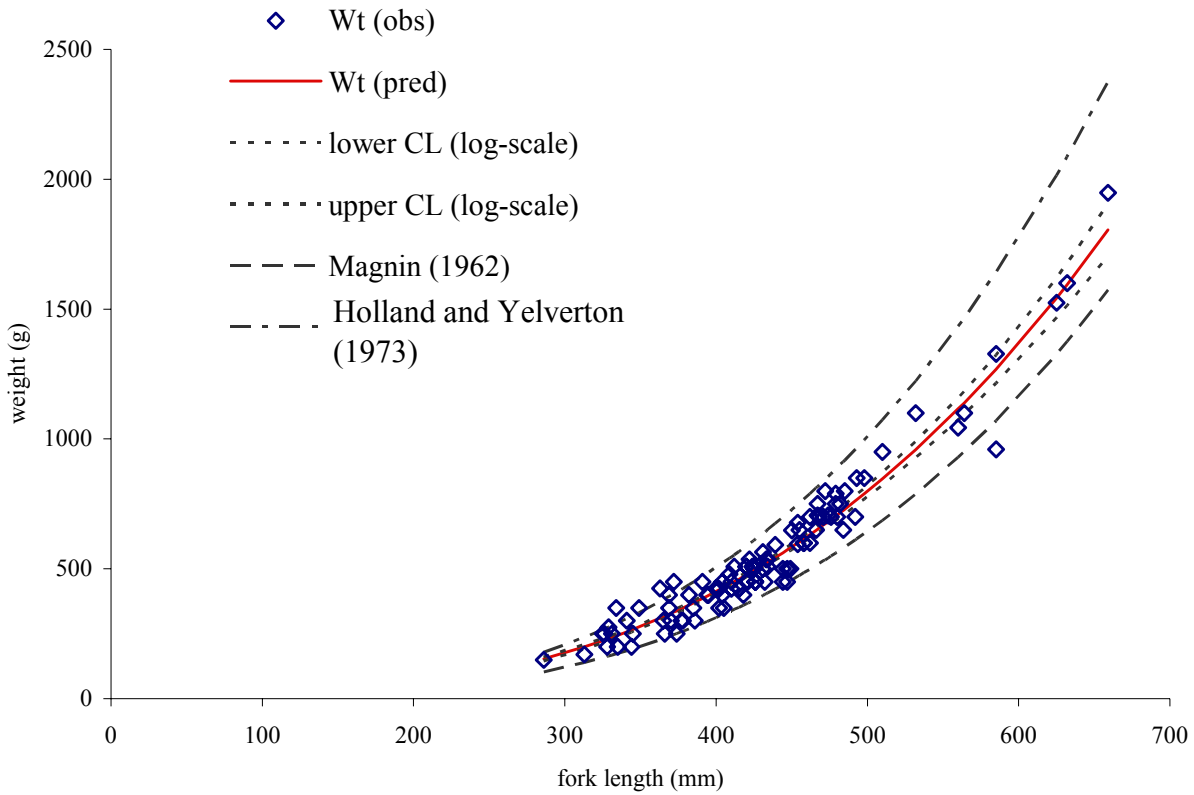

Figure 19. Length weight relationship for Atlantic stugeon captured in Albemarle Sound in 1998 by NCSU crews. Solid line represents the estimated relationship between length and weight, based on non-linear regression analysis. Dashed lines indicate upper and lower 95% confidence limits in log-scale. Length weight relationships for Atlantic sturgeon derived by Magnin (1964) and Holland and Yelverton (1973) are also shown.

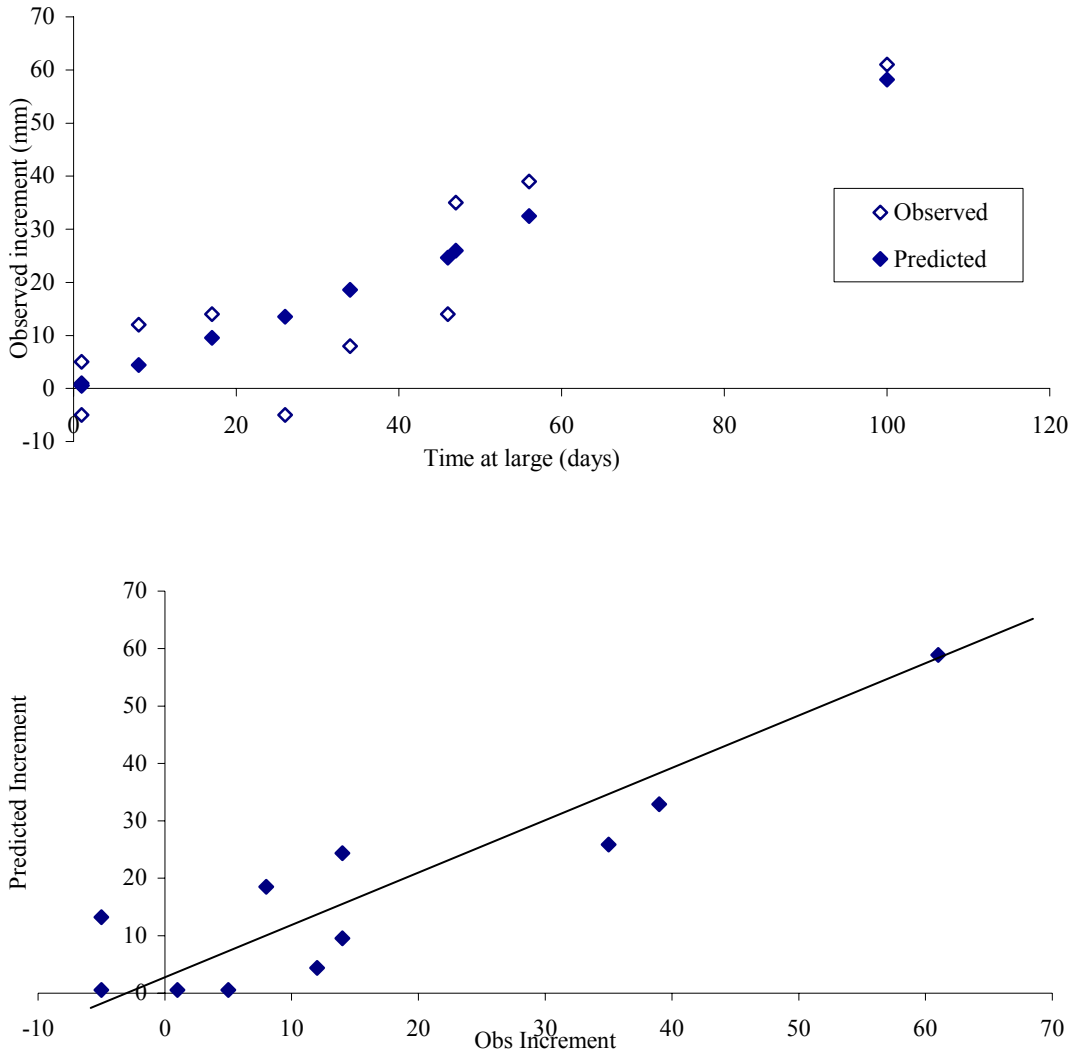

Figure 20. Observed and predicted length increment (change in length) versus time at large (upper panel) ai size at release (lower panel) for recaptured Atlantic sturgeon from Albemarle Sound in 1998. Negative growth is indicative of measurement error. The line represents 1:1 correspondence between data and model

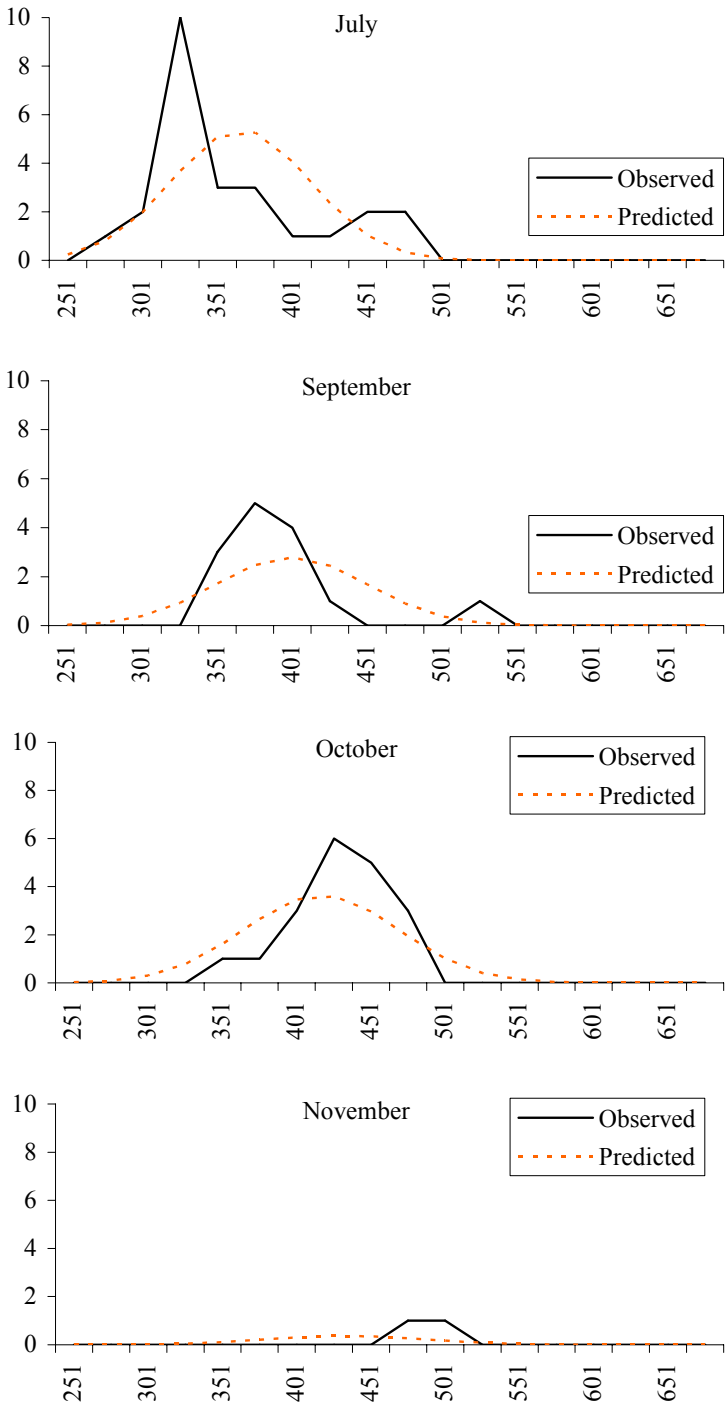

Figure 21. Predicted and observed changes in length composition for Atlantic sturgeon captured in western Albemarle Sound during July, September, October, and November 1998.

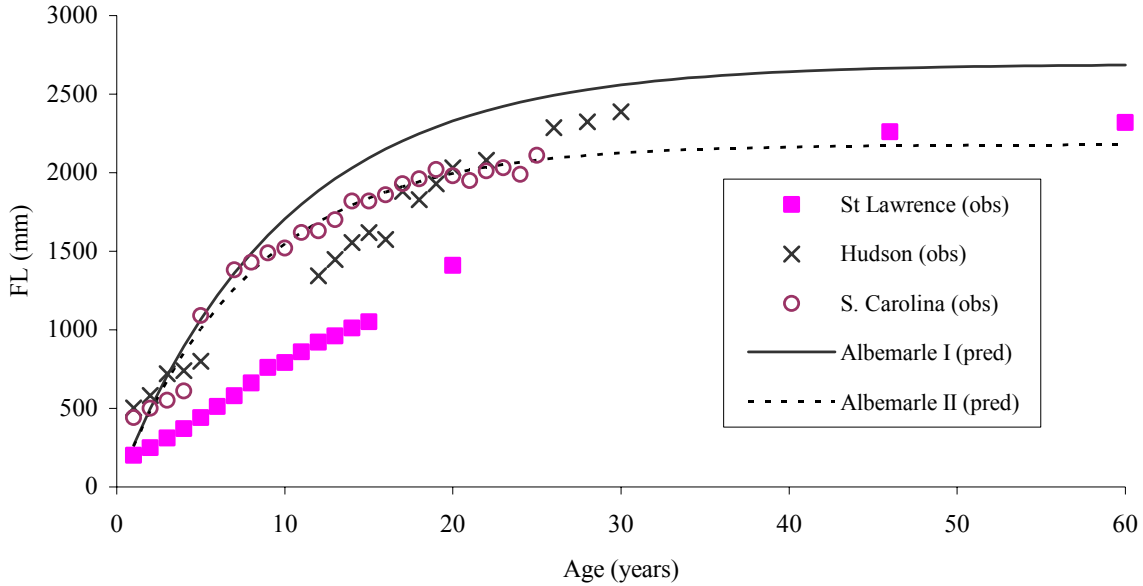

Figure 22. Von Bertalanffy growth curves for Atlantic sturgeon from Albemarle Sound based on length increment and length composition data. Albemarle I represents growth curve obtained by setting L_∞ equal to maximum length reported for an Atlantic sturgeon from the Roanoke River (2,692 mm, Roanoke News 1908). Albemarle II represents growth curve obtained by setting L_∞ equal to average length of age-21+ Atlantic sturgeon from other systems (St. Lawrence River: Magnin 1964; Hudson River: Dovel and Bergrenn 1983; South Carolina: Smith et al. 1982).

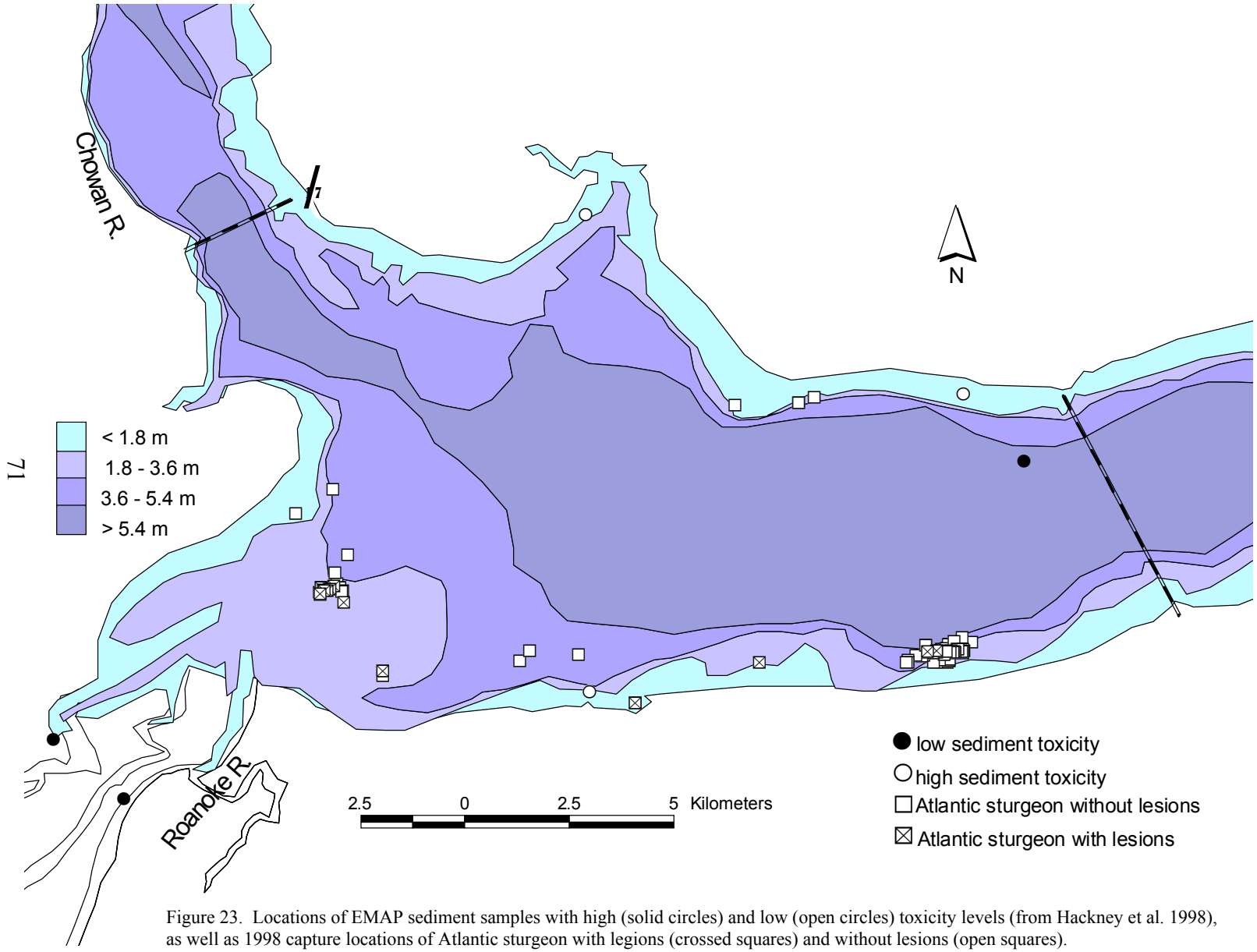

Figure 23. Locations of EMAP sediment samples with high (solid circles) and low (open circles) toxicity levels (from Hackney et al. 1998), as well as 1998 capture locations of Atlantic sturgeon with legions (crossed squares) and without lesions (open squares).

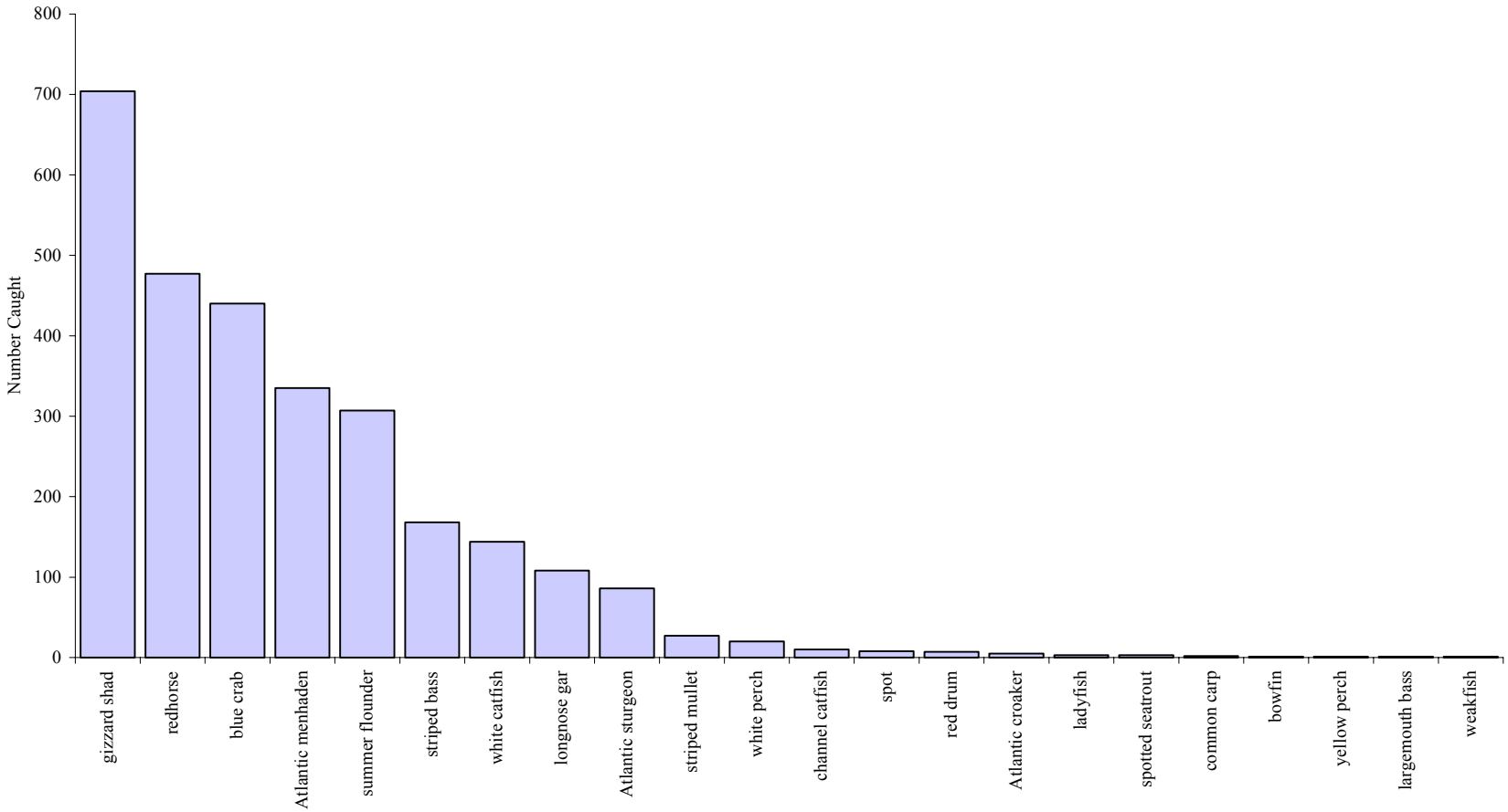

Figure 24. Total number of species captured in 1998 NCSU gillnet samples in western Albemarle Sound. Sampling was conducted using 10.2 cm stretch mesh gillnets.

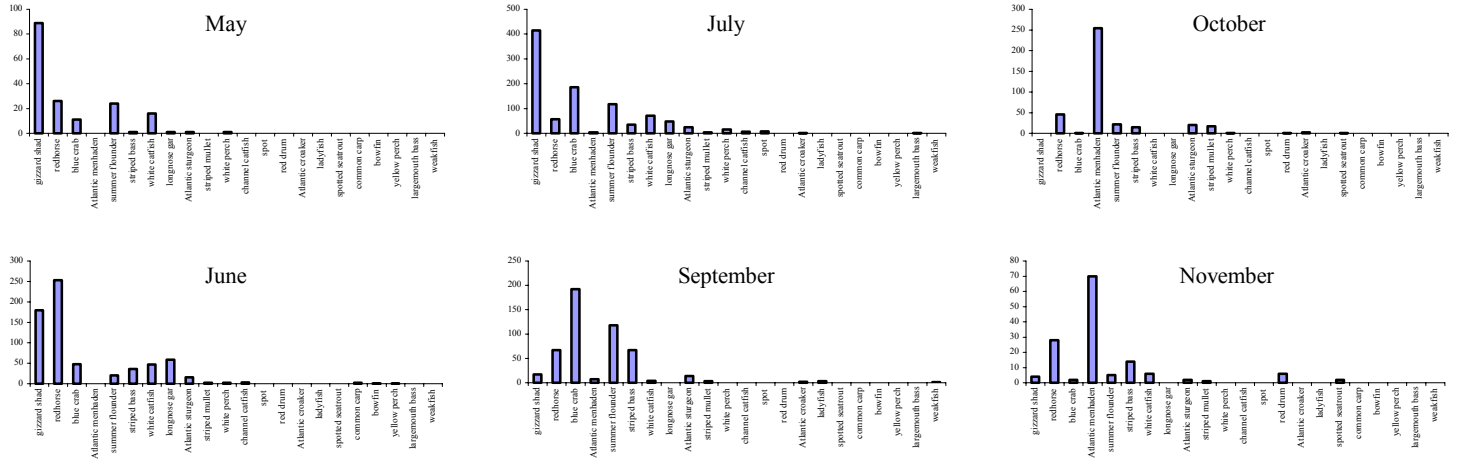

Figure 25. Monthly captures for all species encountered during gillnet sampling by NCSU crews in western Albemarle Sound in 1998

Appendix Table 1. Summary of relocations of telemetered Atlantic sturgeon in Albemarle Sound 1997-

Fish ID	Date	Time	Latitude	Longitude	Depth (m)	Substrate
357	16-Jul-97		36.127800	-76.101750	3.0	
357	17-Jul-97		36.128017	-76.100933		SAND
357	21-Jul-97		36.131000	-76.100517	2.4	SAND
357	25-Jul-97		36.129550	-76.099383	2.3	SAND
357	5-Aug-97		36.129650	-76.099583	2.1	SAND
357	11-Aug-97		37.129617	-77.099483	2.1	SAND
357	4-Oct-97		37.129617	-77.099483	2.1	
456	21-Jul-97		36.017200	-76.593100	2.6	
456	22-Jul-97		36.016983	-76.594083	3.4	ORM
456	25-Jul-95		36.001850	-76.588883	5.6	ORM
456	5-Aug-97		36.001750	-76.589117	5.6	ORM
456	4-Oct-97		36.001750	-76.589117	5.6	
555	9-Aug-97		36.119467	-76.085833	5.5	
555	10-Aug-97		36.118883	-76.085150	4.4	SAND and OR
555	12-Aug-97		36.109200	-76.097633	4.9	ORM
555	13-Aug-97		36.080967	-76.173917	5.5	ORM
447	9-Aug-97		36.119467	-76.085833	5.5	
447	12-Aug-97		36.115883	-75.959333	5.3	ORM
447	4-Oct-97		36.019883	-76.304283	6.1	ORM
366	9-Aug-97		36.119467	-76.085833	5.5	
249	13-Aug-97		36.115300	-76.085583	4.3	
258	2-Sep-97		36.000883	-76.066650	4.9	
348	14-Nov-97		35.994300	-76.411617	4.6	ORM
384	15-May-98	release	35.937833	-76.608333		
384	16-May-98	12:00	36.004500	-76.644500	3.6-5.4	
384	22-May-98	8:41	35.983667	-76.670167	3.7	
384	23-May-98	10:49	35.982333	-76.665667	3.7	ORM
384	23-May-98	19:28	35.965000	-76.635500	4.6	ORM
384	24-May-98	9:07	35.964333	-76.642500	4.6	ORM
384	24-May-98	18:40	35.962833	-76.636333	4.6	ORM
384	25-May-98	11:46	35.963333	-76.635333	4.6	ORM
384	25-May-98	18:55	35.962167	-76.645333	4.6	ORM
384	26-May-98	9:30	35.963833	-76.647000	4.6	ORM
384	27-May-98	19:10	35.975500	-76.637833	4.6	ORM
384	28-May-98	11:04	35.964667	-76.637167	3.6-5.4	ORM
384	28-May-98	16:20	35.968333	-76.633167	5.4 +	ORM
384	29-May-98	8:40	35.968667	-76.635667	3.6-5.4	ORM
384	1-Jun-98	19:00	35.968833	-76.643667	3.6-5.4	ORM
384	2-Jun-98	9:20	35.970333	-76.647333	3.6-5.4	ORM
384	3-Jun-98	16:40	35.994000	-76.660167	4.3	ORM
384	4-Jun-98	10:10	35.985167	-76.656667	4.3	ORM
384	4-Jun-98	18:26	35.983167	-76.651167	4.3	ORM
384	5-Jun-98	9:37	35.979167	-76.648833	4.6	ORM
384	6-Jun-98	12:55	35.983667	-76.655333	4.3	ORM
384	7-Jun-98	14:50	35.970500	-76.635500	4.6	ORM
384	8-Jun-98	13:15	35.959667	-76.629833	4.3	ORM

Fish ID	Date	Time	Latitude	Longitude	Depth (m)	Substrate
384	9-Jun-98	10:45	35.967667	-76.629167	4.6	ORM
384	9-Jun-98	16:52	35.968667	-76.624167	4.6	ORM
384	10-Jun-98	9:25	35.967833	-76.612500	4.6	ORM
384	10-Jun-98	18:45	35.964333	-76.634833	3.6-5.4	ORM
384	12-Jun-98	12:45	35.961333	-76.608000	4.6	ORM
384	13-Jun-98	11:50	35.961500	-76.608667	4.9	ORM
384	14-Jun-98	10:10	35.960833	-76.609500	3.6-5.4	ORM
384	15-Jun-98	11:05	35.961500	-76.610000	4.9	ORM
384	16-Jun-98	12:30	35.961500	-76.610000	4.9	ORM
384	16-Jun-98	16:35	35.961500	-76.610000	4.9	ORM
384	17-Jun-98	13:45	35.961500	-76.610000	4.9	ORM
384	17-Jun-98	18:55	35.961000	-76.609167	4.9	ORM
384	18-Jun-98	0:00	35.961500	-76.610667	4.9	ORM
384	18-Jun-95	16:55	35.961667	-76.610333	4.9	ORM
384	19-Jun-98	9:10	35.961833	-76.609500	5.8	ORM
384	19-Jun-98	17:25	35.961167	-76.610000	5.8	ORM
384	20-Jun-98	7:00	35.961833	-76.609500	5.5	ORM
384	21-Jun-98	7:50	35.961167	-76.609333	5.8	ORM
384	22-Jun-98	13:35	35.960333	-76.609000	5.8	ORM
276	18-Jun-98	release	35.949333	-76.631500	4.3	ORM
276	18-Jun-98	11:52	35.955667	-76.636167	4.3	
276	18-Jun-98	17:10	35.969000	-76.641000	5.2	
276	19-Jun-98	9:52	35.969500	-76.691833	3.7	ORM
276	19-Jun-98	18:00	35.961833	-76.698667	3.4	ORM
276	20-Jun-98	7:40	35.965667	-76.674167	4.3	ORM
276	21-Jun-98	8:25	35.953667	-76.663500	4.3	ORM
276	25-Jun-98	9:30	35.956833	-76.673833	4.0	ORM
276	25-Jun-98	14:22	35.956333	-76.667167	4.0	ORM
276	25-Jun-98	17:37	35.955833	-76.667833	4.3	ORM
276	26-Jun-98	8:03	35.954833	-76.667833	3.4	ORM
276	30-Jun-98	14:00	35.944000	-76.627167	1.8	SAND
276	1-Jul-98	11:25	36.001500	-76.588000	1.8 - 3.6	ORM
276	1-Jul-98	18:45	36.004000	-76.592500	3.6-5.4	ORM
276	2-Jul-98	9:30	36.001500	-76.586333	<1.8	ORM
276	2-Jul-98	17:33	36.002167	-76.586500	5.5	ORM
276	3-Jul-98	8:15	36.002833	-76.579833	1.8	SAND
276	4-Jul-98	10:30	36.003000	-76.588500	5.5	ORM
276	5-Jul-98	10:35	36.003000	-76.583833	1.8	SAND
276	6-Jul-98	15:13	36.003667	-76.583667	1.8	SAND
276	7-Jul-98	10:10	36.005000	-76.585500	1.8	SAND
276	7-Jul-98	20:30	36.003500	-76.582167	1.8	SAND
276	8-Jul-98	8:25	36.003667	-76.584167	2.4	SAND
276	9-Jul-98	13:40	36.004000	-76.582833	2.4	SAND
276	16-Jul-98	11:47	35.994333	-76.570667	>5.4	
276	17-Jul-98	9:40	36.005000	-76.588000	2.7	SAND
276	18-Jul-98	15:26	36.004333	-76.596833	5.5	ORM
276	20-Jul-98	11:17	35.999500	-76.570167	5.8	ORM
276	21-Jul-98	12:49	36.008000	-76.559500	1.5	SAND
276	22-Jul-98	8:55	36.003833	-76.572333	4.6	ORM

Fish ID	Date	Time	Latitude	Longitude	Depth (m)	Substrate
2336	2-Jun-98	release	35.963500	-76.674500	3.0	ORM
2336	3-Jun-98	16:15	35.975333	-76.645667	4.6	ORM
2336	4-Jun-98	9:25	35.955000	-76.630333	4.6	ORM
2336	4-Jun-98	18:00	35.994333	-76.626667	5.2	ORM
2336	5-Jun-98	10:10	35.984500	-76.581667	5.5	ORM
2336	6-Jun-98	12:30	35.98650	-76.605167	5.5	ORM
465	3-Jul-98	release	35.950667	-76.539333	2.4	SAND
465	4-Jul-98	12:40	36.023167	-76.655000	3.6-5.4	ORM
465	5-Jul-98	10:10	36.021667	-76.655500	3.6-5.5	ORM
465	6-Jul-98	12:56	36.033833	-76.695500	>5.4	ORM
465	7-Jul-98	09:53	36.035500	-76.690667	>5.4	ORM
465	7-Jul-98	17:00	36.037500	-76.697500	>5.4	ORM
465	8-Jul-98	08:25	36.028667	-76.684500	>5.4	ORM
465	9-Jul-98	13:10	36.034667	-76.691833	>5.4	ORM
465	14-Jul-98	07:41	36.018667	-76.662000	4.9	ORM
465	15-Jul-98	09:50	36.024500	-76.698333	1.8-3.6	ORM
465	17-Jul-98	10:00	36.013333	-76.656333	4.9	ORM
465	18-Jul-98	14:39	36.011000	-76.652667	4.9	ORM
465	20-Jul-98	10:00	36.009500	-76.652333	4.9	ORM
465	21-Jul-98	12:10	36.009667	-76.666667	4.9	ORM
465	22-Jul-98	11:10	35.987500	-76.659167	4.3	ORM
465	22-Jul-98	17:30	35.981833	-76.651667	4.3	ORM
465	23-Jul-98	15:35	36.028000	-76.671667	1.8-3.6	SAND
465	24-Jul-98	08:46	35.993333	-76.665167	3.6-5.4	ORM
465	27-Jul-98	12:08	36.013167	-76.633833	>5.4	ORM
465	29-Jul-98	14:12	36.010667	-76.637167	3.6-5.4	ORM
465	30-Jul-98	11:48	36.013667	-76.630000	>5.4	ORM
2345	20-Jul-98	release	35.979500	-76.683000	3.0	ORM
2345	21-Jul-98	08:27	35.984833	-76.676500	3.4	ORM
2345	24-Jul-98	10:30	36.003167	-76.523000	1.5	SAND
2345	27-Jul-98	12:30	36.030833	-76.647500	1.8-3.6	SAND
2345	29-Jul-98	13:50	36.031167	-76.654167	3.0	SAND
2345	30-Jul-98	11:30	36.029500	-76.648500	3.0	SAND

Appendix Table 2. Summary of catch for all species encountered during 1998 gillnetting efforts by NCSU crews in Albemarle Sound.

Date Ret.	Atlantic Sturgeon	gizzard shad	white catfish	redhorse sp.	summer flounder	blue crab	longnose gar	common carp	white perch	striped bass	bowfin	striped mullet	yellow perch	channel catfish	Atlantic croaker	Atlantic menhaden	spot	largemouth bass	weakfish	ladyfish	spotted seatrout	red drum
28-May-98	0	1	0	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28-May-98	0	2	1	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10-Jun-98	1	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11-Jun-98	0																					
15-Jun-98	0	1	1	17	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
16-Jun-98	0	0	2	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17-Jun-98	0	3	0	4	1	6	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18-Jun-98	0	4	0	0	0	6	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-Jun-98	1	0	1	3	6	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24-Jun-98	0	14	0	3	6	8	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
24-Jun-98	0	14	0	12	2	14	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
25-Jun-98	0	9	1	4	1	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
25-Jun-98	0	0	0	6	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-Jun-98	0	13	0	3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01-Jul-98	1	12	0	0	0	15	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
02-Jul-98	2	5	0	0	1	9	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0
07-Jul-98	4	31	0	3	1	3	0	0	4	0	0	0	0	0	0	0	1	0	0	0	0	0
08-Jul-98	1	25	0	0	4	7	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
15-Jul-98	0	1	0	1	1	4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
20-Jul-98	1	4	1	14	3	11	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0
22-Jul-98	0	0	2	1	3	5	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28-May-98	0	21	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28-May-98	0	14	8	15	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
29-May-98	1	33	1	2	17	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
29-May-98	0	18	1	2	4	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02-Jun-98	10	28	15	42	2	2	5	0	0	8	1	0	0	0	0	0	0	0	0	0	0	0
03-Jun-98	9																					
11-Jun-98	2	22	4	50	0	0	5	0	0	9	0	2	0	0	0	0	0	0	0	0	0	0
16-Jun-98	0	3	20	81	2	1	15	0	1	7	0	0	0	0	0	0	0	0	0	0	0	0
17-Jun-98	1	40	0	15	0	0	15	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0
18-Jun-98	1																					
19-Jun-98	0	28	3	0	0	1	11	1	0	5	0	0	0	0	0	0	0	0	0	0	0	0
02-Jul-98	0	12	10	1	8	35	8	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0
03-Jul-98	1	85	11	3	12	16	0	0	4	4	0	0	0	3	0	1	0	0	0	0	0	0
07-Jul-98	0	46	13	8	7	1	11	0	4	8	0	0	0	0	0	0	0	0	0	0	0	0
08-Jul-98	5	45	6	14	26	9	0	0	0	0	0	2	0	1	0	0	2	0	0	0	0	0
16-Jul-98	3	43	11	2	17	10	0	0	2	1	0	0	0	0	0	2	4	0	0	0	0	0
17-Jul-98	2	37	9	1	14	26	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
21-Jul-98	1	33	6	7	6	16	13	0	1	10	0	1	0	1	0	0	0	0	0	0	0	0
22-Jul-98	3	36	2	2	15	19	3	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
11-Sep-98	8	0	0	61	32	25	0	0	0	50	0	0	0	0	0	5	0	0	1	0	0	0
12-Sep-98	6	17	4	6	86	167	0	0	0	17	0	3	0	0	2	2	0	0	0	3	0	0
12-Oct-98	20	0	0	46	22	1	0	0	1	15	0	17	0	0	2	254	0	0	0	0	1	1
14-Nov-98	2	4	6	28	5	2	0	0	0	14	0	1	0	0	0	70	0	0	0	0	2	6