Distribution of Shortnose Sturgeon in the Lower Savannah River

Results of Research Conducted 1999-2000

Final Report to Georgia Ports Authority

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Executive Summary

During 1999-2000, 57 shortnose sturgeon were captured in the lower Savannah River. Of these, acoustic transmitters were implanted in 32 (15 juveniles and 17 adults). The fish were tracked and their habitat utilization patterns were determined. Juveniles used two relatively small areas very intensively. When water temperatures were <22°C, they concentrated in the vicinity of the intersection of the Front and Middle rivers (river kilometer (rkm) 31), moving about in both the Front and Middle rivers. When temperatures were >22°C, they moved well upriver from the area of proposed deepening, concentrating especially around rkm 47.5. Salinity at this location was consistently 0.1 ppt. Adult movement patterns were similar in that the fish moved upriver (especially concentrating around rkm 47.5) when temperatures were high. During low temperature periods they moved downriver again in the vicinity of the Front/Middle River intersection. However, movements were more extensive than those exhibited by juveniles, and some fish moved downriver almost to the mouth of the river during this time. Several fish received transmitters with a depth option. They were always located on or near the bottom +/- (1.5 meters).

During 1988-1992, juveniles were concentrated in Kings Island Turning Basin. It appears that harbor modifications (deepening; tide gate removed from service; New Cut closed) since then have changed the hydrographic conditions and caused the fish to move from that area. No juveniles were found as far downriver as the turning basin in this study.

A separate study of adult abundance in the Savannah River resulted in evidence that the population is larger than in 1992. However, this is attributed to the stock enhancement program conducted during 1985-1992 rather than to natural expansion of the population. The low catch rate of juveniles in the present study suggests that natural recruitment is still quite low. In the southeast, this recruitment bottleneck is generally attributed to poor water quality in the nursery habitat (the fresh/brackish water interface area).

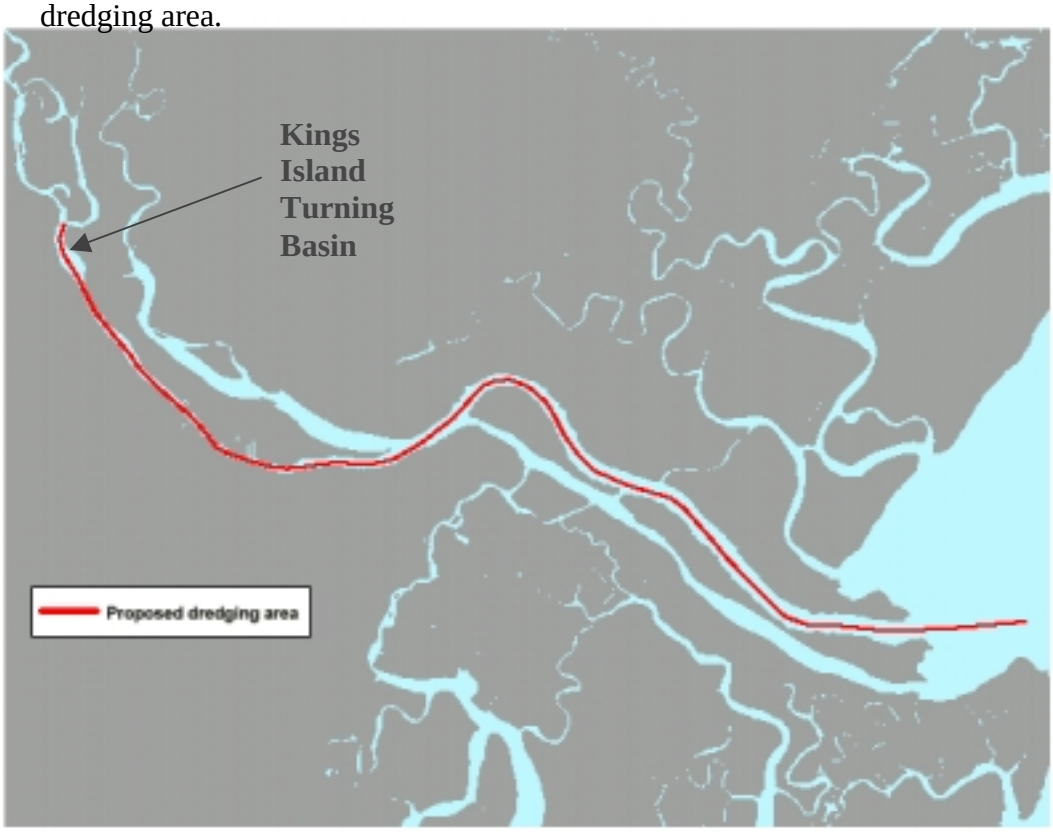
Introduction

The shortnose sturgeon, *Acipenser brevirostrum*, inhabits Atlantic coast rivers from New Brunswick, Canada to northern Florida (Vladykov and Greenley 1963) with at least 16 populations identified (Kynard 1997). Most populations are now depleted or extirpated, and the species is listed as endangered in the United States. Seasonal movements and habitat utilization patterns differ between southern and northern populations of shortnose sturgeon (Collins et al., in press). In the south, adults typically spawn in late winter well upriver (179-278 rkm in the Savannah River) but spend the rest of the year in the vicinity of the fresh/brackish water interface (Collins and Smith 1993). Population declines are believed to be due to a combination of over-harvesting and habitat loss from damming and water quality degradation (Collins et al 2000). This is also believed to be true in the lower Savannah River.

The Savannah River basin drains an area of over 26,000 km^2. Its headwaters are in the Blue Ridge Mountains of North Carolina, South Carolina, and Georgia. The Seneca and Tugaloo rivers join near Hartwell, Georgia to form the Savannah River. From there the river flows approximately 500 km in a southeasterly direction to the Atlantic Ocean and serves as a boundary between South Carolina and Georgia. The river is used for a variety of recreational, industrial, and municipal purposes. Much of the lower Savannah is bordered on the north by the Savannah River National Wildlife Refuge and on the south by the city of Savannah, which has a deep-water port and considerable industrial development. The river is impounded at a number of points; the dam farthest downriver is at Augusta, GA. Previous studies by Hall et al. (1991) indicated that shortnose sturgeon utilized the vicinity of the saltwater/freshwater interface (near the city of Savannah), with the adults making extensive use of the estuary, including the Front, Middle, and Back Rivers. The shortnose sturgeon nursery area was, at that time, located in the Kings Island

Turning Basin (KITB) around rkm 31 (Hall et al. 1991). Water quality models indicate that the planned deepening of the river channel (rkm 0-31.5) will lower the dissolved oxygen (D.O.) levels and raise the salinities in these areas (Figure 1).

Figure 1. The Savannah River estuary, with red indicating the proposed dredging area.



Adult shortnose sturgeon can tolerate at least short periods of low D.O. and high salinities, but juveniles have been shown to be less tolerant of these conditions in laboratory studies. The primary objectives were to evaluate the status, distribution, and recruitment of shortnose sturgeon in the Savannah River, in particular juveniles, by capturing and tracking them.

Methods

The study was conducted by South Carolina Department of Natural Resources (SCDNR) personnel during August 1999-December 2000. Shortnose sturgeon were captured using anchored gill and trammel nets. The nets were typically 7.62cm stretch mesh fished throughout a slack tide (high or low) near the freshwater/saltwater interface. Sampling began in the KITB, the historic aggregation area, and expanded to cover rkm 30-60. Most sampling took place during the day, but some net sets were also conducted at night.

Captured fish were measured (total length-TL and fork length-FL) to the nearest mm. Fish were then placed in a 123-qt. cooler with flow-through river water. This was supplemented with oxygen during periods of high temperature. Each fish received a PIT tag injected at the base of the dorsal fin. Dart tags were then placed near the injection site. Tissue samples were collected for genetic analyses and a leading pectoral fin ray was collected for age determination.

Adult shortnose sturgeon (defined as >56 cm TL) received an acoustic transmitter (Sonotronics, Inc.) measuring 90.0mm x 18.0mm and weighing 12g (water weight) with a life span of 14 months. Transmitters were sterilized in Betadine solution prior to implantation. The abdominal incision was closed using sterile non-absorbable suture material. A thin layer of petroleum jelly was placed over the incision to protect against water intrusion and infection. The condition of the fish was assessed, and then it was released at the original capture site. Location, depth, salinity, dissolved oxygen, and temperature were recorded.

Juvenile shortnose sturgeon received either an acoustic transmitter (Sonotronics, Inc) measuring 28.0mm x 8.0mm and weighing 2.5g (water weight) or a depth-indicating acoustic transmitter (Sonotronics, Inc) measuring 45.0mm x 9.5mm and weighing 3.0g (water weight). All transmitters used for the juvenile fish had a life span of 60 days. The same surgical procedures

were used for both the adult and juvenile fish. Following implantation, the condition of the fish was assessed, and it was released at the original capture site. In a few cases where water temperatures were in excess of 28^{o}C, the transmitters were attached externally using a modified dart tag.

Tracking of the fish was conducted from boats using acoustic receivers and both directional and omni-directional hydrophones (Sonotronics, Inc). Searches were conducted at least one time per week and covered the Front and Middle rivers. In cases where fish were lost, the Back River was also searched. Latitude/longitude, water quality (dissolved oxygen, salinity, temperature), and depth were recorded for each location of a fish. In July and August 2000, separate 24-hour tracking events were conducted. One target fish was located and tracked continuously by alternating shifts of personnel. Water quality, GPS coordinates, and physical landmarks of the fish's location were recorded every 15 minutes for the duration.

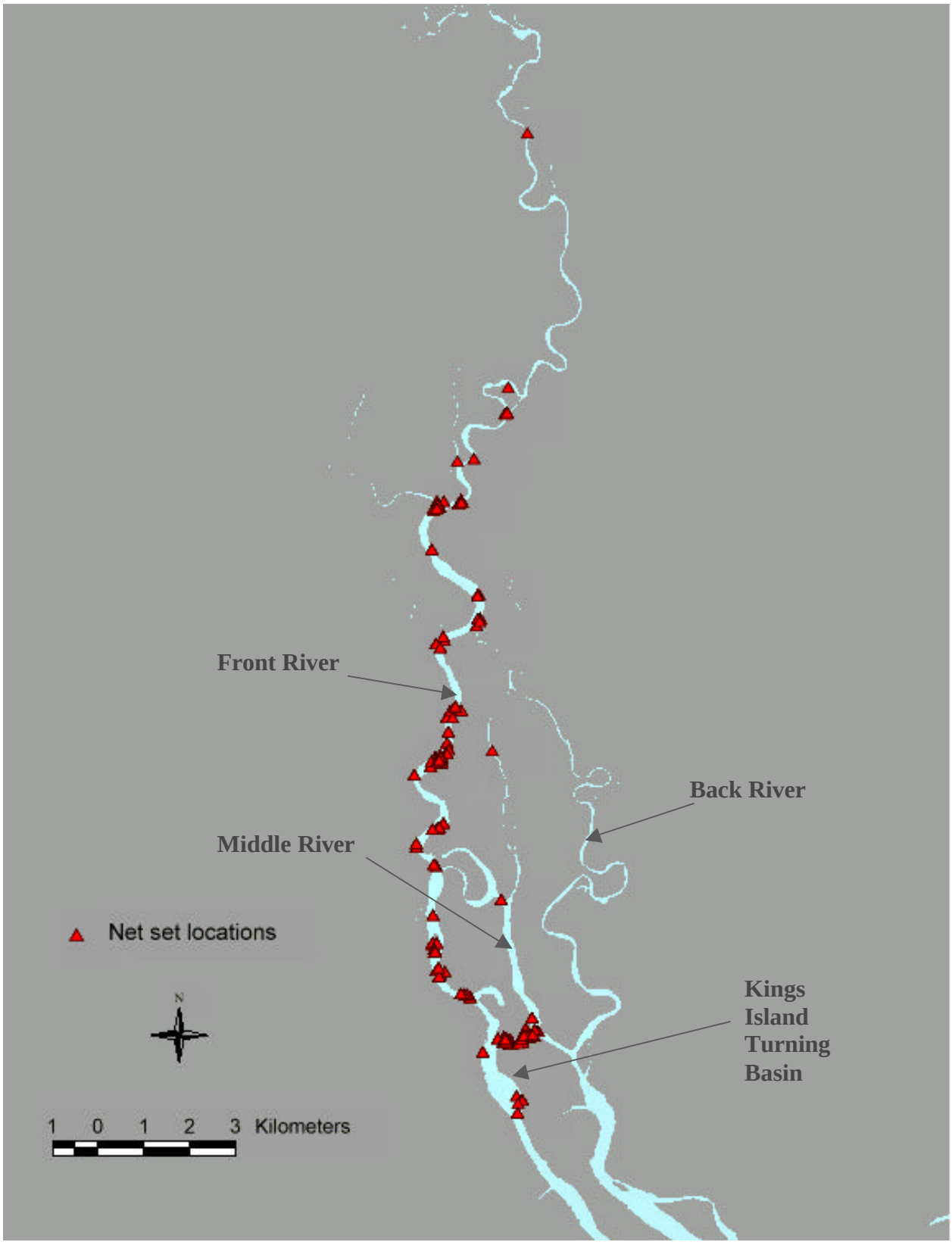
Substrate samples were collected with a bottom grab (Wildco-Ekman, Inc) when fish intensively utilized a specific area. This was done to characterize the substrate and to identify potential food sources.

Results

Net Sets

A total of 497 net sets were conducted between rkm 30.6 and 60.0 for a total of 197.96 net hours (1 net hour= 100yds of net/ 1 hour) (Figure 2). The locations of the net sets were chosen based on previous research projects and life history information. Net sets were conducted in all seasons throughout the year in attempts to capture and implant fish with transmitters. Mean water quality parameters for different seasons for juvenile and adult shortnose sturgeon capture locations are presented in Table 1. Fifty-seven shortnose sturgeon were captured. Twenty-eight fish were

Figure 2. Locations of 497 gill and trammel net sets in the lower Savannah River.



juveniles (juveniles defined as < 56cm TL) ranging from 37.2-54.5 cm TL, of which 2 were recaptured. One juvenile (51.2cmTL) was recaptured eight days after it received a transmitter and the other (37.6cmTL) had been captured and tagged three months prior to the recapture date. The remaining 29 shortnose captured were adult fish. They ranged in size from 56.1 to 101.5 cm TL and 3 were recaptured fish.

Table 1. Mean water quality parameters at capture locations of juvenile and adult shortnose sturgeon.

Juvenile Captures

Season	°C	Sal.	D.O.	No. Fish
Spring	20.8	2.5	7.09	4
Summer	----	----	----	----
Fall	19.6	6.8	6.58	11
Winter	13.6	4.8	8.40	11

Adult Captures

Season	°C	Sal.	D.O.	No. Fish
Spring	22	3.7	6.55	3
Summer	29	0.5	6.07	10
Fall	19.6	4.7	6.88	8
Winter	12.2	4.8	8.38	6

Capture data for juvenile and adult shortnose sturgeon were analyzed with respect to water temperature. The temperature of 22^{0}C was chosen to show the separation pattern between

habitats used during warm and cool seasons. The majority of the juvenile captures when water temperatures were below 22^0C were located in the lower range of the net sets (Figure 3, Table 2). The majority of captures took place in the Middle River <1 km from the confluence of the Front and Middle rivers (Figure 4). This area is on average 6.1 meters shallower than the Front River, and the average salinity is half that of the Front River. A relatively shallow sill appears to create a natural buffer from higher salinities observed in the Front River.

Table 2. Date, location, fork length, total length, and water quality parameters for captured juvenile shortnose sturgeon for water temperature < 22°C. Note MR refers to the Middle River, (I)= salinity for net set, and (O)=salinity for net haul.

Date	River Kilometer	Fork	Total	Temperature	Salinity (O)	Salinity (I)	Depth (m)
11-Nov-99	31.4	42.2	48.8	18.6	1.1	2.1	9.8
17-Nov-99	35.4 MR	46.3	53.2	17.4	7.5	3.0	8.5
18-Nov-99	31.4	34.1	39.6	18.2	12.6	8.4	8.5
10-Dec-99	1.8 MR	32.6	37.2	14.9	8.8	8.3	6.4
10-Dec-99	1.8 MR	42.5	49.2	14.9	8.8	8.3	6.4
17-Dec-99	3.5 MR	44.0	51.3	13.8	4.4	3.4	7.0
17-Dec-99	3.5 MR	46.2	54.1	13.8	4.4	3.4	7.0
17-Dec-99	3.5 MR	46.3	53.1	13.8	4.4	3.4	7.0
13-Jan-00	31.4	32.3	37.2	13.7	9.3	8.4	10.1
14-Jan-00	34.8	45.3	53.1	13.5	6.0	0.7	11.0
14-Jan-00	34.8	41.2	48.2	13.5	6.0	0.7	11.0
16-Feb-00	.81 MR	40.4	45.7	12.8	1.4	1.6	6.1
16-Feb-00	.81 MR	43.7	50.1	13.1	1.1	1.4	7.0
16-Feb-00	.81 MR	38.5	45.1	13.1	1.1	1.4	7.0
22-Mar-00	.81 MR	32.4	37.6	17.7	2.8	1.9	8.5
22-Mar-00	.64 MR	43.2	50.1	17.7	2.8	1.9	8.5
12-Apr-00	1.1 MR	46.5	53.6	18.5	1.1	1.3	6.7
26-Oct-00	32.7	47.0	53.4	21.0	9.5	9.3	9.1
01-Nov-00	.5 MR	42.9	49.5	21.1	14.9	12.2	11.0
16-Nov-00	35.0	47.1	54.2	18.3	7.5	NA	13.4
29-Nov-00	33.8	40.3	45.5	14.2	9.8	10.1	12.8
29-Nov-00	33.6	47.6	54.5	14.2	9.8	10.1	12.8

Figure 3. Locations where Juvenile shortnose sturgeon were captured in the lower Savannah River.

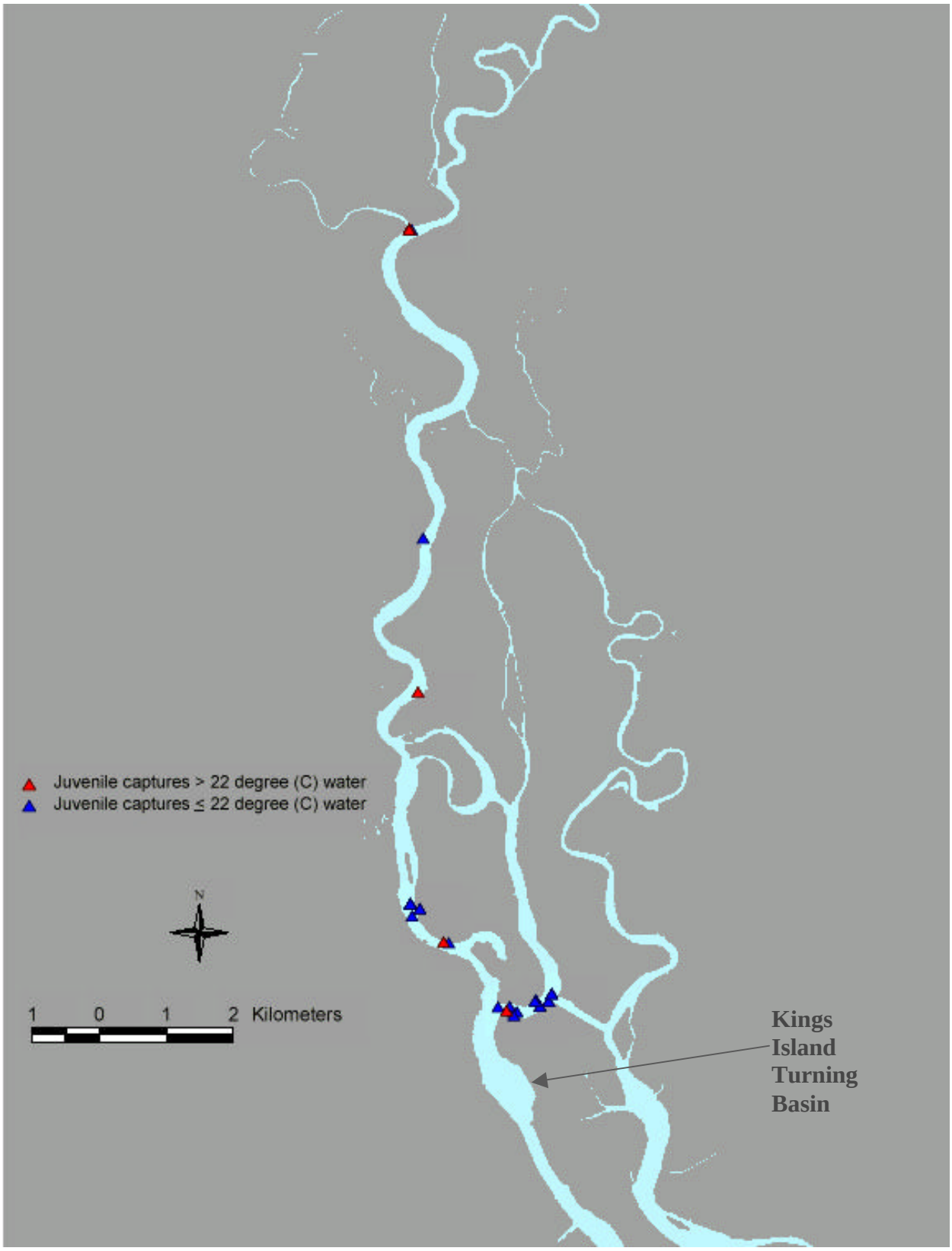


Figure 4. Habitat at rkm 31.4 used by juvenile shortnose sturgeon.

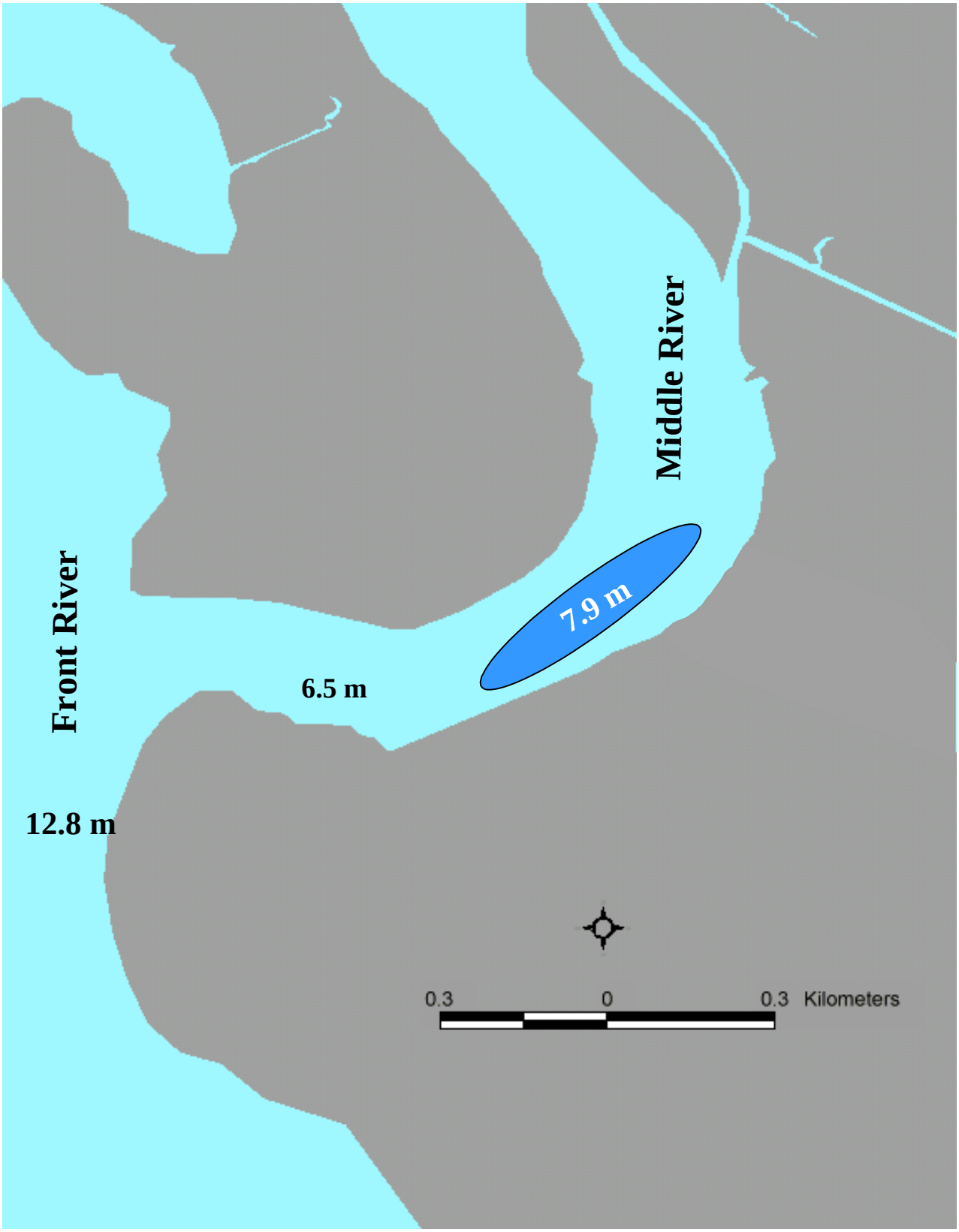


Table 3. Date, location, fork length, total length, and water quality parameters for captured juvenile shortnose sturgeon for water temperature > 22°C. Note MR refers to the Middle River, (I)=salinity for net set, and (O)=salinity for net haul

Date	River Kilometer	Fork	Total	Temperature	Salinity (O)	Salinity (I)	Depth (m)
22-Sep-99	46.5	45.6	51.9	23.7	0.1	0.1	10.1
22-Sep-99	46.5	42.4	49	23.7	0.1	0.1	10.1
24-Sep-99	46.5	41.1	46.6	22.5	0.1	0.1	10.4
11-May-00	37.5	39.5	44.5	26.2	3.7	3.6	11.3

Captures when the water temperatures were >22^{0}C occurred throughout the range of the net sets (Figure 3, Table 3). However, captures of juveniles during this time were limited (4 fish captured), perhaps because water quality parameters limited juvenile movement resulting in low catch rates with the passive gears used. The capture locations for the 29 adult sturgeon were more widespread than that of the juvenile shortnose sturgeon. They are able to endure areas of poorer water quality such as lower dissolved oxygen concentrations and higher salinities. The majority of captures when temperatures were <22^{0}C occurred below Port Wentworth (rkm 34.6) in the Front River or just inside the Middle River at the first bend (Figure 5, Table 4). In contrast, when temperatures were >22^{0}C, no adults were captured below the mouth of Steamboat River (rkm 22.8)(Figure 5, Table 5).

Figure 5. Locations where adult shortnose sturgeon were captured in the lower Savannah River.

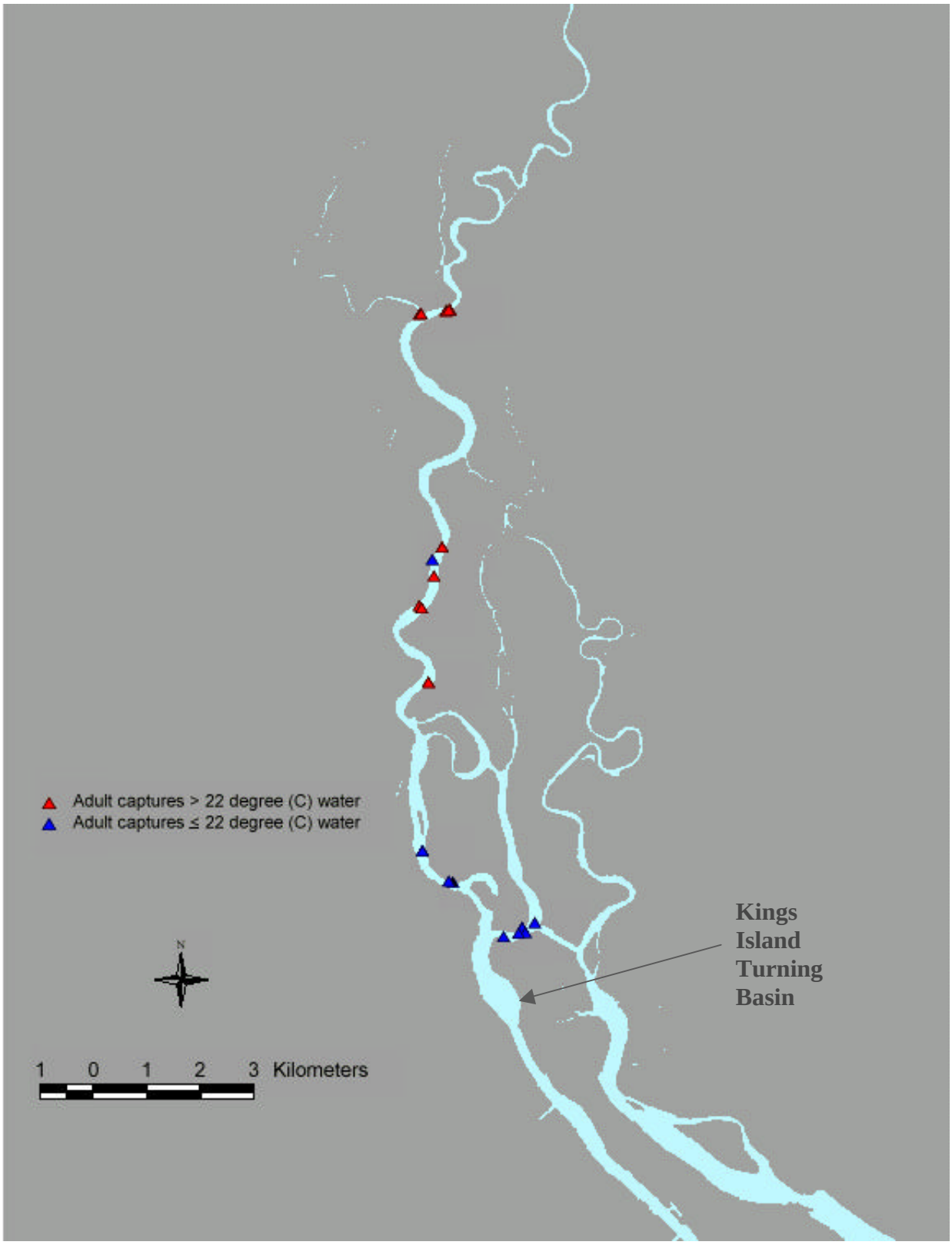


Table 4. Date, location, fork length, total length, and water quality parameters for captured adult shortnose sturgeon for water temperature < 22°C. Note MR refers to the Middle River, (I)=salinity for net set, and (O)=salinity for net haul.

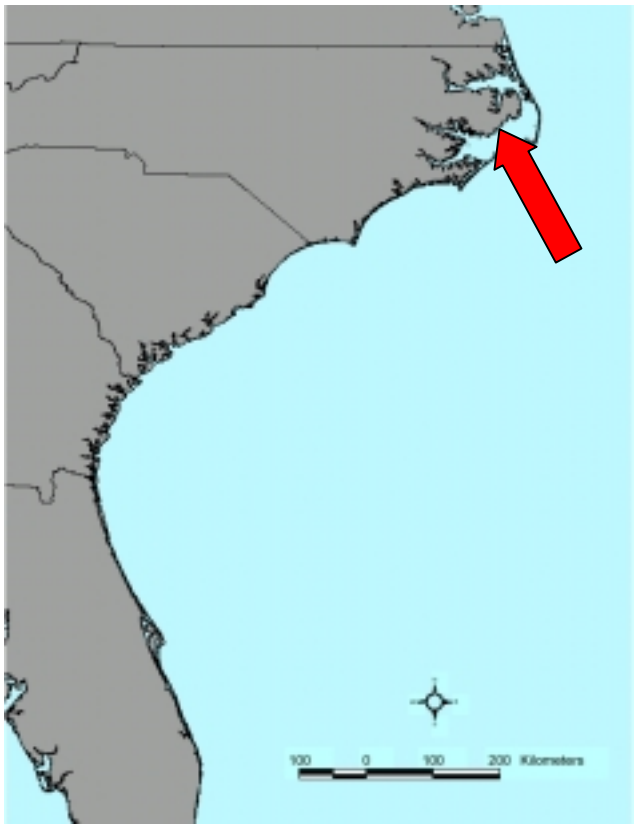
Date	River Kilometer	Fork	Total	Temperature	Salinity (O)	Salinity (I)	Depth (m)
17-Dec-99	3.5 MR	54.3	62.8	13.8	4.4	3.4	7.0
21-Jan-00	32.0	50.0	57.7	12.0	6.6	6.0	11.9
02-Feb-00	.16 MR	55.0	61.6	7.5	14.0	1.2	7.3
04-Feb-00	39.4	69.7	80.9	6.8	0.0	0.1	5.8
16-Feb-00	.81 MR	48.7	57.3	13.1	1.1	1.4	7.0
16-Feb-00	.81 MR	51.2	58.8	13.1	1.1	1.4	7.0
24-Mar-00	.64 MR	49.0	56.1	17.8	3.7	3.5	9.1
11-Oct-00	.81 MR	50.9	57.5	20.3	3.3	3.6	6.4
26-Oct-00	32.7	72.5	77.8	21.0	9.5	9.3	9.1
29-Nov-00	33.8	57.5	65.5	14.2	9.8	10.1	12.8
29-Nov-00	33.5	48.4	57.3	14.2	9.8	10.1	12.8

Table 5. Date, location, fork length, total length, and water quality parameters for captured adult shortnose sturgeon for water temperature > 22°C. Note MR refers to the Middle River, (I)=salinity for net set, and (O)=salinity for net haul.

Date	River Kilometer	Fork	Total	Temperature	Salinity (O)	Salinity (I)	Depth (m)
04-Aug-99	38.6	72.0	83.0	30.6	1.1	0.6	6.7
22-Sep-99	46.5	82.3	95.9	23.0	0.1	0.1	7.6
22-Sep-99	46.5	72.2	82.6	23.0	0.1	0.1	7.6
22-Sep-99	46.5	60.1	63.2	23.7	0.1	0.1	10.1
11-May-00	36.8	53.9	62.3	26.2	3.7	3.6	11.3
11-May-00	36.8	55.4	63.6	26.2	3.7	3.6	11.3
08-Jun-00	40.2	51.9	61.4	27.0	0.5	0.4	10.1
08-Jun-00	40.2	64.6	74.9	27.0	0.5	0.4	10.1
16-Jun-00	40.0	78.8	89.8	28.2	1.2	0.6	7.3
20-Jun-00	39.4	59.5	69.1	28.6	0.1	0.1	7.9
20-Jun-00	39.4	74.0	84.1	28.6	0.1	0.1	7.9
18-Jul-00	47.5	52.5	59.4	29.9	0.1	0.1	5.5
18-Jul-00	47.5	89.6	101.5	29.9	0.1	0.1	5.5
09-Aug-00	49.1	63.2	71.4	28.4	0.1	0.1	5.5
09-Aug-00	49.1	47.5	56.8	28.3	0.1	0.1	4.9
05-Oct-00	47.5	47.2	56.7	22.8	0.1	0.1	5.8

One recaptured adult was a hatchery fish released in the Savannah River during a previous stock enhancement program, one was recaptured one year and eight months after its original capture (at that time the fish had a biopsy taken of the gonad that indicated it was a reproducing female fish), and one was captured by another project one year earlier. Also, two Atlantic sturgeon that were tagged on the Savannah River were recaptured in North Carolina waters by gill net fishermen. (Figure 6.)

Figure 6. N.C. recapture location of 2 juvenile Atlantic sturgeon from the Savannah River.



Age

Pectoral spines were dried, sectioned with a low-speed saw (Isomet, Inc.), mounted on microscope slides, and read by a biologist experienced in determining fish ages. Nominal ages were established for 36 individuals (note that the annual nature of rings in spines has not been validated for shortnose sturgeon).

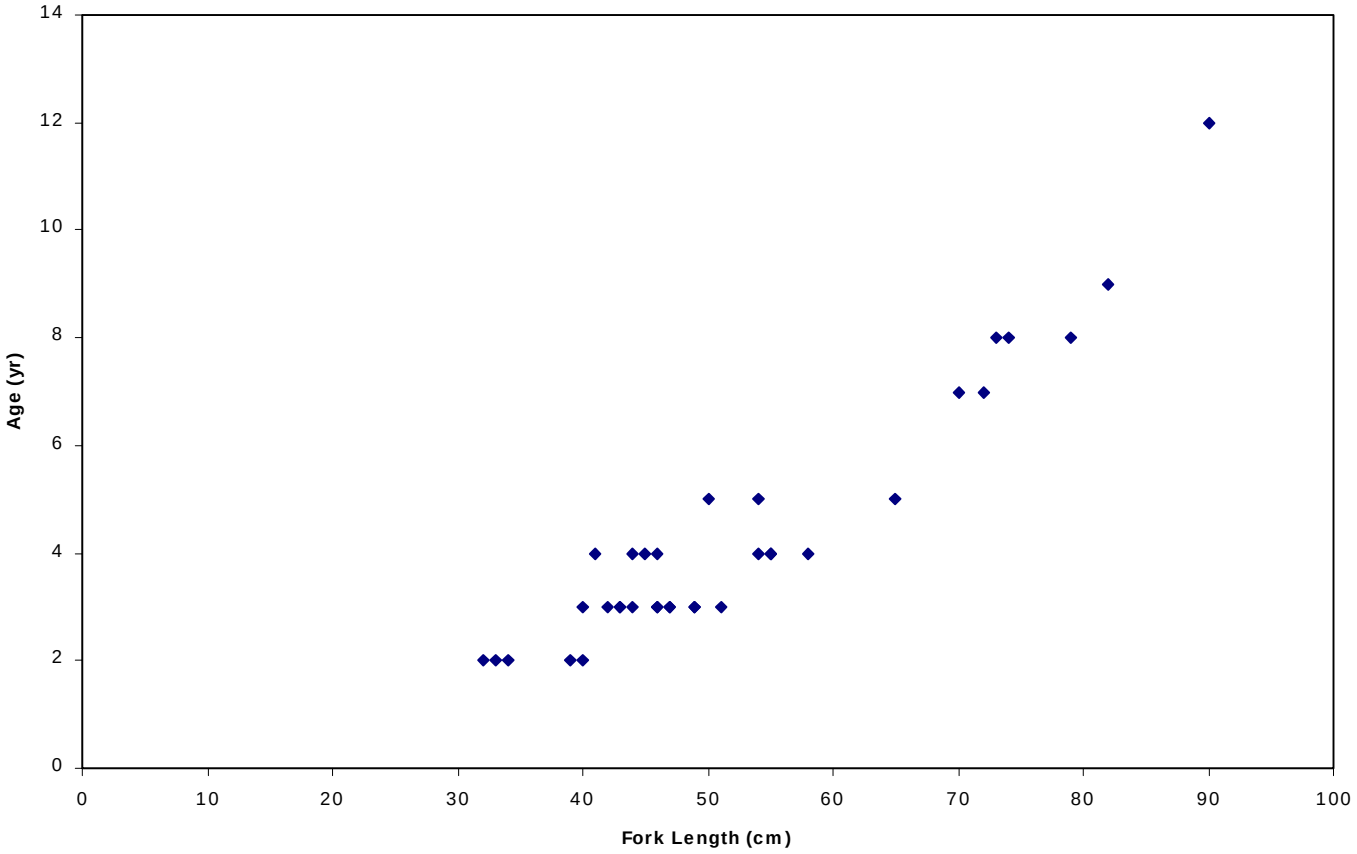
The ages ranged from 2 to 12 (Figure 7). Using 56 cm FL as the juvenile/adult benchmark, all but 9 fish were juveniles. Although the sample size of large fish was small, length at age apparently begins to asymptote at about 70-90 cm FL. The ranges in length at age were substantial (for example, age 3 fish were 40-52 cm FL) with a large amount of overlap even at young ages. This suggests that estimating ages using length frequency distributions would result in a significant amount of error.

The smallest size class (30-35 cm FL) was designated as age 2. However, based on the generally accepted hypothesis that juveniles move into the nursery habitat as early age 1 individuals, it is possible that the ages assigned are actually one year too old. This could occur if, for example, an extra annulus is deposited due to physiological impacts of arriving in the estuary. The age distribution presented in Figure 7 would then simply be shifted downward by one year.

Telemetry

A total of 32 fish received transmitters. Fifteen of these fish were juveniles. The type of transmitter used was determined by size of the fish and water temperature. If the fish was determined to be a juvenile, a smaller transmitter was used, and if the water temperature was above 28^{o}C, the tag was attached externally to eliminate the stress involved with surgery. All juveniles were implanted with smaller 60-day transmitters (with the exception of one that received an

Figure 7. Length at nominal age for shortnose sturgeon from the Savannah River.



external transmitter), of which 5 had depth options. Eleven smaller adults received the internal 60 day transmitters (3 having depth options), 3 larger adults were implanted with the 14 month transmitter, and 3 received 60 day transmitters externally attached. Of the 32 fish with transmitters, data were collected from 19. Problems with the transmitters, losing the externally attached transmitters, and possible trans-intestinal expulsion could be the causes for the lost fish. For a number of reasons (limited 60 day transmitter life and the inability of manufacturer to supply transmitters on schedule), there are limited data for juvenile sturgeon during summer as strictly defined. Also, telemetered adult fish may have participated in spawning migrations to upriver spawning sites (~rkm 275) (Hall et al 1991). In addition, some sturgeon may have been fish that had been stocked during 1985-1992 (Smith and Collins 1996) and failed to imprint on the river. These fish may have left the river in search of their (nonexistent) natal system (Smith et al., in press).

The temperature of 22^{0}C was used in the analysis of telemetry data to show separation of seasons and habitats. The juvenile shortnose sturgeons were found between rkm 31.2-46.5 at temperatures of 19.4-28.9^{o}C, salinities of 0.1-17.6 ppt., and depths between 2.1 and 14.9 m (Table 6).

Table 6. Mean water temperature, salinity, and D.O. by season at locations where juvenile shortnose sturgeon were found.

Season	°C	Sal.	D.O.
Spring	**19.9**	**1.4**	**7.84**
Summer	**27.3**	**2.0**	**6.36**
Fall	**21.1**	**3.3**	**7.06**
Winter	**12.3**	**5.4**	**8.36**

They were found well upriver (rkm 47.5) when water temperatures were greater than 22^0C and moved downriver to the vicinity of rkm 31 when the water temperature dropped below 22^0C (Figure 8). They appeared to congregate in two areas during the cool period. In spring months they were located in an area just down from the Houlihan bridge in the Front River (rkm 34.3), and in winter months they were found just inside the Middle River in a 7.9 meter deep hole (rkm 31.3). This area where the Middle River meets the Front River is of particular interest (Figure 4). Nine fish were captured in this area with total lengths of < 50 cm TL and 4 measuring < 40 cm TL, suggesting this area is critical nursery habitat for the young shortnose sturgeon. Juveniles were especially tracked in this area throughout winter and into spring when they began moving upriver. Interesting enough, no juveniles were tracked in or below the Kings Island Turning Basin (rkm 30), although in past years this was the primary nursery habitat. Depth transmitter readings were on or near the bottom, indicating the sturgeon were utilizing the habitat on or within 1.5 meters of the bottom.

Table 7. Mean water temperature, salinity, and D.O. by season at locations where adult shortnose sturgeon were found.

Season	°C	Sal.	D.O.
Spring	**20.4**	**2.4**	**7.58**
Summer	**28.5**	**0.3**	**6.80**
Fall	**21.7**	**4.7**	**6.45**
Winter	**12.5**	**8.6**	**8.63**

The adult shortnose sturgeons were found between rkm 20.8-48.9 at temperatures of 7.5-29.8^{0}C, salinities of 0.1-21.5 ppt, and depths between 1.5 and 16.7 m (Table 7). The locations for

Figure 8. Juvenile shortnose sturgeon locations in the lower Savannah River.

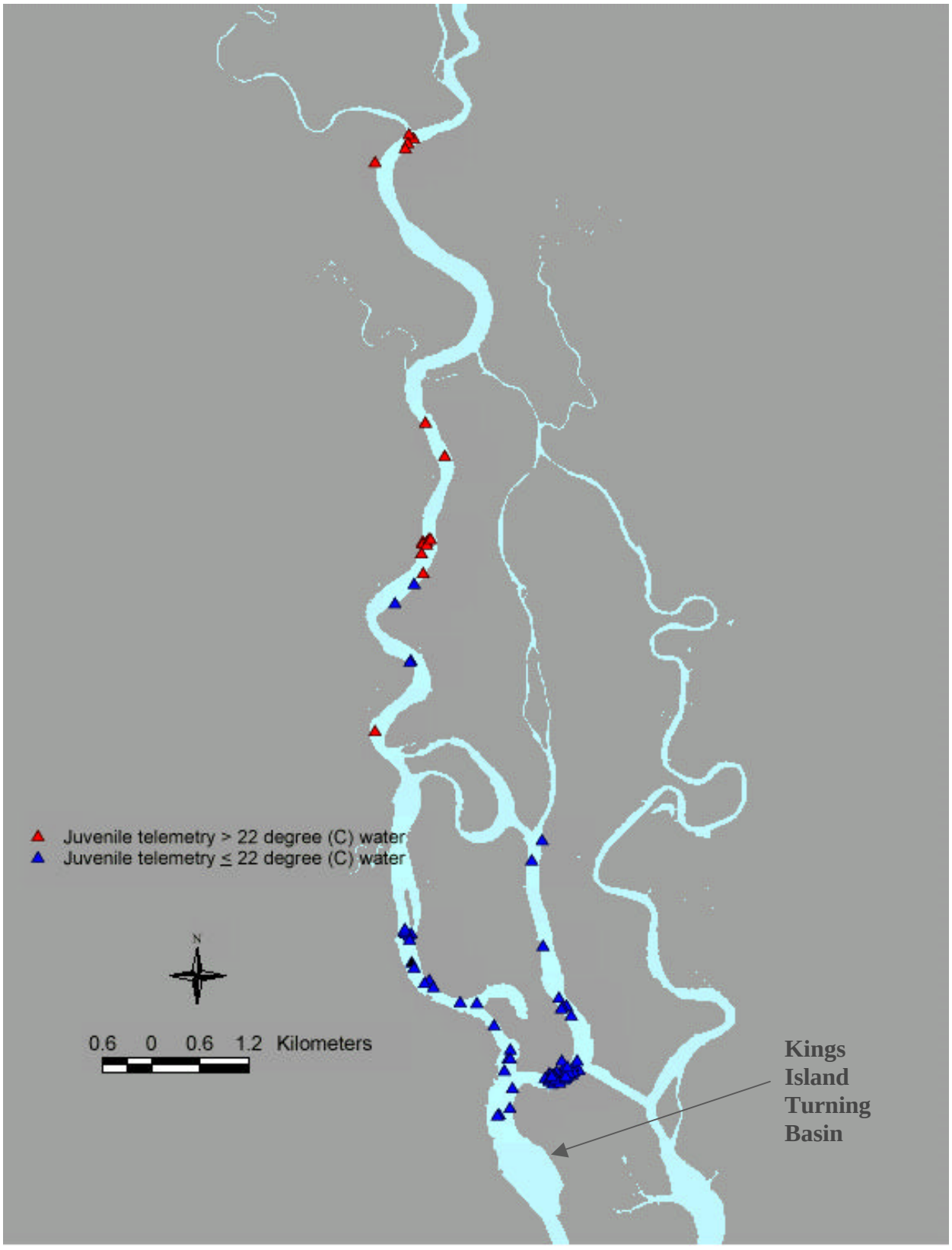
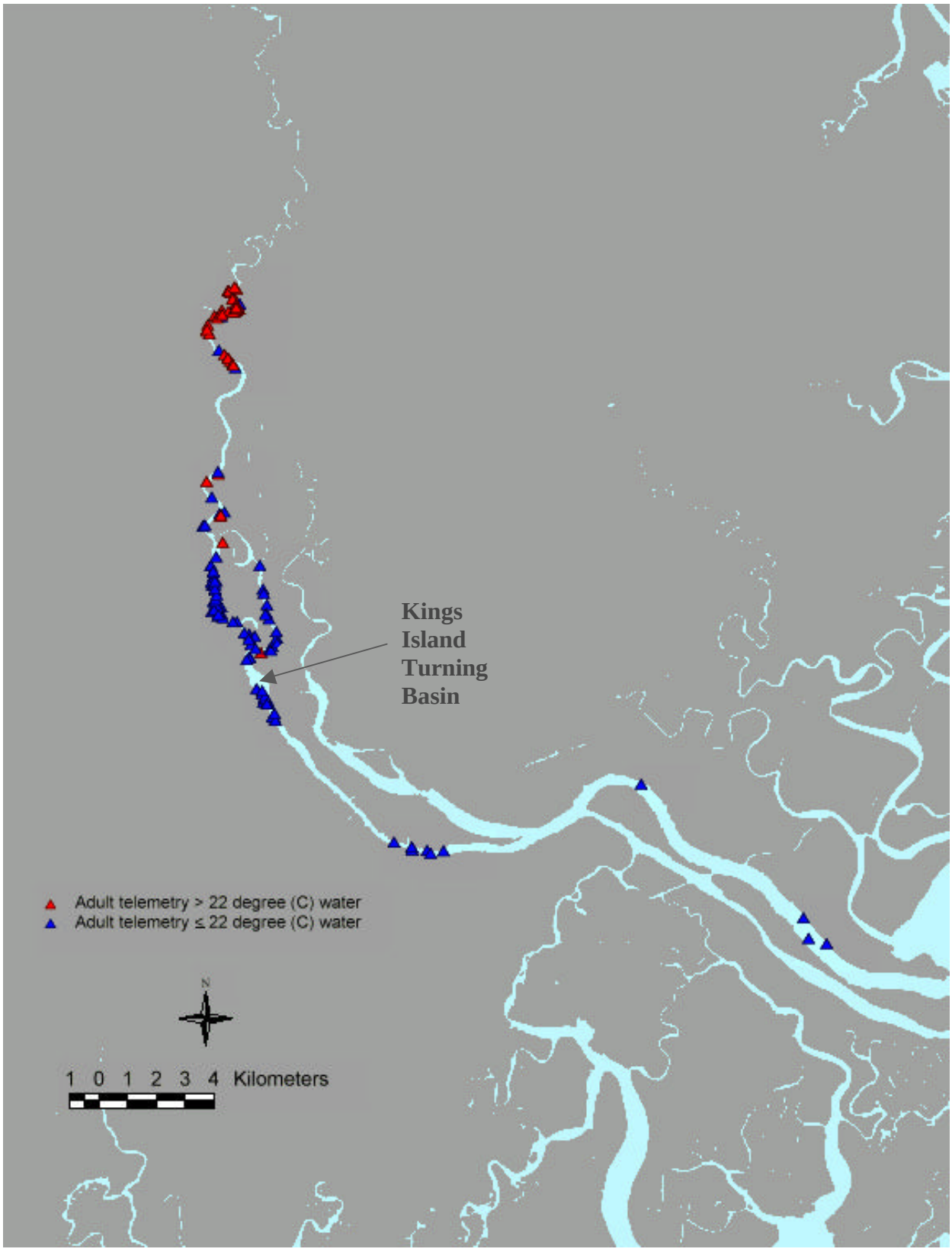


Figure 9. Locations where adult shortnose sturgeon were found in the lower Savannah River



the adult sturgeon were found, as expected, to be more widespread than that of the juvenile fish (Figure 9). Of particular interest was a location used when water temperatures were greater than 22^{0}C (rkm 47.5) where the adults seemed to congregate. This area is characterized by a deep (6.5m) area at a sharp bend in the river beside a large sand bar (Figure 10). It is unknown why this was preferred, but it may have been due to synergistic effects of salinity, D.O., and temperature. Like the juveniles, when water temperatures dropped below 22^{0}C, the adults began a downriver migration and were found in the coldest months well downriver almost to the ocean at rkm 5.5. Due to the larger transmitters with longer battery life implanted in the adult sturgeon, we were able to track them for an extended time. In one case, an adult was tracked for a continuous year (Figure 11). This fish was located in the upper parts of the study area (rkm 47.5) in the warmer months, but as the water temperature started falling (Figure 12) (Oct 99, Sept. 00), the fish moved rapidly downriver to slightly warmer water with higher D.O. concentrations. In the spring months (April and May 00), when the water temperature started to rise, the fish started migrating upriver to areas of cooler water. It is important to note that each year is different due to changing water conditions (high water events, droughts, etc.).

24 hour tracking

Two fish, a juvenile (44.4 cm TL) and an adult (56.8 cm TL), both with external transmitters, were singled out for continuous 24 hour tracking. The first tracking effort occurred in July and for the duration the juvenile fish did not move up or down-river, staying at rkm 36.4 (Figure 13). The fish did, however, make movements across the river channel. Some reasons for the limited movements may be the extreme water temperatures (29.1-29.9^{o}C) and low dissolved

Figure 10. Habitat at rkm 47.5 used by adult shortnose sturgeon

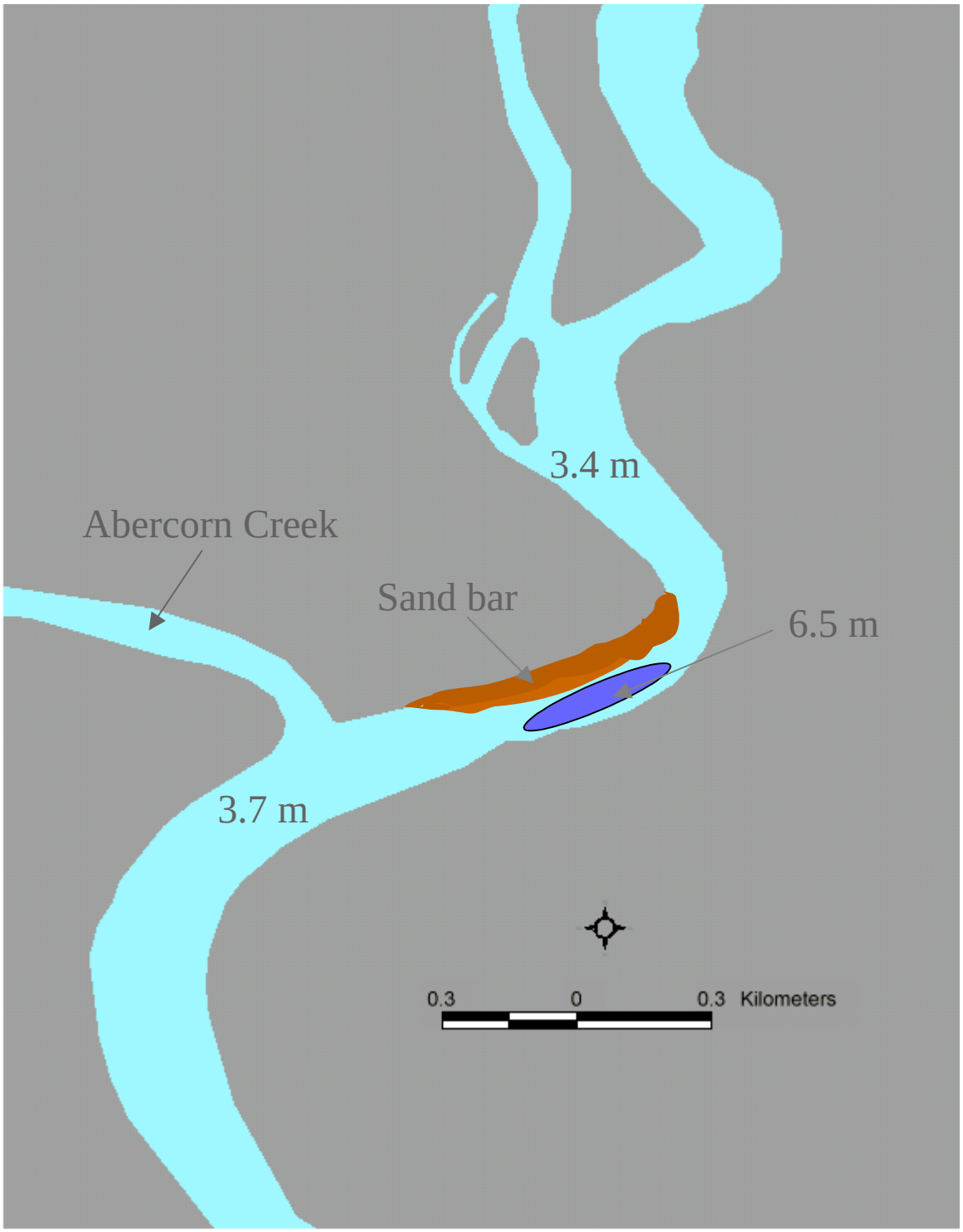


Figure 11. Movements throughout a year of an adult shortnose sturgeon.

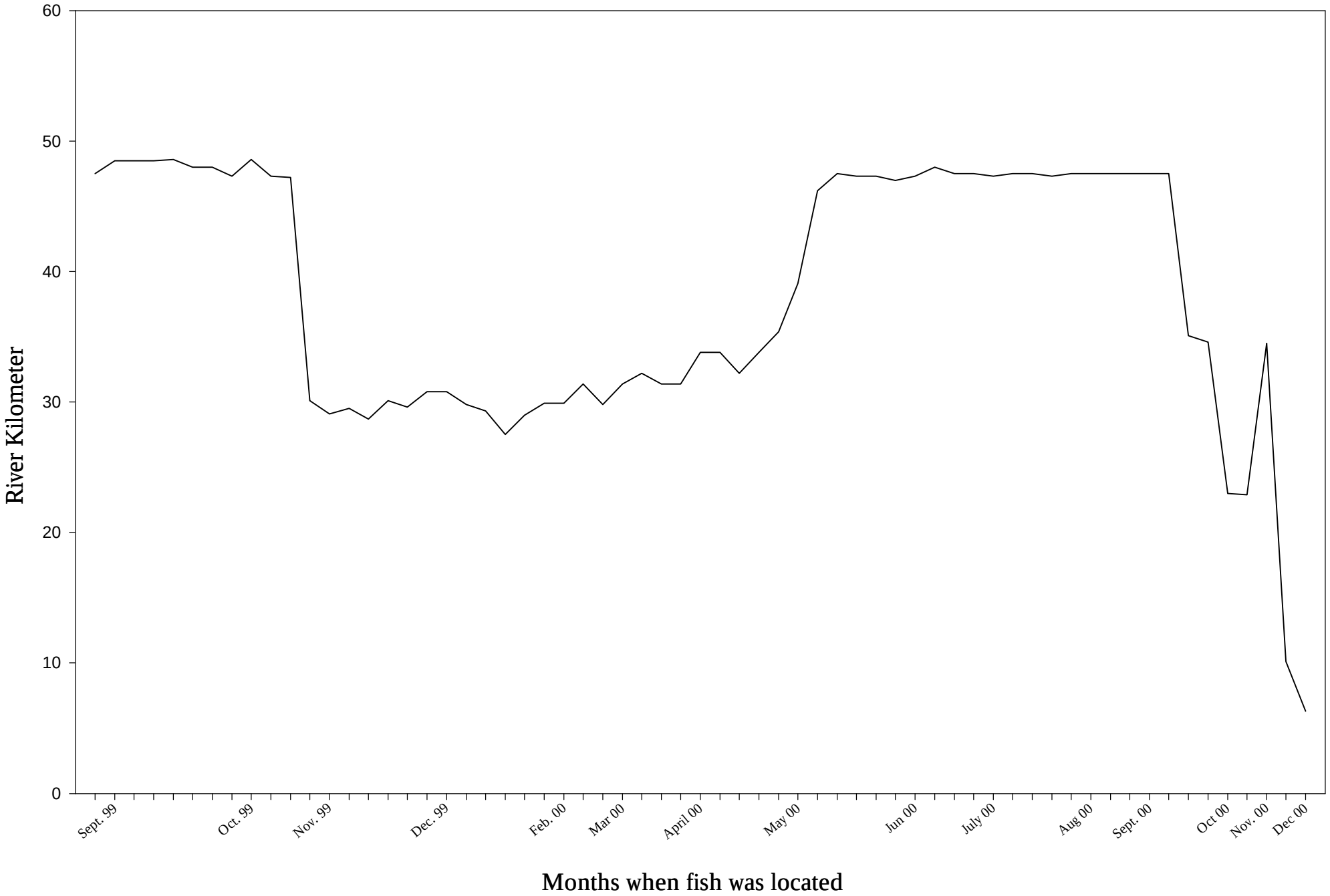


Figure 12. Water Quality parameters affecting the movement of an adult shortnose sturgeon.

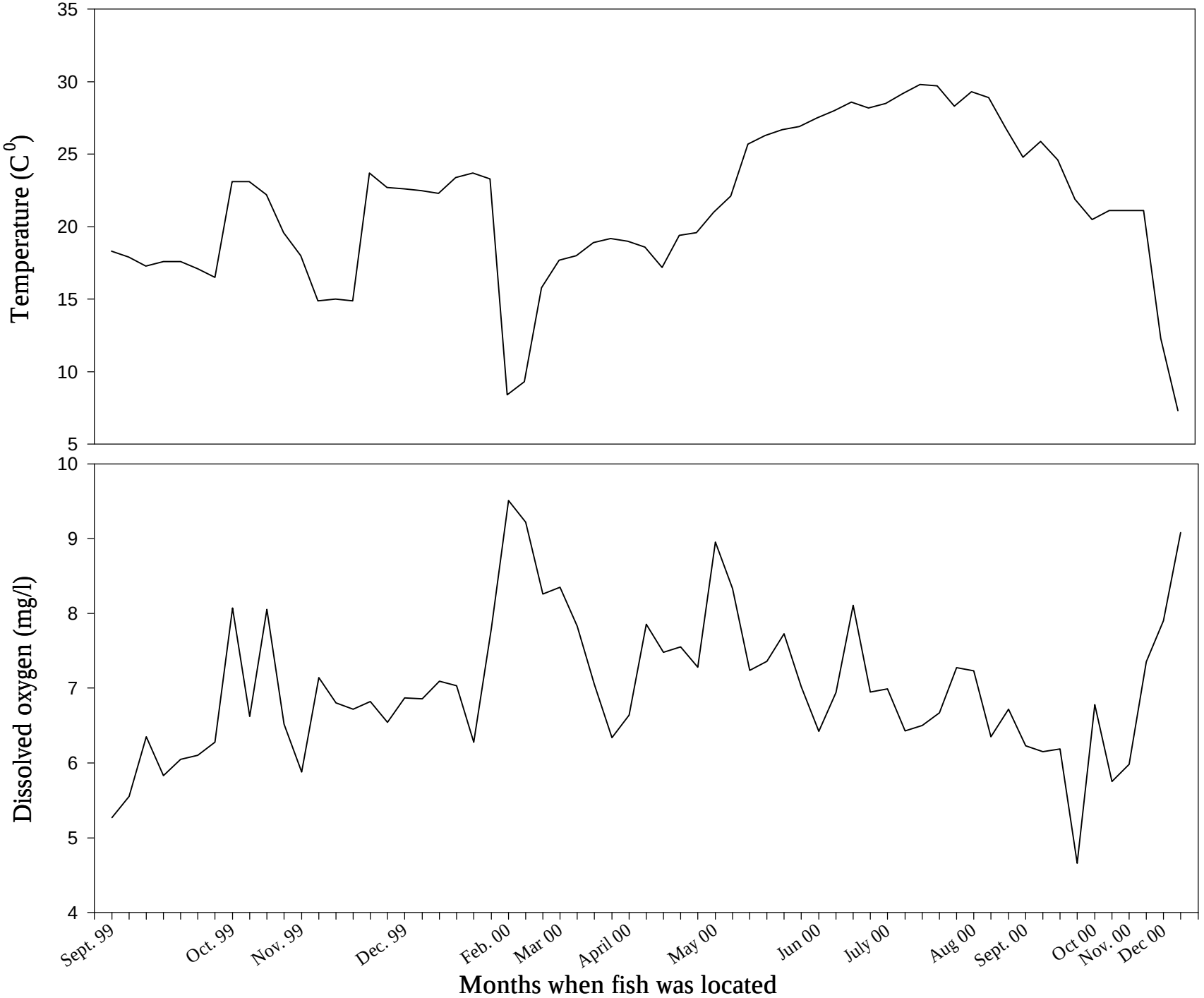
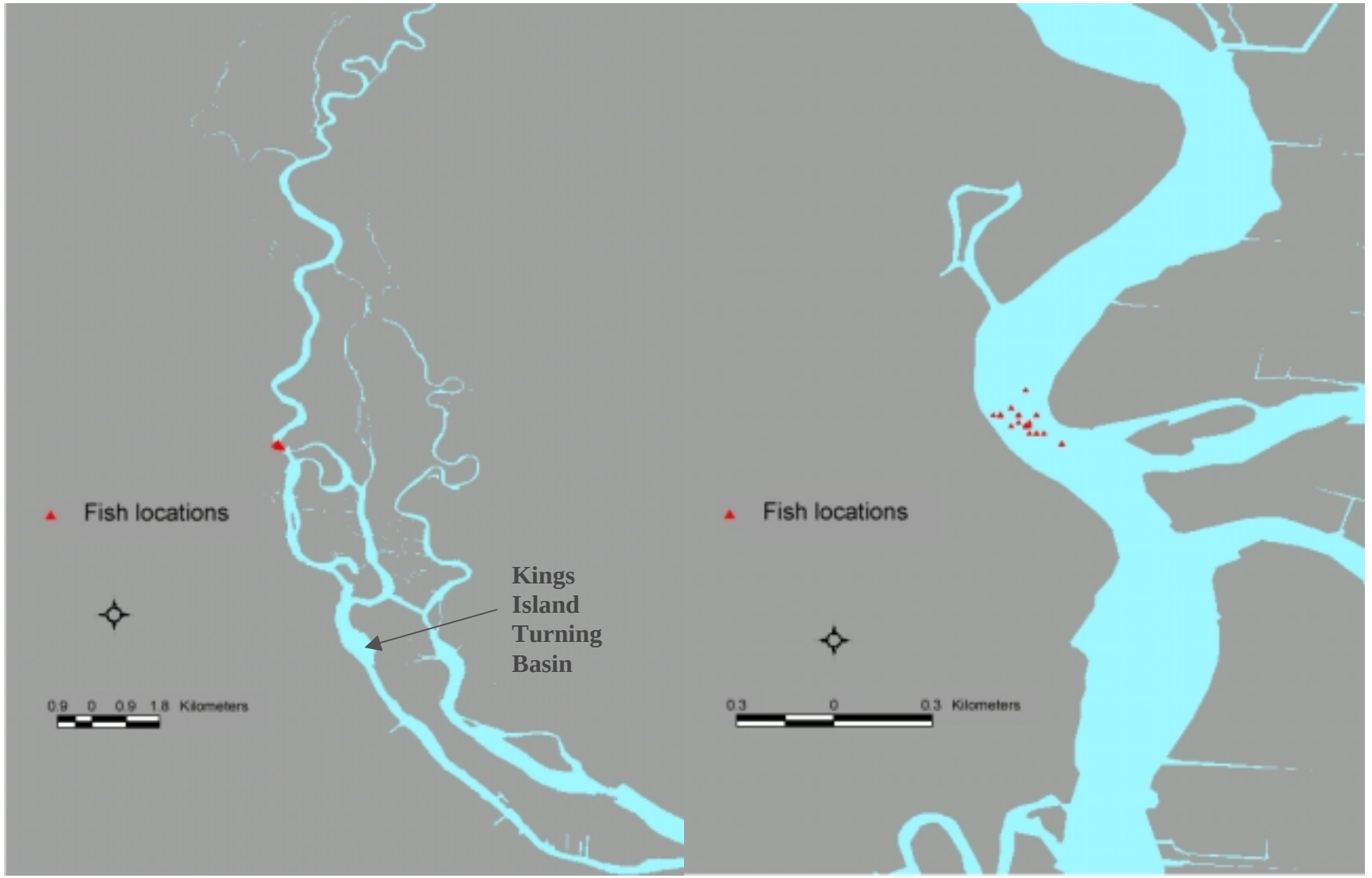


Figure 13. Hourly locations of a juvenile shortnose sturgeon tracked for 24 hours.



oxygen (3.05-6.86 mg/l). Although the depth range was 3.8 to 13.8 m, the most frequent location for the fish was in a 13.8 meter deep hole in the river channel. The salinity in this area ranged from 0.1 to (briefly at high tide) 13.3 ppt.

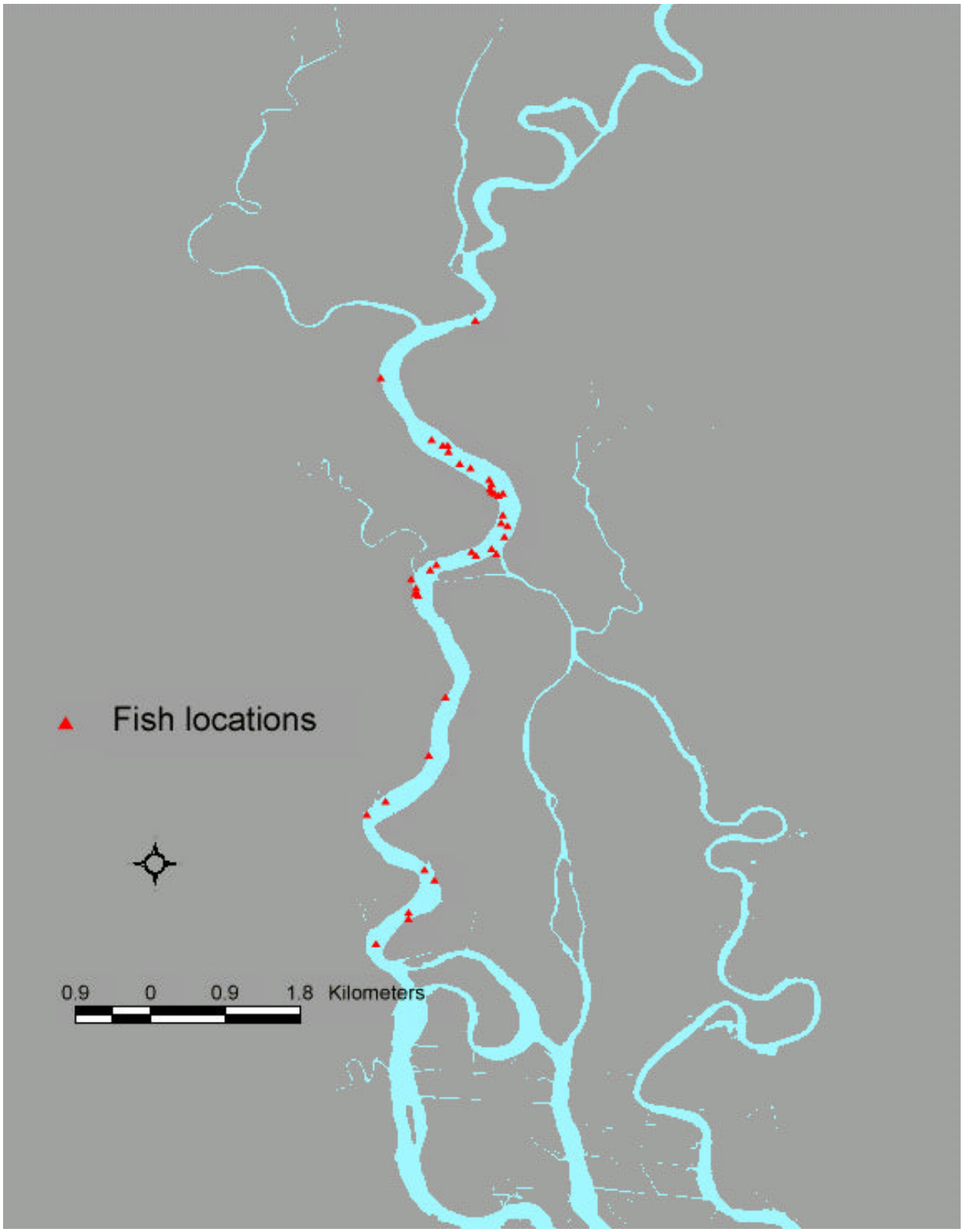
The adult fish tracked in August exhibited greater movement. The fish moved between rkm 36.7 and rkm 49.1 where the salinity remained 0.1 for the duration, dissolved oxygen ranged from 4.20 to 9.00 mg/l, temperatures were 28.3°C- 29.4°C, and depths ranged from 2.7 to 11.0 m (Figure 14).

Water Quality

Dissolved oxygen concentrations, salinities, and water temperature were measured for every net set and at every location where a fish was found through telemetry (Appendix 1). The net set water quality data occurred between rkm 27.04 and 60.0 year round during 1999-2000. The data for the telemetry were gathered between rkm 5.5 and 49.0.

Although tolerances increase with age, juvenile shortnose sturgeon are stressed by reduced DO levels and even moderate salinities (Jenkins et al. 1993). For example, significant mortality was noted for fish approximately 2.5 months old when held in salinities as low as 11 ppt. Similarly, fish of that age began dying at DO levels of 3.0 mg/L and below. In Savannah Harbor, juveniles were not captured in salinities greater than 13 ppt (although a telemetered fish was located very briefly in 17 ppt) or DO levels less than 4.0 mg/L. Synergistic effects of temperature, DO level, and salinity have not been tested, but field observations indicate high stress at temperatures >27°C. This may be a factor prompting juveniles to move upriver into an area with barely detectable salinity (average 0.1 ppt) during summer while preferring to be downriver in slightly higher salinities (average 5.4 ppt) during winter. In addition, low DO levels in the nursery habitat may be

Figure 14. Hourly locations of an adult shortnose sturgeon tracked for 24 hours.



exacerbated by dredging activity. Brown and Clark (1968) found that dredging caused a 16-83% reduction in DO. However, this effect likely varies tremendously with substrate type, and whether dredging affects DO in the vicinity of sturgeon would have to be determined empirically. (Appendix 2).

Substrate samples

Seven bottom grabs were obtained at five different sites (rkm 31.2, .05 in the Middle River, 34.3, 35.0, and 47.5) (Figure 15,Table 9). Grabs were taken where telemetry data showed aggregations of fish for an extended time. Most of these sites consisted of sand with the exception of some mud and other matter. Amphipods and benthic worms were found in only the first two substrate samples. It appeared that the shortnose sturgeon were selecting their habitats based on dissolved oxygen, temperature, and salinity rather than the substrate type.

Table 9. Date, location, and composition of substrate samples taken on the Savannah River.

Date	GPS	Location (RKM)	Visual Description
02/02/00	3208.45 x 8108.48	31.2	Mud, leaves...mostly mud/silt
02/02/00	3208.40 x 8108.48	31.2	Mostly sand..some mud, leaves, pebbles, detritus
02/02/00	3208.61 x 8108.13	.48 MR	Mostly sand..some mud, leaves,barnacle shell, few pebbles
03/21/00	3209.47 x 8109.25	34.3	sand
03/21/00	3209.81 x 8109.34	34.7	sand
8/24/00	3215.00 x 8108.78	47.5	All sand; no pebbles, shell, or clay.
8/24/00	3215.00 x 8108.78	47.5	Pebbles, rocks, and corbicula shells. Small amount of sand

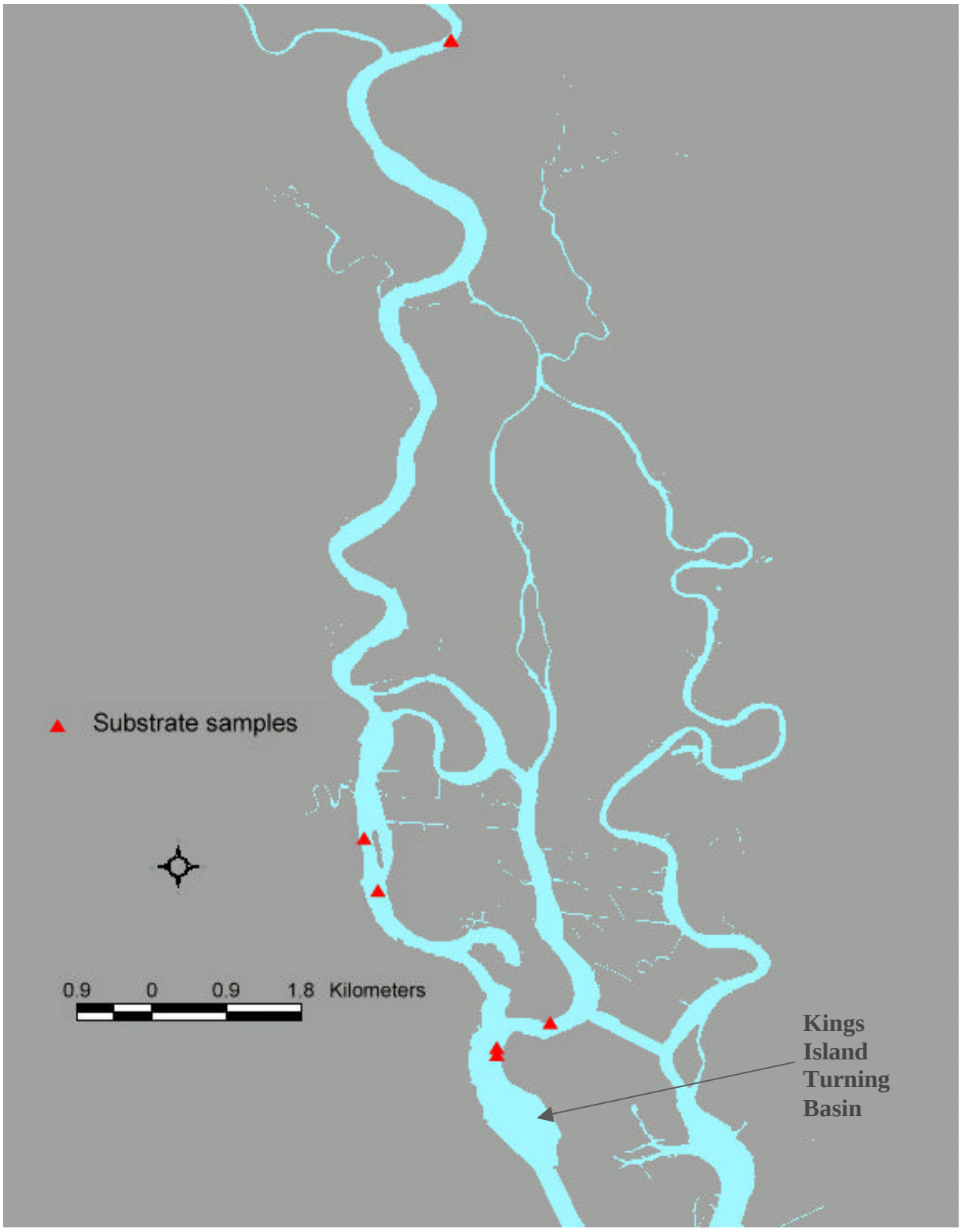
Conclusions

Telemetered shortnose sturgeon in the Savannah River exhibited obvious seasonal upriver/downriver migrations not associated with spawning. Juveniles and adults moved upriver during periods of warm (>22°C) water temperatures and downriver during periods of low water

temperatures. During warm months both adults and juveniles were concentrated in a very small (<1.5 km) section of the river, especially the segment rkm 46.5-47.5. During cool months both used the area just below Houlihan Bridge (~ rkm 34.3) down to the confluence of Front and Middle rivers (rkm 31.3), and during the coldest period they especially used the area at this confluence and up into the Middle River. During winter the juveniles were concentrated in a small, deep (7.9 m) area just inside the mouth of the Middle River. Water quality data suggest that the sill between this hole and the Front River may minimize salinity fluctuations associated with the tidal cycle. Adults were less concentrated than juveniles during winter. Adults were found in the Front River and appeared to wander extensively in the Middle River but were not found in the Back River. In addition, during December 2000 two adults were found as far downriver as rkm 5.5. This occurred just prior to project termination, so movements from there are unknown. One hypothesis as to why these two fish moved so far down relates to the possibility that these were stocked fish that were just reaching sexual maturity and had not imprinted on the river (spawning migration generally occurs in Dec.-Jan.) and were therefore emigrating (Smith et al., in press).

Previous studies conducted during 1985-1992 identified Kings Island Turning Basin as the nursery habitat for shortnose sturgeon juveniles. In the present study no juveniles were ever located as far downriver as the turning basin. This suggests that harbor modifications during the intervening period resulted in water quality changes that caused the fish to abandon the nursery area. The present nursery area is fragmented, with seasonal up/down river movement between two areas. Seasonal migration of juveniles had not previously been observed for southern populations. Depth-indicating transmitters indicated that these fish were demersal during both periods of residency and periods of migration (note that the transmitter error was +\- ~ 1.5 m).

Figure 15. Locations where substrate samples were taken.



Nominal ages of shortnose sturgeon were estimated as 2-12 years. Although the sample size was relatively small, the maximum age was much lower than that reported in previous studies. However, all of those studies were conducted with northern populations. The low maximum age supports the theory that the generation time of southern populations is shorter than that of those in the northern portion of the species' range; i.e., southern shortnose sturgeon grow faster, mature earlier, and die sooner than those in the north.

A separate study of adult shortnose sturgeon in the Savannah River, which temporally overlapped the present study, suggested that the number of adults in the river is much higher than in 1992. However, this is attributed to the stock enhancement program conducted by USFWS and SCDNR during 1985-1992 rather than to improved recruitment. The low catch/effort for juveniles in the present study was similar to that observed during 1990-1992, suggesting that a recruitment bottleneck still exists. A recent study that combined data from a number of sources in NC, SC, and GA concluded that there were two primary causes of the declines and extirpations of sturgeon populations in the southeast: bycatch mortality in shad and shrimp fisheries (adults), and water quality degradation in the nursery habitat (juveniles) (Collins et al. 2000).

In summary, juvenile shortnose sturgeon occupy habitats likely to be affected by the proposed harbor deepening during periods when bottom water temperatures are <22°C. The demersal nature of these fish makes them vulnerable to bottom water quality degradation and to direct mortality from dredging operations. Lack of increase in catch/effort relative to a previous study suggests no increase in recruitment over the past 8 years. Capture of now-mature fish stocked from a hatchery and an apparent increase in the number of adults in the river indicate that shortnose sturgeon stock enhancement can be successful, but stocking can be considered only as a stopgap measure unless recruitment bottlenecks are removed.

Acknowledgements

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