Movements of Gulf of Mexico Sturgeon in the Apalachicola River, Florida

John S. Odenkirk,[1] *U.S. Fish and Wildlife Service Field Office, 1612 June Avenue, Panama City, Florida 32405*

Abstract: A telemetry study was conducted in the Apalachicola River/estuary, Florida, to determine migratory behavior of anadromous Gulf of Mexico sturgeon. Ultrasonic (remote and mobile units) and radio telemetry gears were used to assess movements of sturgeon in both fresh and saltwater. Transmitter-equipped fish (N = 10) began fall migration between 22 September and 19 October 1987, and averaged 4.6 days to descend 152 km to the lower Apalachicola River where freshwater "staging areas" were utilized for periods of 0–20 days prior to moving into brackish river water. Three sturgeon continuously monitored during river exit spent 8–12 hours in brackish river water, apparently osmoregulating before making nocturnal exits to Apalachicola Bay. Ultrasonic monitoring was largely unsuccessful, although 3 sturgeon were tracked into saltwater and monitored in Apalachicola Bay for up to 4 hours. Ultrasonic remote sensors located in barrier island passes were partially functional and recorded sturgeon movement in West Pass. Seven of the radio-tagged sturgeon returned to the Apalachicola River in spring 1988. Smaller fish returned significantly earlier in the year than did larger ones.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 43:230–238

Gulf of Mexico sturgeon stocks have decreased in abundance in recent decades, resulting in their being Federally listed as a species of special concern (Wood 1988). Florida passed a moratorium on the taking of sturgeon in 1984. Although several studies have investigated Gulf of Mexico sturgeon biology (Huff 1975) and freshwater migratory patterns (Huff 1975, Wooley and Crateau 1982, Wooley and Crateau 1985), information concerning saltwater migrations is confined to limited tag returns from commercial trawling reported by Wooley and Crateau (1985). Although it is generally accepted that adult sturgeon leave Apalachicola Bay and enter the Gulf of Mexico to overwinter, overwintering locations and migration routes are unknown.

Analysis of Gulf of Mexico sturgeon movements requires integration of radio and ultrasonic telemetry techniques. Radio telemetry has been widely used to

[1]Present address: Virginia Department of Game and Inland Fisheries, 1320 Belman Road, Fredericksburg, VA 22401.

monitor movements of freshwater fishes (Winter 1977, Johnsen 1980, Buckley and Kynard 1985, Wooley and Crateau 1985, Hurley et al. 1987), and ultrasonic telemetry has proven effective for monitoring fish movements in both freshwater (Henderson et al. 1966, Johnsen and Hasler 1977, Coutant and Carroll 1980) and marine systems (Koo and Wilson 1972, Hawkins et al. 1980, Yeager 1982, McKibben and Nelson 1986). Trefethen (1956) discussed the versatility of the ultrasonic tag for use in both fresh and saltwater but noted a decreased range in turbulent or saline systems. In freshwater, it has been determined that radio transmitters are easier to locate than are their ultrasonic counterparts (Dudley et al. 1977, Moss 1985). However if submerged tracking in estuarine or marine environments is desired, an ultrasonic tag must be used.

In order to facilitate tracking of migrating anadromous Gulf of Mexico sturgeon (*Acipenser oxyrhynchus desotoi*), I employed a double tagging method—using both radio and ultrasonic tracking gear in addition to stationary ultrasonic remote sensors. My primary goal was to follow migrating sturgeon out of the Apalachicola River to locate their unknown winter habitat areas in Apalachicola Bay and/or the Gulf of Mexico. In addition, I investigated various migratory aspects of the sturgeon including swimming rates and dates of river exit in fall and entry in spring.

Assistance of members of the Apalachicola River and Bay Research Preserve is gratefully acknowledged. All members of the Panama City Field Office contributed to this study, and this paper would not have been possible without them. Finally, sincere thanks goes out to all those who reviewed this manuscript for their time and editorial comments.

Methods

This study was conducted in Florida on the Apalachicola River and estuary. The Apalachicola River originates at the junction of the Flint and Chattahoochee Rivers just north of the Florida-Georgia state line and drains an area of about 2,600 km^2. The only dam on the 171.4 km long river, the Jim Woodruff Lock and Dam (JWLD), is located at the Apalachicola River headwaters and impounds 15,175-ha Lake Seminole (Barkuloo et al. 1987).

The Apalachicola Bay estuary covers 62,879 ha (Barkuloo et al. 1987) and is relatively shallow, averaging 2 to 3 m in depth (Livingston 1983). The bay is bounded by a series of barrier islands that are separated by 4 natural openings to the Gulf of Mexico. An additional man-made opening (Sike's Cut) was established in the mid 1950s (Fig. 1). Tides in Apalachicola Bay are diurnal to semidiurnal and usually range from 0.13 to 0.23 m (Livingston 1984).

For the purpose of this paper, the term "lower river" refers to the length of the Apalachicola River, including its tributaries and distributaries, from its mouth (river kilometer (rkm) 0.0) upriver to the mouth of the Brothers River at rkm 19.4. The Brothers River has been identified as an important fall pre-migration sturgeon "staging area" by Wooley and Crateau (1985). Saltwater intrusion during fall months rarely occurs above rkm 9.7.

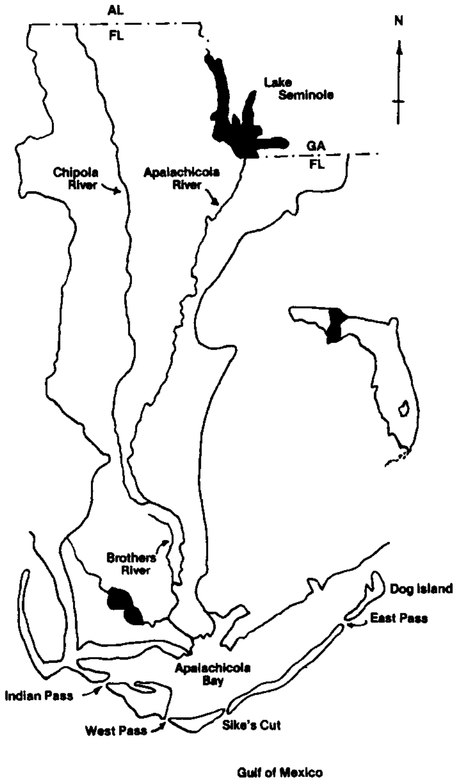

Figure 1. The Apalachicola River and bay system.

Ten Gulf of Mexico sturgeon were captured and equipped with transmitters for the study. Eight sturgeon were captured between May and September 1987 with 7.6- to 25.4-mm stretched mesh sinking monofilament gill nets set in the stilling basin immediately below JWLD. An additional 2 sturgeon were netted in the Brothers River in November 1987 during their fall migration to the Gulf of Mexico. Following capture, the sturgeon were measured, weighed and implanted with 4 Floy "t-tags" in the pectoral and pelvic fins. Seven sturgeon were then tagged with a radio transmitter and an ultrasonic transmitter (double tagged), and 3 others were given only radio tags. Radio transmitters were supplied by Advanced Telemetry Systems, Inc., Isanti, Minn., and operated at 40 MHz with a life expectancy of 24 months. Ultrasonic tags from Sonotronics (Tucson, Ariz.) broadcast at 75 KHz and had a life expectancy of 14 months. Radio and ultrasonic tags were cylindrical and had an air weight of 54 and 42 g, respectively. Sturgeon tagged with transmitters weighed from 28.1 to 69.4 kg (mean = 45.7 ± 15.8 SD) and were from 1,650 to 2,083 mm (mean = 1,892 ± 167 SD) in total length.

Transmitters were applied externally by a method similar to that described by Wooley and Crateau (1985). Braided monel wire was passed through holes drilled in the sturgeon's fourth and fifth dorsal scutes and pre-drilled holes in the resin coating of the transmitters, pulled tight, and secured with stainless steel sleeves. Individual sturgeon were identified by either a radio frequency (0.010 MHz spacing) on a radio scanning receiver or by a unique series of signals on a single frequency on an ultrasonic receiver.

Tracking of Gulf of Mexico sturgeon in 1987 was divided into 3 phases. In phase I of the program, sturgeon occupied summer habitat areas in the upper portions of the Apalachicola River, and positions were verified at least every other day to determine initiation of downriver migration. The onset of migration initiated Phase II of the tracking program, which involved monitoring departure dates and downriver movement of sturgeon until they reached the lower river. During this time, telemetry observations were made at least 5 times weekly. Continual tracking was initiated in phase III of the operation when fish were in or below fall "staging" areas (Wooley and Crateau 1985) located near rkm 19. Because heavier, older sturgeon had completed several migrations and would probably yield the greatest insight regarding migration routes, sturgeon were prioritized on a weight basis regarding their desirability for tracking. The heaviest double-tagged sturgeon was located first, and if contact was lost, the next largest fish was tracked.

Mobile tracking was conducted from 2 4.9-m open-cockpit fiberglass vessels. All boats were equipped with LORAN-C and VHF marine radios to facilitate determination of location while tracking sturgeon in open water. Water temperatures and salinities (surface and bottom) were taken frequently (at all new locations or every half hour) with a YSI Model 33 salinity meter.

Remote ultrasonic sensors were installed in abandoned navigational markers located in East, West, and Indian passes to monitor lost contacts and to evaluate the use of barrier island passes. Other channels to open Gulf waters were precluded from the study due to shallowness and excessive width (north of Dog Island) and recent construction (Sike's Cut).

Ultrasonic remote sensors consisted of a model USR–6 Smart 1 receiver (Sonotronics; Tucson, Ariz.) wired to a cassette tape recorder. These components were powered by a 12-v car battery, and the entire system was enclosed in a 0.61 m^2 galvanized weather-sealed metal box. The box was attached to an abandoned navigational structure approximately 1 m above high-tide elevation. A hydrophone was mounted on a steel pipe which was attached to a submerged piling on the structure. The Smart 1 scanning receivers were internally programmed and supplied with 24-hour clocks. Tape recorders were activated by passing tagged sturgeon and tag identity and passage times were recorded.

During winter months, lower portions of the Apalachicola River system were monitored weekly to determine if any tagged sturgeon had remained in freshwater. Beginning March 1988, radio telemetry observations were conducted at least every other day by boat or airplane to document river entry dates of returning radio-tagged fish.

Data were analyzed using the Statistical Analysis System (SAS) PC Version 6.03 on an IBM PC AT. Linear regression procedures were used to examine the relationships between several aspects of migratory behavior. A probability value of 0.05 was employed to detect significance in all statistical tests.

Results

Telemetry Equipment Performance

During field operations with telemetry equipment, several problems were encountered with the ultrasonic equipment. Initially, remote sensor sensitivity was so high that even slight noises such as dolphins, snapping shrimp, croakers, grunts, and boat engines caused units to function, thereby quickly using all available recording tape. This condition was alleviated to some extent by rheostats, but adjustment was time consuming and range (approximately 1.0 km when set most sensitively) was sacrificed to delete extraneous marine sound. In addition, barnacles formed on the hydrophones, further reducing sensitivity. Finally, wave action demolished 2 hydrophones and currents often generated sufficient noise to activate remotes and completely mask all other sounds.

Mobile ultrasonic receivers exhibited similar problems. Furthermore, electronic testing conducted after the study revealed that transmitter tags were highly directional instead of omnidirectional as was originally believed. This seriously inhibited open water tracking.

Effective range of radio transmitters was at least 0.8 km and frequently over 1.5 km. In contrast, signal strength from ultrasonic transmitters depended upon the orientation of the tagged sturgeon and was usually between 0.3 and 0.8 km.

Fall Sturgeon Migration

Eight Gulf of Mexico sturgeon were monitored during phase I of the tracking program (the remaining 2 sturgeon were captured in the lower river later in the program). Initial departures from summer habitat area below JWLD during 1987 were as follows: 22 September, surface water temperature 27.8° C, 1 sturgeon; 14 October, water temperature 19.5° C, 5 sturgeon; 19 October, water temperature 20.0° C, 2 sturgeon. Transmitter-tagged sturgeon weight and onset of fall migration were not significantly related ($r^2 = 0.06$; $P > 0.55$).

Phase II tracking indicated that the first radio-tagged sturgeon to leave JWLD took 28 days to reach the lower river. The remaining 7 fish averaged 4.6 days to cover the 150.4 rkm to the lower river and swam at an approximate rate of 32.7 km/day.

No significant relationship existed between time of descent (days) of transmitter-tagged sturgeon and body weight ($r^2 = 0.06$; $P > 0.57$). Tagged sturgeon occupied freshwater portions of the lower river for periods up to 20 days before entering brackish water. In most cases, this time was spent in deeper portions of the Brothers River identified as a fall staging area by Wooley and Crateau (1985).

Phase III of the tracking program was initiated on 29 October and lasted until 11 November 1987. Three double-tagged sturgeon (weight range = 33–66 kg) were successfully monitored throughout their lower river descent, across the saltwater interface, and into Apalachicola Bay. No sturgeon were successfully tracked completely through Apalachicola Bay and into the Gulf of Mexico; however, 1 sturgeon did activate a remote sensor in West Pass, although extended mobile tracking had been unsuccessful.

The 3 sturgeon monitored continuously during their movements from Apalachicola River to Apalachicola Bay generally behaved in a similar manner. The sturgeon entered the bay between 31 October and 10 November 1987. Each fish, after passing through the saltwater interface near rkm 5.0 approached the river's mouth and began to swim up and downriver erratically, never moving more than 0.5 km in either direction and remaining in brackish river water (salinities < 3.0 ppt) for periods ranging from 8 to 12 hours (mean = 10.2 hours) before entering the bay.

Salinities and temperatures taken at rkm 0.0 during river exit ranged between 3.5–7.0 ppt and 17.5°–19.5° C at the surface and 14.0–17.5 ppt and 18.5°–19.0° C at the bottom. Tagged sturgeon exited the river at 0130, 2215 and 0540 hours.

Two of the 3 sturgeon monitored were lost within 1 hour after entering the open water of Apalachicola Bay. In both cases signal loss was attributed to nearby commercial fishing vessels and associated subsurface engine sounds which obliterated ultrasonic tag signals. Before signal loss, sturgeon traveled approximately 1 km southward along an intracoastal waterway channel at a depth of approximately 3 m. The remaining sturgeon was tracked on an erratic southwesterly course for 4 hours in water 2.0 to 2.7 m deep to a point approximately 5 km southwest of the river mouth. Twenty hours after contact was lost, this sturgeon activated a remote sensor in West Pass for a period of 21 minutes. No data were obtained from the remaining 4 double tagged sturgeon, and no transmissions from any of the 10 transmitter equipped sturgeon were received between 11 November 1987 and 10 March 1988.

Spring Sturgeon Migration

Seven of the 10 transmitter-equipped sturgeon returned to the Apalachicola River between 11 March and 20 April 1988. The date of river entry was positively related with fish size ($r^2 = 0.85$; $P < 0.003$). Tagged fish did not linger in the vicinity of the salt/freshwater interface but moved steadily upstream at the approximate rate of 10 km/day.

Discussion

Results of this study confirm that Gulf of Mexico sturgeon in the Apalachicola River system are anadromous, migrating to the saline waters of the Bay and/or Gulf to overwinter and returning to the river in spring. Freshwater migration of the sturgeon observed in the present study was comparable to that reported by Wooley and Crateau (1985). Downstream migrations were initiated from 30 September - 6 November (surface water temperature = 23.0°–20.5° C) in 1983 (Wooley and Crateau 1982) and occurred from 22 September – 19 October (surface water temperatures = 27.8°–20.0° C) in 1987 (present study). Swimming rates of transmitter equipped fish were 24.3 km/day and 20.5 km/day, respectively. In both studies, sturgeon used freshwater "staging areas" in the Brothers River for periods up to 24 days (20 days in present study) prior to moving into saline areas of the lower Apalachicola River. The extended period of residence (8–12 hours) in river waters of low salinity before river exit suggest a period of osmoregulatory adjustment. Wooley and Crateau (1982) suggested that during this period sturgeon were awaiting environmental cues before moving out into Apalachicola Bay. In the present study, 2 sturgeon exited the river at night during an incoming tide, while the third fish exited just prior to dawn during an outgoing tide.

After entering Apalachicola Bay all 3 sturgeon apparently used the intracoastal waterway channel until they encountered depths >2 m. Based on observed swimming directions, it appeared that bay exit would occur either through Sike's Cut or West Pass. Exit through Sike's Cut, a recently constructed pass <5 m deep, was not considered likely. West Pass, the deepest of all Apalachicola Bay passes, has a maximum depth of nearly 16 m and was the only pass of the three monitored where sturgeon movement was recorded.

Net water current patterns in the Apalachicola estuary move to the west, and West Pass appears to be a major outlet for the discharge of estuarine water to the Gulf (Livingston 1984). Wooley and Crateau (1985) reported 3 sturgeon tag returns from sturgeon captured in shrimp trawls in the Gulf. Two of these returns were outside Indian Pass, while the other occurred a short distance southeast of West Pass. It appears then that sturgeon migrating from Apalachicola Bay to the Gulf of Mexico follow prevailing currents and exit through the 2 western-most passes (Indian and West passes).

Although no data were found indicating that sturgeon migrating into the river during March and April 1988 paused to osmoregulate, it seems likely that at least a short period of adjustment was necessary. This inconsistency with fall migratory behavior may be partially explained by spring flooding. Water quality sampling indicated that freshwater extended well out into the bay where sturgeon possibly "staged" and were not detected during survey flights.

The spring arrival of smaller fish before larger individuals may have been due to sexual differences. It is quite common for smaller male sturgeon to precede larger females on spring migrations (Parauka, U.S. Fish and Wildl. Serv., personal commun.). Additionally, most of the larger fish examined by Huff (1978) were female.

Because of the inability of the ultrasonic tracking equipment to monitor sturgeon movements, location(s) of overwintering sites are still unknown. Further research is needed to document Gulf of Mexico sturgeon marine migration routes and to determine if critical overwintering habitat exists in the Gulf of Mexico. Ultrasonic equipment currently available to fisheries workers greatly reduces the capability of extended marine tracking. The double tagging method described herein has the potential to be an excellent methodology for investigating migration of large anadromous fish, especially when remote sensors are used, but the potential is currently limited due to technological constraints. It is hoped that improvements in future gear design will permit tracking of anadromous fish in marine and estuarine waters.

Literature Cited

Barkuloo, J. M., L. Patrick, L. Stith and W. J. Troxel. 1987. Natural resources inventory Apalachicola-Chattahoochee-Flint River basin. U.S. Fish and Wildl. Serv, Field Off. Panama City, Fla. 154pp.

Buckley, J., and B. Kynard. 1985. Yearly movements of shortnose sturgeons in the Connecticut River. Trans. Am. Fish. Soc. 114:813–820.

Coutant, C. C., and D. S. Carroll. 1980. Temperatures occupied by ten ultrasonic-tagged striped bass in freshwater lakes. Trans. Am. Fish. Soc. 109:195–202.

Dudley, R. G., A. W. Mullis and J. W. Terrell. 1977. Movements of adult striped bass (*Morone saxatilis*) in the Savannah River, Georgia. Trans. Am. Fish. Soc. 106:314–322.

Hawkins, A. D., G. G. Urquhart and G. W. Smith. 1980. Ultrasonic tracking of juvenile cod by means of a large spaced hydrophone array. Pages 461–469 *in* Amlaner, D. J., Jr. and D. W. MacDonald, eds. A handbook of biotelemetry and radio tracking. Pergamon Press, N.Y. 804pp.

Henderson, H. F., A. D. Hasler and G. C. Chipman. 1966. An ultrasonic transmitter for use in studies of movements of fishes. Trans. Am. Fish. Soc. 95:350–356.

Huff, J. A. 1975. Life history of the Gulf of Mexico sturgeon *Acipenser oxyrhynchus desotoi* in the Suwannee River, Florida. Mar. Resour. Pub. 16. Fla. Dep. Nat. Resour. St. Petersburg, Fla.

Hurley, S. T., W. A. Hubert and J. G. Nickum. 1987. Habitats and movements of shovelnose sturgeons in the upper Mississippi River. Trans. Am. Fish. Soc. 116:655–662.

Johnsen, P. B. 1980. The movements of migrating salmonids in the vicinity of a heated effluent determined by a temperature and pressure sensing radio telemetry system. Pages 781–783 *in* Amlaner, D. J., Jr. and D. W. MacDonald, eds. A handbook of biotelemetry and radio tracking. Pergamon Press, N.Y. 804pp.

———, and A. D. Hasler. 1977. Winter aggregations of carp (*Cyprinus carpio*) as revealed by ultrasonic tracking. Trans. Am. Fish. Soc. 106:556–559.

Koo, Ted S. Y., and J. S. Wilson. 1972. Sonic tracking striped bass in the Chesapeake and Delaware Canal. Trans. Am. Fish. Soc. 101:453–462.

Livingston, R. J. 1983. Resource atlas of the Apalachicola estuary. Fla. Sea Grant College. Pub. 55. 64pp.

———. 1984. The ecology of the Apalachicola Bay system: an estuarine profile. U.S. Fish and Wildl. Serv., Washington, D.C. FWS/OBS 82/05. 148pp.

McKibben, J. N. and D. R. Nelson. 1986. Patterns of movement and grouping of gray reef sharks, *Carcharhinus amblyrhynchos,* at Enewetak, Marshall Islands. Bul. Mar. Sci. 38:89–110.

Moss, J. L. 1985. Summer selection of thermal refuges by striped bass in Alabama reservoirs and tailwaters. Trans. Am. Fish. Soc. 114:77–83.

Trefethen, P. S. 1956. Sonic equipment for tracking individual fish. U.S. Fish and Wildl. Serv., Spec. Sci. Rep., Fisheries 179:1–11.

Winter, J. D. 1977. Summer home range and habitat use by four largemouth bass in Mary Lake, Minnesota. Trans. Am. Fish. Soc. 106:323–330.

Wood, D. A. 1988. Official lists of endangered and potentially endangered fauna and flora in Florida. Fla. Game and Fresh Water Fish Comm., Tallahassee. Pub. GCF 88/9-022. 19pp.

Wooley, C. M., and E. J. Crateau. 1982. Observations of Gulf of Mexico sturgeon

(*Acipenser oxyrhynchus desotoi*) in the Apalachicola River, Florida. Fla. Sci. 45:244–248.

——— and ———. 1985. Movement, microhabitat, exploitation, and management of Gulf of Mexico sturgeon, Apalachicola River, Florida. N. Am. J. Fish. Manage. 5:590–605.

Yeager, D. M. 1982. Ultrasonic telemetry of striped bass and white bass hybrids in the Escambia River, Florida. Proc. Annu. Conf. Southeast. Assoc. Fish and Wild. Agencies 36:62–73.