Movement and Habitat Use of Subadult Gulf Sturgeon in Choctawhatchee Bay, Florida

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Abstract: The Gulf sturgeon *(Acipenser oxyrinchus desotoi)* is a threatened anadromous species in the Gulf of Mexico. Nineteen subadult Gulf sturgeon were equipped with ultrasonic transmitters (34–40 kHz) in the Choctawhatchee River and Bay during fall 1996 and 1997 before their entry into marine habitat. The movement and habitat use of Gulf sturgeon in the estuarine/marine environment was determined from November through April 1996–1999. A total of 344 sonic contacts were made in this study. We documented fish location using a GPS and recorded water depth, temperature, salinity, substrate type, and distance from shore. Subadult Gulf sturgeon migration from the freshwater riverine system to the marine system was influenced by an increase in river flow and a decrease in water temperature. Fish moved throughout Choctawhatchee Bay, but mostly used shoreline areas. The use of 5 geographic areas by 95% of telemetered Gulf sturgeon may be linked to food availability. Gulf sturgeon overwintered for 5–6 months from November through April in Choctawhatchee Bay, Santa Rosa Sound, and Pensacola Bay. After overwintering in Choctawhatchee Bay, telemetered subadults returned back to the Choctawhatchee River in late April through May when mean water temperatures ranged from 18 to 25 C. Several telemetered fish were relocated in the Muddy Lake area of the river and remained there for several days before downstream or upstream migration.

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The Atlantic sturgeon *(Acipenser oxyrinchus)* consists of 2 subspecies, the Gulf sturgeon *(A. oxyrinchus desotoi)* and the Atlantic sturgeon *(A. oxyrinchus oxyrinchus)* (Vladykov 1955). The Gulf sturgeon occurs in most river systems of the northern Gulf of Mexico from the mouth of the Mississippi River to the west coast of peninsular Florida, as far south as Tampa Bay (Wooley and Crateau 1985). The

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anadromous Gulf sturgeon uses coastal rivers from early spring through late fall and resides in estuarine and marine habitats in the Gulf of Mexico during winter (Huff 1975).

Abundance of Gulf sturgeon has decreased substantially from historical levels due to over exploitation, habitat loss due to dams, unregulated harvesting, and water pollution (Livingston et al. 1974, U.S. Army Corps Eng. 1978, U.S. Fish and Wildl. Serv., Gulf States Mar. Fish. Comm., and Natl. Mar. Fish. Serv. 1995). The Gulf sturgeon was listed in 1991 as "threatened" under the Endangered Species Act.

The Gulf Sturgeon Recovery/Management Plan recommends the use of ultrasonic telemetry to monitor Gulf sturgeon movements in estuarine and marine waters where most feeding and growth occurs (Mason and Clugston 1993). Once estuarine and marine distribution patterns have been characterized, subsequent studies can better define essential habitat requirements (U.S. Fish and Wildl. Serv., Guf States Mar. Fish. Comm., and Natl. Mar. Fish. Serv. 1995)1995).

The small amount of information known about the location of Gulf sturgeon overwintering habitats comes primarily from by-catch records of anglers (Wooley and Crateau 1985). Odenkirk (1989) noted that Gulf sturgeon left Apalachicola Bay during fall and over wintered in the Gulf of Mexico, but little information supported this hypothesis. Except for the Suwannee River, Florida (Huff 1975, Foster 1993, Mason and Clugston 1993, Carr et al. 1996, Foster and Clugston 1997, Sulak and Clugston 1999), the Apalachicola River, Florida (Wooley and Crateau 1985, Odenkirk 1989), the Pascagoula River, Mississippi (Murphy and Skaines 1994, Slack and Ross 1998, Heise et al. 1999*a*, 1999*b*), and the Pearl River, Mississippi and Louisiana (Knight 1996, Morrow et al. 1998), limited data existed on the timing of out migration of other Gulf sturgeon populations. Our study objectives were to determine habitat use and movement of subadult Gulf sturgeon during overwintering periods in marine waters.

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Methods

Study Area

Choctawhatchee Bay covers approximately 335 km^2 with average water depths ranging from 2–3 m (eastern portion) to 9–13 m (western portion). The primary (95%) freshwater input to the bay is the Choctawhatchee River (Fig. 1), which drains a watershed approximately 12,033 km^2 in southeast Alabama and northwest Florida (Goldsmith 1966, U.S. Fish and Wildl. Serv. 1991) and the primary marine input from the Gulf of Mexico is through East Pass at Destin, Florida. This entrance was created in 1929 and has been maintained by periodic dredging by the U.S. Army Corps of Engineers. Besides the main entrance, entrances to the bay at both east and west ends via the Intercoastal waterways also have been maintained by the U.S. Army Corps of Engineers.

Choctawhatchee Bay is characterized by fine sediments with high organic con-

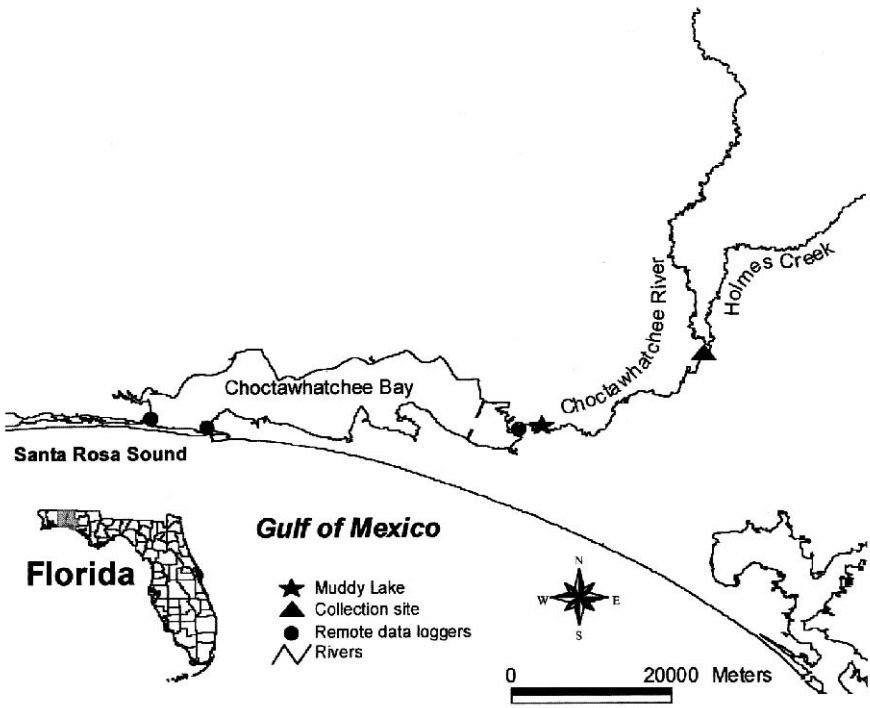

Figure 1. Location of the study area and remote data loggers used to detect movement of telemetered subadult Gulf sturgeon in the lower Choctawhatchee River and passage through Destin Pass and Santa Rosa Sound. Gulf sturgeon collection site and Muddy Lake staging area on the Choctawhatchee River are also shown.

tent. In the bay, the shelf-slope margin, the river mouth, and the western end are characterized by coarse sediments. Fine, organically-laden sediments, are found in the deeper basins of the bay (Livingston 1986, 1987, U.S. Dep. Agric. 1993). The 2 species of seagrasses, *Halodule wrightii* and *Ruppia maritima*, are concentrated in the western section of the bay and grow primarily at depths of 1–2 m (Burch 1983).

Fish Capture, Handling, and Tagging

Gulf sturgeon were collected during fall in the Choctawhatchee River about 50 river kilometers upriver from the bay (Fig. 1) using drift and fixed mono- and multifilament gill nets of 2.5–3.7 m depth and 30.5–45.7 m lengths. Stretched mesh sizes ranged from 7.6 cm to 22.9 cm. Average soak time for set nets was 1.5 hours. Fish were measured for total length (TL), fork length (FL) to the nearest 0.5 cm, and weighed to the nearest 0.1 kg with a spring scale. All fish were tagged with 4 external Floy T-bar tags (Floy FD-67 T-bar, Floy Tag, Seattle, Wash., with a Dennison Tag Fast II fastener gun with tags) inserted in each pectoral and pelvic fin rays, and 1 internal Passive Integrated Transponder (PIT) tag (12 mm, Biomark, Boise, Idaho) injected in the fleshy area at the base of the dorsal fin. Commercial ultrasonic tags (34.00 to 40.00 kHz, Sonotronics, Tucson, Ariz., models CT-82-2, CT-82-3, and CHP-87-L) were externally attached at the base of the dorsal fin as described by Carr et al. (1996). A sharp ice pick was used to penetrate the tissue to provide a path for tag attachment. Monel wire (45 kg strength) was threaded through the tag and the holes in the tissue and braided on the opposite side of the dorsal fin. No backing plate was used on the braided side of the dorsal fin. The ultrasonic tags weighed from 5 to 12 g and had an expected battery life of 12 to 18 months. A topical antibiotic ointment (Neosporium) was placed on the dorsal fin entry and exit wounds. Each fish was tagged upon capture and released immediately at the capture site. The fish were monitored periodically for at least 30 minutes after release.

Tracking

Fish were tracked with a portable digital receiver (Sonotronics USR-5W) and a directional hydrophone (Sonotronics DH-4). To aid in the detection of Gulf sturgeon movement into and out of Choctawhatchee Bay, remote monitoring sites were established at the entrances to East Pass and Santa Rosa Sound (Fig. 1) during November 1997 to May 1998 and November 1998 to May 1999. The monitoring system consisted of an automatic scanning receiver (Sonotronics USR-90), directional hydrophone (DH-4), and data logging system (DL-95, HP 1000CX 1-MB palmtop PC) powered by a 12-volt deep cycle battery. The data logging system recorded the frequency and pulse interval of the ultrasonic tag and logged the time and date when the tagged fish passed the monitoring site. Data were stored in ASCII files and exported by using a PCMCI SRAM memory card. An additional remote monitoring site was maintained in the lower portion of the Choctawhatchee River (Fig. 1) to document timing of migration to the bay during October and November 1997 and 1998. The re-

mote monitoring systems were checked weekly for maintenance and to download data.

Choctawhatchee Bay was divided into 1.5-km^2 areas and tracking routes were mapped out to stop at 1- to 3-km intervals to listen for telemetered fish. Depending on sea conditions, the bay was searched bi-weekly from November 1996 to April 1997, weekly from November 1997 to May 1998, and bi-weekly from November 1998 to May 1999. Periodic searches were conducted in Santa Rosa Sound and the Gulf of Mexico. The Florida Marine Research Institute, as part of an ongoing fishery investigation project, monitored for telemetered Gulf sturgeon at fixed sampling locations in Choctawhatchee Bay and Santa Rosa Sound from November 1996 to May 1997. Also, in a companion study, biologists from the Florida Department of Environmental Protection (DEP) conducted bi-weekly searches in Santa Rosa Sound and Escambia Bay from November 1997 to May 1998 and October 1998 to November 1999.

Coordinates of telemetered fish were recorded using a hand-held Geographical Positioning System (GPS; Magellan Meridian XL, 25-m or better accuracy, Magellan Systems Corp., San Dimas, Calif.). The distance from shore was estimated for each fish location. Depth (m) was recorded using a digital depth sounder (Fish Ray 100 with accuracy to 15 cm by Aquatic Ecosystems, Apopka, Fla.). Water temperature and salinity were measured at surface and bottom with YSI Model 55 and YSI Model 33 S-C-T meters. Substrate samples were collected with either a Petite or standard PONAR sampler. Substrate type was categorized as mud, silt, or sand, and the presence or absence of any potential prey items were noted.

Data Analysis

The timings of fish movements were compared with river flows (U.S. Geol. Surv. 2001), water temperature, salinity, and depth to examine the effects of these variables on fish behavior. Fish age was determined from fish length as described by Huff (1975) and Jenkins (unpubl. data). Use of geographic areas in Choctawhatchee Bay was determined by percentages of telemetered fish relocations. Linear regression was used to examine the relationships between weight and length of tagged fish. An αlevel of 0.05 was employed to determine significance in all statistical tests.

Results

Tagging

Nineteen subadult Gulf sturgeon were fitted with external ultrasonic tags in the lower Choctawhatchee River, including 6 (weighing from 5.5 kg to 18.9 kg) collected from September through November 1996 and 13 (weighing from 4.2 kg to 20.0 kg) collected from September through October 1997 (Table 1). Four-year-old Gulf sturgeon averaged 5.7 kg in weight while fish ages 5 to 7 averaged 11.7 kg to 17.5 kg in weight (Table 2). There was a strong correlation ($r^2 = 0.93$) between length (cm) and weight (kg) for subadult Gulf sturgeon (Fig. 2).

Table 1. Catch statistics and duration of tracking for subadult Gulf sturgeon in Choctawhatchee Bay, Florida.

Fish No.	Age (years)	Total length (cm)	Weight (kg)	Date tagged (d/m/y)	Date ended[a] (d/m/y)	Tag life (months)	Days out	Contacts (*N*)
1	4	104	5.5	07/11/1996	28/03/1997	14	141	10
2	4	104	5.9	05/11/1996	11/03/1997	14	116	5
3	5	129	12.6	26/09/1996	12/05/1998	18	592	25
4	6	135	12.7	09/10/1996	18/03/1998	18	515	26
5	7	146	16.4	26/09/1996	28/03/1997	18	179	11
6	7	150	18.9	26/09/1996	28/03/1997	18	179	5
7	4	95	4.2	25/09/1997	06/03/1998	12	132	12
8	4	98	4.2	08/10/1997	05/05/1998	14	208	15
9	4	104	5.3	25/09/1997	23/04/1998	12	209	17
10	4	109	7.5	23/09/1997	02/04/1999	14	555	40
11	4	116	7.3	02/10/1997	28/04/1998	14	207	16
12	5	112	11.2	15/10/1997	28/02/1998	14	106	10
13	5	116	12.0	02/10/1997	17/11/1998	18	380	8
14	5	124	10.9	23/09/1997	24/03/1999	14	552	21
15	6	135	13.4	18/09/1997	06/04/1999	14	570	39
16	6	137	14.1	25/09/1997	04/05/1998	18	220	21
17	7	142	16.2	02/10/1997	06/03/1999	18	530	35
18	7	147	16.2	02/10/1997	23/12/1998	18	456	19
19	7	148	20.0	15/10/1997	01/05/1998	14	197	9

a. Date when last located in Choctawhatchee Bay.

Table 2. Mean (SE) total length (cm) and weight (kg) of subadult Gulf sturgeon at various age groups.

Age (years)	*N*	Total length (cm) $\bar{x}$(SE)	Weight (kg) $\bar{x}$(SE)
4	7	104 (2.61)	5.7 (0.50)
5	4	120 (3.84)	11.7 (0.38)
6	3	136 (0.67)	13.4 (0.40)
7	5	147 (1.33)	17.5 (0.80)

Fall 1996 Downstream Migration

Telemetered Gulf sturgeon migrated downstream from the collection site during the second week in October when water temperature was 20 C. The new moon appeared on 12 October. Two age-7 fish (No.'s 5 and 6) moved 10 rkm downstream to Muddy Lake where depths ranged from 6.2 m to 8.1 m and substrate was coarse sand (Fig. 1). No salinity was detected during the period of fish residency and water temperatures ranged from 18.3 C to 22.2 C. The fish remained in Muddy Lake for 2 weeks prior to entering Choctawhatchee Bay. A total of 45 relocations were recorded for 6 Gulf sturgeon from November 1996 through March 1997 during 17 tracking events. The daily discharge of the Choctawhatchee River measured at Bruce, Florida

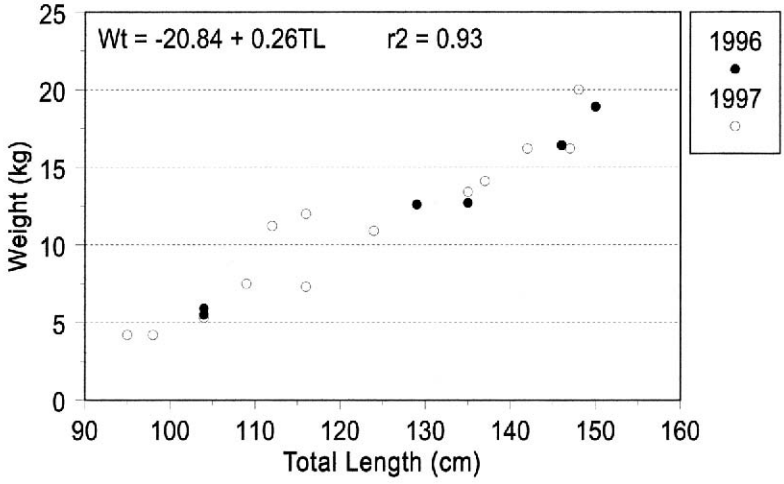

Figure 2. Relationship between weight and total length of subadult Gulf sturgeon.

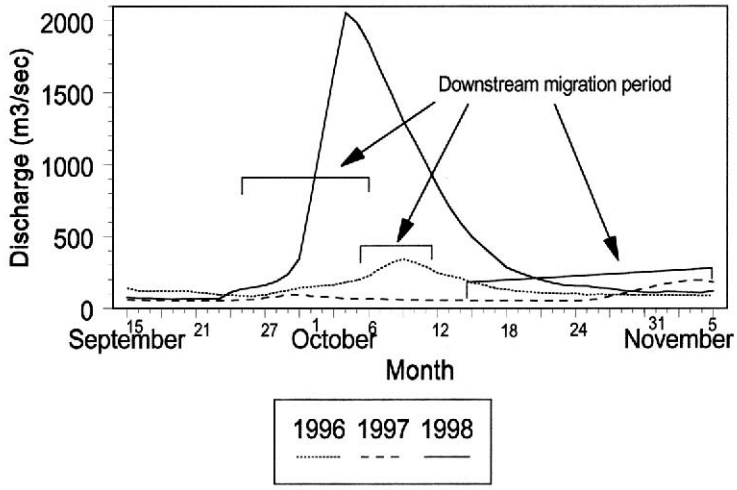

Figure 3. Choctawhatchee River discharge 1996–1998 and telemetered subadult Gulf sturgeon movement from the Choctawhatchee River to the bay, 1996–1998.

(about 10 rkm downstream from the fall Gulf sturgeon capture location), was 158 m^3/second on 1 October 1996 and increased to 363 m^3/second on 9 October 1996 (Fig. 3) and steadily decreased to 95 m^3/sec on 31 October 1996 (U.S. Geol. Surv. 2001).

1996–97 Overwintering

Upon entering Choctawhatchee Bay, movements of the 6 Gulf sturgeon were segregated according to age. Two age-4 fish (No.'s 1 and 2) occupied the north shore of Choctawhatchee Bay and moved 11 km and 19 km, respectively, east to west from the mouth of Choctawhatchee River. Fish ≥5 years (No.'s 3, 4, 5, and 6) occupied the south shore of Choctawhatchee Bay. The age-5 fish (No. 3) moved 17.5 km to the west, the age-6 fish (No. 4) was relocated 92 km to the west in Santa Rosa Sound (Fig. 4) and 1 age-7 fish (No. 5) was found 26 km west of the river mouth. The other age-7 fish (No. 6) was relocated 38 km west of the river mouth at Destin Pass on 12 December 1996 and again in the western portion of Choctawhatchee Bay on 28 March 1997. During this 115-day period, the entire bay was searched on numerous occasions and several short searches (1 to 5 km) were conducted along the east and

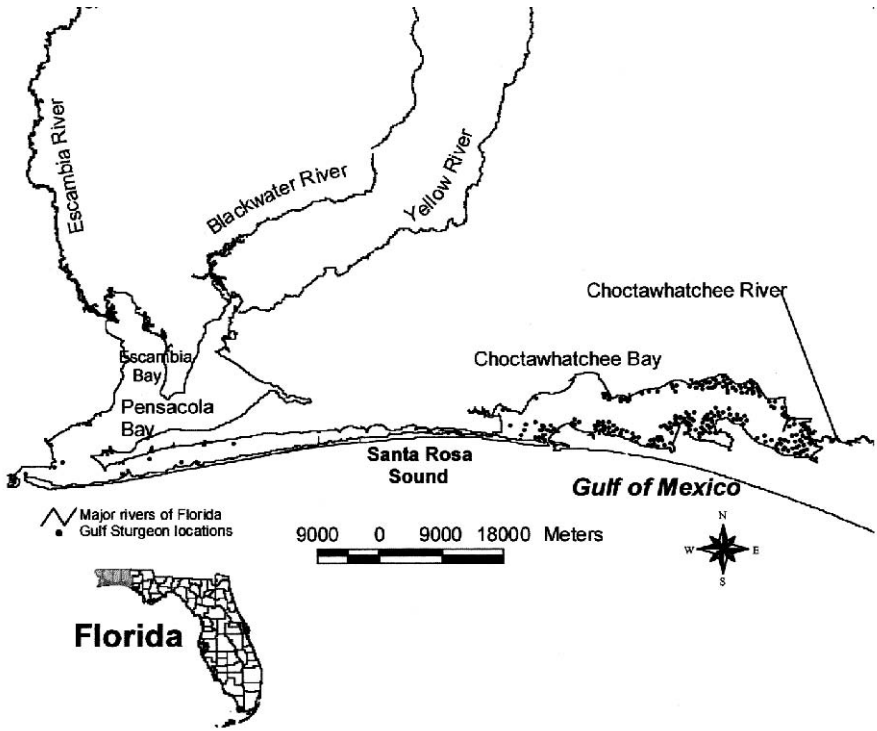

Figure 4. Relocation sites of telemetered subadult Gulf sturgeon within Choctawhatchee Bay and adjacent estuarine and marine waters from 1996 to 1999.

west shoreline in the Gulf of Mexico. We suspect that fish No. 6 may have departed the bay and spent time in the Gulf of Mexico.

Telemetered Gulf sturgeon were found consistently along both shorelines in Choctawhatchee Bay at depths of 1.5 m to 3 m and 100 m to 1 km from shore. Both shorelines consist of mostly sand mixed with shell along with pockets of mud. Amphipods *(Lepidactylus sp.)* were noted in the substrate samples. The age ≥5 fish (No.'s 3, 4, 5, and 6) were relocated periodically in the western part of Choctawhatchee Bay at depths up to 10.5 m. Water temperature in Choctawhatchee Bay ranged from 7.6 C during the latter part of January 1996 to 23.0 C in late March 1997. The bottom salinity ranged from 0.1 ppt to 25.0 ppt in the northeastern portion of East Bay and ranged from 8.5 ppt to 33.3 ppt in the western portion, near Destin Pass. Salinity was 24.5 ppt in 1997 when fish No. 4 was recorded in Santa Rosa Sound.

Spring 1997 Upstream Migration

All tagged fish returned to the Choctawhatchee River between 23 March and 30 April 1997. The new moon occurred on 6 April 1997. Fish No.'s 1 and 2 were relocated in the lower river (Muddy Lake) during the second and third week in April and water temperature in the river ranging from 20.0 to 22.0 C. These fish remained in the area for about 2 weeks before moving upstream. The daily discharge of the Choctawhatchee River recorded at Bruce, Florida was 172 m^3/second on 1 April 1997, decreased to 131 m^3/second on 23 April 1997, and increased to 281 m^3/second on 30 April 1997 (U.S. Geol. Surv. 2001).

Fall 1997 Downstream Migration

Two fish (No.'s 3 and 4) collected during fall 1996 had functioning ultrasonic transmitters. These Gulf sturgeon moved downstream from the summer resting/collection site during the last 2 weeks in October 1997 as water temperatures decreased from 22 to 19 C. The daily discharge (Fig. 3) of the Choctawhatchee River measured at Bruce, Florida was 90 m^3/second on 1 October 1997, decreased to 59 m^3/second on 15 October 1997, and increased to 164 m^3/second on 31 October 1997 (U.S. Geol. Surv. 2001). The tagged fish were recorded from 19 October through 5 November 1997 at the remote data logger positioned on the lower Choctawhatchee River (Fig. 1). Downstream fish migration peaked in the lower river between 27 October and 5 November 1997. The new moon occurred on 31 October 1997.

No tagged subadults were recorded by the lower river remote data logger after 5 November 1997, when water temperature in the river dropped to 15.8 C. Water temperature in Choctawhatchee Bay near the river mouth was 19.0 C at the same period. No relationship between timing of river departure and fish age was found. One 5-year old fish (No. 3) tagged in the 1996 season, was recorded at the lower river remote monitoring station on 19 October 1997, 8 days prior to the arrival of any other tagged fish. Water temperature at that time was 23 C. Fish No. 3 was recorded by the remote data logging unit at Destin Pass 26 days after its relocation by the lower river remote data logger. Following this, fish No. 3 was recorded by the remote data logger

on 30 November 1997 and was recorded later by the Destin remote data logger on 3 March 1998.

1997–98 Overwintering

A total of 15 Gulf sturgeon, 2 from the 1996 study and 13 from the 1997 study, were monitored in Choctawhatchee Bay, Santa Rosa Sound, and Pensacola Bay from November 1997 to April 1998. Tagged fish were relocated 212 times during 23 tracking events (Fig. 4). Gulf sturgeon did not segregate by age as they did in the previous year. For example, an age 4 fish (No. 11) spent 127 days along the south shoreline in the western end of the bay at Destin Pass. Fish No. 11 moved very little during 14 tracking periods and stayed at Destin Pass with movements averaging 0.5 km between relocations. A 6-year-old fish (No. 16) spent 2 weeks on the south shore, then traveled to the north shore for 4 months and returned to the south shore for 1 month. An age 6 fish (No. 4) tagged in 1996 moved along the south shoreline of the bay during the 1996–97 monitoring period (Oct. 1996–Mar. 1997). Fish No. 4, however, spent the first 5 weeks during the 1997–98 monitoring period retracing its 1996–97 route along the south shore and then moved to the north shoreline for the next 5 months.

Habitat Use

Gulf sturgeon used 5 geographic areas (East Bay, Alaqua/Hammock Point, Mid Bay Bridge, San Destin, and Destin Pass) in Choctawhatchee Bay during 1997–98 monitoring period (Fig. 5). The Alaqua/Hammock Point area, located on the north shore in the eastern part of the bay, comprised 34% of the relocations during the tracking period. Nine of 15 telemetered fish spent from a few weeks to several months in the Alaqua/Hammock Point area from November 1997 to April 1998. Fish relocated in this area occurred at depths from 0.6 m to 4.5 m ($\bar{x}$ = 2.1 m). Salinity during the period averaged 6.3 ppt (Table 3). The Alaqua/Hammock Point area had sand substrate and no rooted aquatic vegetation.

Twenty percent of relocations occurred at the Mid Bay Bridge area (Fig. 5). Seven of the 15 tagged fish occupied the north and south shoreline of the area from February through April 1998 and ranged from 0.9 m to 8.2 m ($\bar{x}$ = 3.2 m) in depth. Salinity averaged 9.9 ppt during the period (Table 3). Substrate on the northern shoreline consisted of sand and lacked vegetation while the south shoreline had a sand/mud substrate with patches of sea grass.

The San Destin area is located on the south shore east of Mid Bay Bridge (Fig. 5). Nine of the 15 tagged fish were relocated in the San Destin area from November 1997 through April 1998. The San Destin area accounted for 16% of the tagged fish relocations. Fish were found at an average depth of 2.5 m. Salinity during the period averaged 9.1 ppt. Substrate consisted of sand with small patches of sea grass.

The Destin Pass area, located in the southwestern portion of the bay, accounted for 15% of the tagged fish relocations (Fig. 5). Six of the 15 tagged fish frequented the area from November 1997 through April 1998 and were found in depths ranging from 1.8 m to 9.1 m ($\bar{x}$ = 4.7 m). The bottom salinity at Destin Pass, the main entrance

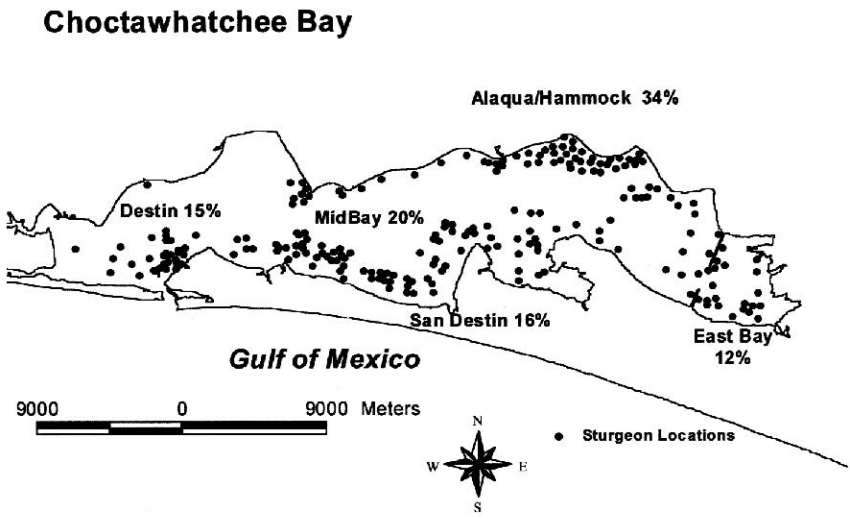

Figure 5. Geographic areas and percent of use by telemetered subadult Gulf sturgeon in Choctawhatchee Bay.

Table 3. Mean (SE) and range of bottom salinity (ppt) in Choctawhatchee Bay during monitoring periods from 1996–97 to 1997–98.

Congregation Area	Low	High	$\bar{x}$(SE)	*N*
East Bay (Nov–Dec)	0.1	25.0	11.5 (1.80)	18
East Bay (Apr–May)	0.0	15.2	5.1 (1.58)	14
Alaqua/Hammock	0.1	23.0	6.3 (0.67)	56
Mid Bay Bridge	0.8	25.0	9.9 (0.86)	53
San Destin	2.2	22.0	9.1 (1.04)	31
Destin Pass	8.5	33.3	18.8 (1.83)	18

to the Gulf of Mexico, averaged 18.8 ppt (Table 3). The substrate in Destin Pass was generally sand with some small patches of sea grass.

The East Bay area, eastern section of the bay, accounted for 12% of fish relocations. Fish were relocated primarily in November and December after departure from the Choctawhatchee River and in April and May upon return to the river. No relocations occurred in East Bay from January through March. Salinity in East Bay averaged 11.5 ppt from November through December and 5.1 ppt from April through May (Table 3). Fish relocations occurred at an average depth of 2.7 m. The substrate in East Bay was mostly mud mixed with some sand. Vegetation was absent in the area.

Almost all telemetered fish were relocated in Choctawhatchee Bay; however, 2

fish (No.'s 13 and 19) spent time in Santa Rosa Sound and Pensacola Bay (Fig. 4). Fish No. 13, age 5, was located 4 times in Santa Rosa Sound from 19 December 1997 through 1 April 1998. This fish was relocated in mid channel and shoreline areas in 2.0 m to 5.2 m depths, 15 ppt to 25 ppt salinities, and sand substrate with sea grass. Fish No. 19, age 7, was located on 3 occasions near the pass connecting Pensacola Bay to the Gulf of Mexico approximately 113 km west of the mouth of Choctawhatchee River from 20 January to 15 March 1998. This fish (No. 19) was relocated in 10.5 m to 12.0 m depths and salinity averaging 18.0 ppt. Both fish (No.'s 13 and 19) returned to Choctawhatchee Bay in March 1998.

Most Gulf sturgeon relocations in Choctawhatchee Bay occurred from 100 m to 1 km from shore in 2 m to 3 m depths. Although movement varied among individuals, age-≥5 fish moved more than age-4 fish. Age-≥5 fish moved an average of 140 km between relocations versus 70 km for age-4 fish. Age-4 fish and 95% of telemetered fish remained in Choctawhatchee Bay during the 1997–98 winter period. Fish No. 3 (tagged on 26 Sep 1996) was not relocated but may have ventured into the Gulf of Mexico.

Spring 1998 Upstream Migration

Gulf sturgeon moved from Choctawhatchee Bay into the Choctawhatchee River from the last week in April through the first 2 weeks in May 1998. Water temperatures during the period ranged from 18.3 to 24.8 C. The new moon was on 26 April 1998. Several fish (No.'s 8, 11, and 15) were relocated in the Muddy Lake area of the river for several days before migrating upstream. The remaining tagged fish moved up river to their summer resting area, approximately 50 rkm upstream from the bay, except fish No. 17. Fish No. 17 was relocated at Mid Bay Bridge in Choctawhatchee Bay on 13 April 1998 (where water temperature was 20.3 C) and in the lower Choctawhatchee River on 23 April 1998 (water temperature was 18.3 C) traveling 32 km in 11 days. On 28 April 1998, fish No. 17 moved 5 rkm down river into Choctawhatchee Bay. Water temperature in the bay was 19.2 C and salinity was 0. On 5 May 1998 fish No. 17 was relocated at the summer resting area, 50 rkm above the bay. Water temperature was 21.3 C. Age of fish and timing of movement from marine to freshwater environments were not correlated. Water discharge for the Choctawhatchee River at Bruce, Florida, was 336 m^3/second on 15 April 1998, increased to 519 m^3/second on 26 April 1998, and decreased to 146 m^3/second on 15 May 1998 (U.S. Geol. Surv. 2001).

Fall 1998 Downstream Migration

Six of 13 ultrasonic tags (No.'s 10, 13, 14, 15, 17, and 18) were still active during the 1998–99 winter monitoring period. These fish were relocated 87 times in 25 search events from October 1998 through April 1999 (Fig. 4) and moved downstream during the first week in October 1998 when the river discharge increased (Fig. 3) from 63 m^3/second on 23 September 1998 to 2175 m^3/second on 4 October 1998 (U.S. Geol. Surv. 2001). Water temperature in the river was 24.5 C on 30 September 1998. All 6 fish were relocated in the eastern portion of Choctawhatchee Bay from 5

to 19 October 1998. Water temperatures ranged from 21.8 to 25.2 C with salinity ranging from 0 to 5.0 ppt.

1998–99 Overwintering

Telemetered fish exhibited the same movement patterns and habitat use during the 1998–99 monitoring period (Oct. 1998–Apr. 1999) as documented in the 1996–97 and 1997–98 periods. Fish (No.'s 10 and 15) moved along the south shoreline of the bay during both seasons. Fish (No.'s 14 and 17) used the north and south shorelines of the bay during both seasons. Also, fish No. 18 was found only on the north shoreline during both monitoring seasons. Fish No. 13 was relocated in November 1998 west of Choctawhatchee Bay in Santa Rosa Sound (Fig. 4) approximately 0.1 km from its 1997 relocation site.

Discussion

Our results confirm that subadult Gulf sturgeon in the Choctawhatchee River and Bay are anadromous, migrating in fall to overwinter in estuarine/marine waters and returning to the river during spring. In our study, all telemetered Gulf sturgeon initiated emigration out of the river with an increase in water flow (Fig. 3) and a decrease in water temperature from 22 to 19 C. The fish departed the Choctawhatchee River between mid-October and early November in 1996 and 1997, peaking in the last week in October when the water temperature decreased to 19 C. No telemetered fish were located in the river after 5 November 1997 when the water temperature was recorded at 15.8 C. Our results are comparable to those reported by Clugston et al. (1995) and Foster and Clugston (1997). They found that in the Suwannee River, Gulf sturgeon usually begin to migrate into marine waters in mid-November as the water cools to 20 C. These results indicate that temperature is the environmental stimulus initiating movements. However, in early October 1998, the discharge in the Choctawhatchee River increased to 2175 m^3/second from 63 m^3/second as a result of Hurricane Georges. Water temperature in the river was 24.5 C. Telemetered subadult Gulf sturgeon departed the river during the first week in October 1998 as the river discharge increased. These fish migrated from the river to marine system 2 to 4 weeks earlier than subadults monitored in 1996 and 1997. Heise et al. (1999*b*), found that the greatest seaward movement of Gulf sturgeon in the Pascagoula River in 1998 corresponded with elevated river flows associated with Hurricane Georges.

Wooley and Crateau (1985) reported that some Gulf sturgeon migrating down the Apalachicola River in the fall would stop at a major downstream tributary for extended periods before moving into Apalachicola Bay. They suggested these were staging areas where Gulf sturgeons undertook osmoregulatory adjustment prior to entering marine waters. Some of telemetered subadult Gulf sturgeon in the Choctawhatchee River stayed for 1 to 2 weeks in the lower Choctawhatchee River (Muddy Lake) during their fall migration. Furthermore, patterns of relocation (multiple days) at the lower Choctawhatchee River remote data logger confirms that some sturgeon stage in this area before entering the bay. The Muddy Lake site was also

used as a resting or staging area for subadult Gulf sturgeon migrating upstream during the spring. Fish would spend a few days to a week at this area (Muddy lake) possibly adjusting to salinity changes before continuing their upstream migration.

Downriver migration of Gulf sturgeon in 1996 and 1997 may have been influenced by the dark of the moon. New moon dates in October 1996 and 1997 coincide with the dates when the majority of telemetered subadults initiated downstream movement. In 1998, the fall migration of subadult fish was influenced by the abnormal high river discharge resulting from Hurricane Georges and could not be linked with the appearance of a new moon. Sulak and Clugston (1998) found that Gulf sturgeon spawning activity in the Suwannee River coincided with the new moon. However, Fox et al. (2000) reported that the new moon did not influence Gulf sturgeon spawning periodicity in the Choctawhatchee River. Subadult movement from the saline Choctawhatchee Bay into the Choctawhatchee River in spring was not associated with moon phase. Fish age was not correlated with departure date from the Choctawhatchee River into the bay in fall or with reentry back in the river in spring.

Most telemetered Gulf sturgeon in Choctawhatchee Bay were located 100 m to 1 km from shore at 2 to 3 m depths. This corresponds with winter habitats in Pensacola and Escambia Bay, Florida, used by telemetered Gulf sturgeon in 1998 and 1999 (Nadine Craft, pers. commun.). Furthermore, Heise et al. (1999*b*) reported that telemetered Gulf sturgeon used shoreline habitat of 1.2 to 4.3 m depths during winter in Mississippi Sound. Fox et al. (2000) captured adult Gulf sturgeon along sand flats in Choctawhatchee Bay at depths of 2 to 6 m. Also, Armstrong and Hightower (1999) reported that commercial gillnetters collected Atlantic sturgeon in near shore areas of Albermarle Sound in less than 3.6 m depths.

In our study, age ≥5 Gulf sturgeon were more active and moved almost twice the distance between relocations than age 4 subadults. In addition, age 4 fish used fewer areas in Choctawhatchee Bay than age ≥5 fish during overwintering periods. All age 4 individuals overwintered in Choctawhatchee Bay during the 1996–97 and 1997–98 monitoring periods while age ≥5 fish were located in Choctawhatchee Bay, Santa Rosa Sound, Pensacola Bay, and possibly the Gulf of Mexico during the same period. Armstrong and Hightower (1999) reported that juvenile Atlantic sturgeon movement 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).

Sea grass beds cover about 4% of bottom area in Choctawhatchee Bay and are concentrated primarily in the western section (Burch 1983). Livingston (1986) found the greatest abundance of benthic macroinvertebrates associated with sea grass beds in deeper western areas of the bay with coarse sandy sediments. Our telemetered Gulf sturgeon were seldom relocated in the western part of the bay, but spent most of the winter in eastern and mid bay shoreline habitats. Mason and Clugston (1993) concluded that sturgeon are opportunistic and have diets restricted to macroinvertebrates. Therefore, for feeding efficiency, target foods must have high population densities that permit mass siphoning. They reported that stomach contents of juvenile Gulf sturgeon (< 20 kg) collected in the mesohaline waters near Suwannee Sound included amphipods, isopods and chironomids.

Fox et al. (2000) reported that the stomach of an adult Gulf sturgeon collected in Choctawhatchee Bay almost exclusively contained commercial species of ghost shrimp, *Lepidophthalmus louisianensis* and *Leptalpheus forceps*. Ghost shrimps are oligohaline burrowers typically found along intertidal and subtidal substrates ranging from sandy mud to organic silty sand and burrow to 1 m depths in soft sediments (Felder and Lovett 1989). Heard et al. (2000) estimated densities of ghost shrimp of 100/m^2 in middle and eastern portions of Choctawhatchee Bay. They suggested ghost shrimp was an important food for ≥1 m long Gulf sturgeon. The haustoriid amphipod *(Lepidactylus triarticulatus)* is another important prey species in sand substrate in water (<3 m) of Choctawhatchee Bay (Heard et al. 2000). Heard et al. (2000) identified over 100 specimens of this small crustacean in stomach contents of an adult Gulf sturgeon from Choctawhatchee Bay.

Foster (2001) found that benthic samples from areas frequented by subadult Gulf sturgeon contained *Lepidactylus sp.* at densities of 15,000/m^2. Foster (2001) suggested that *Lepidactylus sp.* may be important to diets of smaller juvenile sturgeon. *Lepidactylus sp.* and *Lepidophthalmus sp.* at sites occupied by Gulf sturgeon in 5 geographic areas may provide the most readily available source of food in Choctawhatchee Bay for overwintering Gulf sturgeon.

The high occurrences of subadult Gulf sturgeon in eastern and mid portions of the bay may be due to the preference and availability of food. Moser and Ross (1995) reported that some of the estuarine habitats occupied by Atlantic sturgeon in the lower Cape Fear River support very high levels of benthic fauna and important feeding stations. The lack of subadult Gulf sturgeon relocations in the western portion of the Choctawhatchee Bay may be related to the absence of particular preferred food items. Livingston (1986) found that the bottom salinity through the center of Choctawhatchee Bay ranged from 20 to 35 ppt. This may explain why subadult Gulf sturgeon were not utilizing the interior of the bay for any length of time but merely passing through the highly saline habitat to reach the other side.

Further research is needed to document Gulf sturgeon osmoregulatory adjustment. We believe it may be related to foraging, removing external parasites, or obtaining necessary mineral elements that are limited in fresh water. The presence of Gulf sturgeon in 5 geographic areas also shows adapting behavior to saline water environment. The adaptive significance of saline water variation in degree of anadromy between different sizes or strain of sturgeons is unknown. Perhaps the significance is related to the availability and abundance of forage or suitability of saline water quality during the overwintering feeding season. Also, additional factors, such as chemical cuing, may influence distributions and migrations of subadult Gulf sturgeon in the Choctawhatchee River.

We found that the telemetered subadult Gulf sturgeon occupied shoreline habitats in the mid and eastern portion of Choctawhatchee Bay. This distribution appears related to salinity changes within the bay. Salinity in Choctawhatchee Bay is greatest at the western edge and decreases toward east in the bay (Fig. 6). The Alaqua/Hammock area had the lowest mean depth (2.1 m) and salinity (6.3 ppt) of the 5 major geographic areas. Destin Pass had the least number of subadult sturgeon relocations

(15%) in Choctawhatchee Bay and had the greatest mean depth (4.7 m) and highest mean salinity (18.8 ppt) (Fig. 6).

We found that fall migration of telemetered subadult Gulf sturgeon from Choctawhatchee River to the estuarine environment of Choctawhatchee Bay is influenced by water temperature and river discharge. We established that overwintering subadult Gulf sturgeon in Choctawhatchee Bay occupied shoreline habitat at depths of 2–3 m. In addition, we noted subadult Gulf sturgeon occupied the less saline habitat of Choctawhatchee Bay. Foster (2001) and Heard et. al. (2000) suggested that *Lepidactylus sp.*, *Lepidophthalmus louisianensis*, and *Arenicola cristata* in shallow sediments of Choctawhatchee Bay make up the primary food source for overwintering subadult Gulf sturgeon. Their findings support our belief that shallow, sandy, and slightly saline habitats with high densities of benthic burrowing organisms are important feeding areas for subadult Gulf sturgeon. We found that although telemetered subadult fish varied in movement and habitat selection during a seasonal monitoring period, a number of subadult Gulf sturgeon monitored for 2 consecutive seasons exhibited very similar migratory patterns and used the same habitat areas each year. Age-4 telemetered Gulf sturgeon remained in Choctawhatchee Bay during the entire monitoring periods while age-≥5 (N = 4) subadults were relocated west of Choctawhatchee in Santa Rosa Sound and Pensacola Bay and also may have ventured for a period of time in the Gulf of Mexico. Telemetered subadult Gulf sturgeon were in estuarine waters for 5–6 months from November through April during each study period.

All anthropogenic impacts on estuarine habitat and Gulf waters are unknown. Additional information is needed to characterize overwintering marine habitats used by Gulf sturgeon in relation to physical and chemical characteristics, and biological resources indicators. Our information can be used to establish overwintering require-

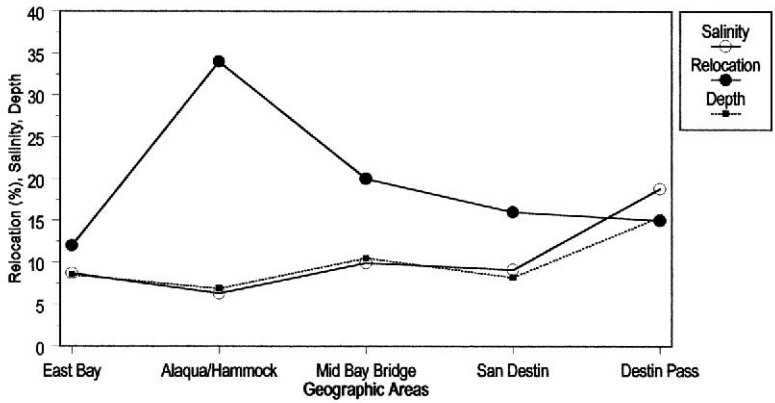

Figure 6. Mean salinity (ppt) and depth (m) versus the percent of telemetered subadult Gulf sturgeon relocations in Choctawhatchee Bay from 1996–1999.

ments of Gulf sturgeon based on habitat use and food preference. Knowledge of Gulf sturgeon estuarine and marine habitat use is an essential component toward its recovery.

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