DOCUMENTATION OF GULF STURGEON SPAWNING IN THE APALACHICOLA RIVER, FLORIDA SPRING 2008

Photo Credit: Jacob Osborne

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Executive Summary

During the spring of 2008, we verified successful Gulf sturgeon spawning in the Apalachicola River via the collection of Gulf sturgeon eggs. We collected Gulf sturgeon eggs at three hard bottom sites in the Apalachicola River; two sites were previously confirmed spawning areas and one was a newly confirmed spawning area. We also documented a 41-day spawning period from April 4 to May 14, 2008.

Background

The Gulf sturgeon, *Acipenser oxyrinchus desotoi,* is an anadromous fish found in coastal river systems from the Suwannee River in Florida to Lake Pontchartrain in Louisiana (Huff 1975 and Wooley and Crateau 1985). The fish was listed as threatened under the Endangered Species Act in 1991. In 1995, a Gulf Sturgeon Recovery/Management Plan was formulated in order to identify priority action items needed to address the numerous life history questions of the fish that remained to be answered and to provide a blueprint for its recovery (FWS 1991 and FWS and GSMFC 1995). In 2003, FWS and NMFS jointly designated Gulf sturgeon critical habitat (FWS and NOAA 2003).

The Gulf sturgeon population in the Apalachicola River below Jim Woodruff Lock and Dam (JWLD) was estimated at 350 fish in 2004 (FWS 2004). The JWLD blocks about 78% of the historical Gulf sturgeon habitat in the Apalachicola-Chattahoochee-Flint (ACF) river system (FWS and GSMFC 1995). Gulf sturgeon spawning habitat has been associated with limestone outcroppings, cobble, gravel, or other hard bottom habitats (Marchant and Shutters 1996, Sulak and Clugston 1998, Fox *et al.* 2000, and Craft *et al.* 2001). Potential Gulf sturgeon spawning habitat identified in the Apalachicola River in 2002 by Parauka and Giorgianni was limited and located in the upper portion of the river. Gulf sturgeon eggs were collected at two of the identified sites in 2005 and 2006 (FWS 2005, Ziewitz 2006, and Pine *et al*. 2006).

Ongoing water management discussions for the ACF river basin could alter flow regimes on the Apalachicola River and possibly affect Gulf sturgeon populations via periodic reductions of the areal extent of spawning habitat.

The objective of the project was to sample three upriver, hard bottom sites to determine the timing, depth, and other conditions associated with Gulf sturgeon spawning. This work builds on the information collected from previous Gulf sturgeon spawning studies conducted in 2005 and 2006 on the Apalachicola River (FWS 2005, Ziewitz 2006, and Pine *et al.* 2006).

Methods

Egg samplers were patterned after Marchant and Shutters (1996) and Fox *et al*. (2000) and consisted of red circular floor buffing pads (20 in diameter) anchored to the river bottom with welded rebar grapples. Gulf sturgeon eggs are demersal and adhesive and will stick to adjacent substrates almost immediately after spawning (Parauka *et al.* 1991 and Sulak and Clugston 1998). The egg samplers used have been shown to be effective at collecting Gulf sturgeon eggs (Marchant and Shutters 1996 and Fox *et al.* 2000), but their efficiency is unknown.

Egg samplers were deployed at 3 of the 7 sites on the Apalachicola River identified and characterized by Parauka and Giorgianni (2002) as potential spawning habitat. These locations were identified as sites 1, 2, and 3 and referred to in this report as the upper site, middle site, and lower site, respectively (Figure 1). Potential spawning sites were identified based on previously established Gulf sturgeon spawning habitat characteristics (Marchant and Shutters 1996, Sulak and Clugston 1998, Fox *et al.* 2000, and Craft *et al.* 2001). Gulf sturgeon spawning sites consist of hard bottom substrate, and are marked by rock, limestone, or hard clay bluffs and limestone outcroppings (Parauka and Giorgianni 2002). We chose to sample the upper and lower sites because they were previously confirmed as Gulf sturgeon spawning sites through the collection of eggs and/or larvae (Wooley *et al.* 1982, FWS 1988, FWS 2005, Ziewitz 2006, and Pine *et al.* 2006), and chose to sample the middle site due to the Pine *et al.* (2006) collection of a single unidentified egg similar in size to a sturgeon egg at that site.

Parauka and Giorgianni (2002) described the upper site as 1,200 ft long with substrate consisting of hard rock, limestone, and cobble. It is marked by a 30-250 ft wide limestone shelf on the east side of the river that is mostly exposed during low flows. The site is located between the U.S. 90 bridge to the north and a railroad bridge to the south. The middle site was described as a 520 ft long and 70 ft wide limestone shelf along the west bank of the river, located about 500 ft north of the Interstate 10 bridge. The lower site was described as a 1,950 ft long limestone shelf running 10 to 20 ft wide along the east bank of the river with hard substrate, gravel, and cobble on the river bottom. It is located approximately 1 mile south of the Interstate 10 bridge.

On April 2, 2008, thirty egg samplers were deployed at both the upper and lower sites, and ten egg samplers were deployed at the middle site. The number of samplers used per site was based loosely on habitat availability as described in Parauka and Giorgianni (2002) and Ziewitz (2006). Additional samplers were added to each site to compensate for lost equipment and to maintain consistency throughout the study. Egg samplers were loosely symmetrically deployed in order to sample a range of depths present over the hard bottom sites. Egg samplers were inspected for Gulf sturgeon eggs every 48-72 hours. In most cases, all Gulf sturgeon eggs found on each pad were removed, each set placed in individual receptacles containing river water, and brought to the Panama City Field Office (PCFO). Each set of eggs was placed in a separate beaker at the field office with added river water, monitored for fungus, development, and hatching, and later preserved in a tissue preservation buffer (Seutin *et al*. 1991). A few larvae were taken from the lab back to the original spawning site and released; however, at least one egg or larvae from each set was preserved.

The preservation of a small amount of eggs and larvae from a threatened species was justified due to the relatively large amount of eggs released by female Gulf sturgeon each year; Chapman *et al.* (1993) reported that three mature Gulf sturgeon had 458,080, 274,680, and 475,000 eggs and were estimated to have an average fecundity of 20,652 eggs/kg (9,366 eggs/lb). Smith *et al.* (1980) estimated that Atlantic sturgeon weighing 50.0 and 100.0 kg (110.2 and 220.5 lbs) would yield over 400,000 and 1,000,000 eggs, respectively.

Water quality parameters including temperature (°C), specific conductivity (µS/cm), salinity (ppt), dissolved oxygen (% saturation and mg/L), and pH were recorded just below the water surface at each of the three egg sampling sites on each sampling day using a YSI 650 MDS meter. In addition, depth and position of each pad, with or without eggs, was recorded at the time and location it was pulled using a hand-held Digital Sonar and hand-held GPS, Garmin GPSmap 76. Water velocity (ft/s), measured at the location of each sampling pad found with eggs, was recorded using a Swoffer model 3000 meter at four depths: just below the surface, 30% of the depth, 60% of the depth, and at the bottom. Provisional daily river discharge data were downloaded from the USGS gauge 02358000, which is located just downstream of the JWLD.

Eight Gulf sturgeons (five adults and three subadults) were collected in the Brothers River, a tributary that enters the Apalachicola River at RM 12.0, during the summer and fall of 2005 and were surgically implanted with 1,100-day Vemco acoustic tags. A Vemco VR-2 remote receiver was deployed on March 25, 2008, at river mile (RM) 101.5 (between the upper site and the middle site) to monitor movement of Gulf sturgeons equipped with Vemco acoustic tags. We also manually monitored for tagged fish at each spawning site and the area below the JWLD on each sampling day using a Vemco 100 receiver.

The egg collection study was terminated after 14 consecutive days without egg collection or when water temperatures exceeded 25°C, which is reported to impair egg growth and survival (Chapman and Carr 1995).

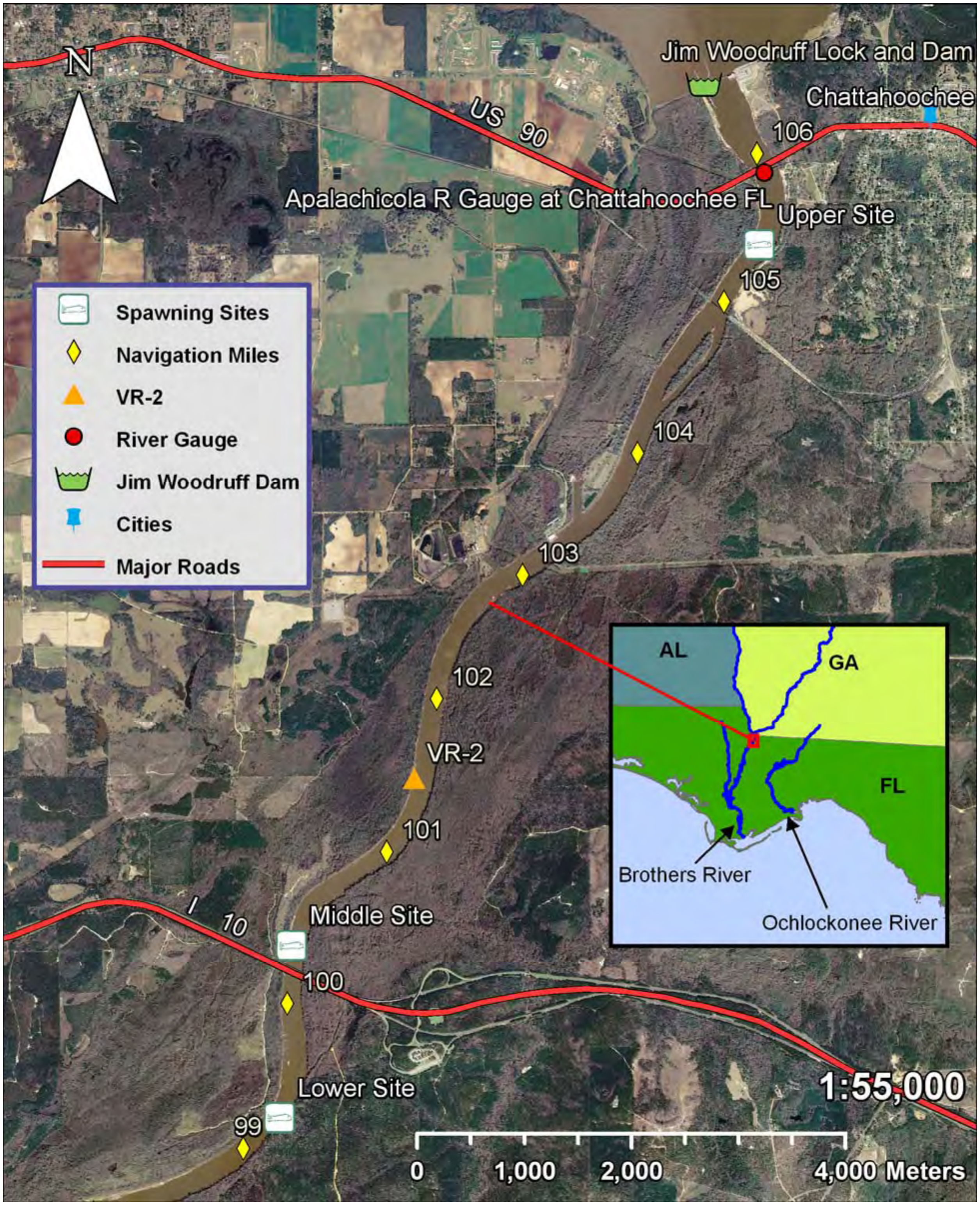

Figure 1. Map of study area on the Apalachicola River. The three egg sampling sites, the VR-2 location at RM 101.5, the location of USGS gauge 02358000, and the JWLD are shown. Inset map shows locations of study area as well as locations where fish were tagged.

Results

Egg collection pads were deployed at all three sampling sites on April 2, 2008, and were removed on May 29, 2008. Water temperature and mean daily discharge during the period ranged from 19.73 to 26.64°C and 6,030 cfs on May 29 to 36,900 cfs on April 10, respectively (Figure 2, Table 1). Median water velocity measured at the collection pads with eggs was as follows: surface, 2.594 ft/s (range, 0.576 – 4.139, n = 98); 30% below surface, 2.416 ft/s (range, 0.806 – 3.398, n = 86); 60% below surface, 1.845 ft/s (range, 0.222 – 2.983, n = 63); and bottom, 0.753 ft/s (range, 0.074 – 1.950, n = 28) (Table 2). Not all velocity measurements were recorded at the greater depths due to physical difficulty operating the flow meter. Egg pad surveys were conducted on 23 sampling days from April 4 to May 28, 2008 with Gulf sturgeon eggs found on 16 of the days surveyed, including the first sampling day. A total of 1,774 pad-inspections were conducted during the sample period with 102 pad-inspections yielding 282 Gulf sturgeon eggs representing all three sampling sites (Table 1). Egg collections peaked during the week of April 14 after the river discharge receded from 35,000 cfs on April 11 to 13,500 cfs on April 14. Fifty-five percent of the total number of eggs was collected during this week from all three sample sites, with eggs collected from the middle and lower sites for the first time. Two-hundred and sixty-two total Gulf sturgeon eggs were removed from the pads and brought to the PCFO where 55 eggs hatched. Five larvae were returned to the upper spawning site in the Apalachicola River, while all other larvae and eggs were preserved.

Upper Site

Two-hundred and four Gulf sturgeon eggs, 72% of the total number of eggs, were collected from 78 total pad-inspections at the upper site during the study (Table 1). Gulf sturgeon eggs were collected on 16 of the 23 total sampling days, from April 4 to May 14, 2008. Water temperature ranged during this period from 19.73 to 24.24°C, and discharge ranged from 6,880 cfs on May 9 to 36,900 cfs on April 10. Discharge ranged from 33,600 to 36,500 cfs on three sample days (4/7, 4/9, and 4/11) when eggs were recovered from the collection pads. During this high water period, many of the pads' buoy lines were underwater and not recoverable; the number of pads inspected ranged from 11 to 17 per sample day. However, on the other 20 sampling days, a lower median discharge of 11,350 cfs (range, 6,520 – 16,500, n = 20) was recorded and the median number of pads inspected at the upper site was 35 pads per sample day (range, 29 – 36, n = 20). Median water quality measurements recorded at the upper site when eggs were collected were as follows: temperature, 21.55°C (range, 19.05 – 24.22, n = 16); specific conductivity, 132 µS/cm (range, 108 – 169, n = 16); salinity, 0.06 ppt (range, 0.05 – 0.08, n = 14); dissolved oxygen concentration, 9.29 mg/L (range, 7.66 – 12.21, n = 14); percent saturation, 102.3% (range, 83.1 – 142.2, n = 12); and pH, 7.68 (range, 7.46 – 8.02, n = 16) (Table 3). Some measurements were not recorded due to errors operating the water quality meter. In addition, based on factory sensor performance guidance for the dissolved oxygen probe, all dissolved oxygen readings taken when the probe charge (measure of electrical resistance) was less than 25 (a unitless relative measure) were omitted because the low probe electrolyte level that this indicates will cause readings to be inaccurate (YSI 2002). Gulf sturgeon eggs were collected at depths ranging from 3.0 to 24.4 ft with a median depth of 10.1 ft (n = 78) (Table 4, Figure 3).

Middle Site

Forty-two Gulf sturgeon eggs, 15% of the total number of eggs, were collected from 14 pad-inspections at the middle site on four sampling days (4/14, 4/16, 4/18, and 5/2) (Table 1). Discharge ranged from 11,000 to 16,500 cfs and water temperature ranged from 19.12 to 23.15°C on the four sampling days. During the high water period (4/7, 4/9, and 4/11), the number of pads checked ranged from 2 to 4; however, on the other 20 sampling days, the median number of pads checked was 13 (range, 10 – 14, n = 20). Median water quality measurements recorded at the middle site when eggs were collected are as follows: temperature, 20.25°C (range, 19.34 – 23.37, n = 4); specific conductivity, 114 µS/cm (range, 111 – 154, n = 4); salinity, 0.05 ppt (range, 0.05 – 0.07, n = 4); dissolved oxygen concentration, 9.37 mg/L (range, 8.57 – 11.65, n = 4); percent saturation, 106.1% (range, 94.0 – 129.7, n = 4); and pH, 7.58 (range, 7.44 – 7.63, n = 4) (Table 3). Gulf sturgeon eggs were collected at depths ranging from 0.5 to 13.5 ft, with a median depth of 11.6 ft (n = 14) (Table 4, Figure 3).

Lower Site

Thirty-six Gulf sturgeon eggs, 13% of the total number of eggs, were collected from 10 pad-inspections at the lower site on two sampling days (4/16 and 4/18) (Table 1). Mean daily discharge and water temperature for the two sampling days were 16,500 and 15,900 cfs and 19.12 and 19.78°C, respectively. The number of pads inspected for eggs fluctuated according to river discharge. During the high water period in the early part of the study (4/7, 4/9, and 4/11), the number of pads inspected ranged from 13 to 17; at the lower discharge level experienced through most of the study, the median number of pads inspected for eggs was 37 (range, 30 – 39, n = 20). Water quality measurements recorded at the lower site for the two sampling days that Gulf sturgeon eggs were collected are as follows: temperature, 18.96 and 19.77°C; specific conductivity, 110 and 115 µS/cm; salinity, 0.05 and 0.05 ppt; dissolved oxygen concentration, 11.85 and 11.74 mg/L; percent saturation, 127.7 and 128.5%; and pH, 7.64 and 7.71 (Table 3). Gulf sturgeon eggs were collected at depths ranging from 6.1 to 13.8 ft with a median depth of 7.0 ft (n = 10) (Table 4, Figure 3).

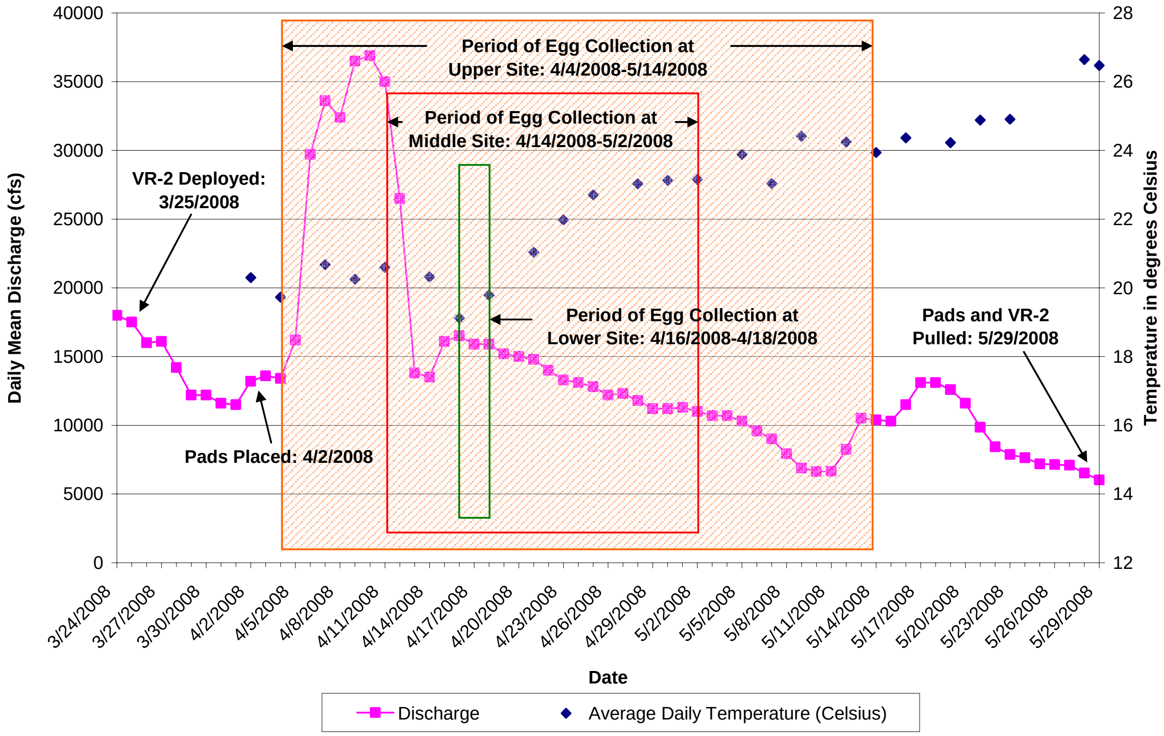

Figure 2. Plot showing daily mean discharge (provisional data, USGS gauge 02358000) and water temperature (averaged between sites) on the Apalachicola River as recorded on sampling days. Dates pertinent to the study are pointed out. Period from first to last egg collection at the upper, middle, and lower site, respectively, are shown in boxes.

Table 1. Comparison of discharge and temperature on each sampling day, and the number of pads inspected, number of pad-inspections with eggs found, and number of eggs collected for each Gulf sturgeon spawning site on the Apalachicola River each sampling day.

Sample Date	Daily Mean Discharge (cfs)	Average Temp. (°C)	***Upper Site***			***Middle Site***			***Lower Site***			***Sites Combined***		
			# Pads	**# Pads with Eggs**	**# Eggs**	**# Pads**	**# Pads with Eggs**	**# Eggs**	**# Pads**	**# Pads with Eggs**	**# Eggs**	**# Pads**	**# Pads with Eggs**	**# Eggs**
4/4/08	13,400	19.73	29	1	2	10	0	0	30	0	0	69	1	2
4/7/08	33,600	20.67	17	2	8	3	0	0	14	0	0	34	2	8
4/9/08	36,500	20.25	11	1	11	2	0	0	13	0	0	26	1	11
4/11/08	35,000	20.59	17	6	13	4	0	0	17	0	0	38	6	13
4/14/08	13,500	20.31	29	11	32	14	4	5	33	0	0	76	15	37
4/16/08	16,500	19.12	33	2	3	14	1	1	37	2	7	84	5	11
4/18/08	15,900	19.78	34	12	46	14	7	32	37	8	29	85	27	107
4/21/08	14,800	21.03	34	5	8	14	0	0	38	0	0	86	5	8
4/23/08	13,300	21.97	36	2	6	13	0	0	38	0	0	87	2	6
4/25/08	12,800	22.71	36	8	15	13	0	0	39	0	0	88	8	15
4/28/08	11,800	23.03	34	1	1	13	0	0	36	0	0	83	1	1
4/30/08	11,200	23.13	35	2	2	13	0	0	37	0	0	85	2	2
5/2/08	11,000	23.15	34	9	17	14	2	4	38	0	0	86	11	21
5/5/08	10,300	23.88	35	12	33	14	0	0	38	0	0	87	12	33
5/7/08	9,000	23.04	36	0	0	14	0	0	38	0	0	88	0	0
5/9/08	6,880	24.41	36	1	2	14	0	0	37	0	0	87	1	2
5/12/08	8,240	24.24	36	0	0	12	0	0	37	0	0	85	0	0
5/14/08	10,400	23.94	35	3	5	12	0	0	37	0	0	84	3	5
5/16/08	11,500	24.36	35	0	0	12	0	0	37	0	0	84	0	0
5/19/08	12,600	24.22	35	0	0	12	0	0	37	0	0	84	0	0
5/21/08	9,850	24.88	34	0	0	12	0	0	37	0	0	83	0	0
5/23/08	7,870	24.91	33	0	0	12	0	0	37	0	0	82	0	0
5/28/08	6,520	26.64	34	0	0	12	0	0	37	0	0	83	0	0
TOTALS			**728**	**78**	**204**	**267**	**14**	**42**	**779**	**10**	**36**	**1,774**	**102**	**282**

Table 2. Range and median of water velocity recordings, measured in ft/s, at various depth intervals at pad-inspection locations where eggs were collected. Not all velocity measurements were recorded at lower depths due to physical difficulty operating the flow meter.

SITES COMBINED	Surface	30% Below Surface	60% Below Surface	Bottom
Velocity Sample Size (n)	98	86	63	28
Minimum Velocity (ft/s)	0.576	0.806	0.222	0.074
Median Velocity	2.594	2.416	1.845	0.753
Maximum Velocity	4.139	3.398	2.983	1.950

Table 3. Range and median of water quality parameters recorded at the upper, middle, and lower site on sampling days when eggs were found at each respective site. Some measurements were not recorded due to errors operating the water quality meter; also, some dissolved oxygen measurements were eliminated according to factory sensor performance guidance for the dissolved oxygen probe (YSI 2002).

UPPER SITE	Temp °C	SpCond µS/cm	Salinity ppt	DO% %	DO Conc mg/L	pH
Sample Size (n)	16	16	14	12	14	16
Minimum	19.05	108	0.05	83.1	7.66	7.46
Median	21.55	132	0.06	102.3	9.29	7.68
Maximum	24.22	169	0.08	142.2	12.21	8.02
MIDDLE SITE	**Temp**	**SpCond**	**Salinity**	**DO%**	**DO Conc**	**pH**
Sample Size (n)	4	4	4	4	4	4
Minimum	19.34	111	0.05	94.0	8.57	7.44
Median	20.25	114	0.05	106.1	9.37	7.58
Maximum	23.37	154	0.07	129.7	11.65	7.63
LOWER SITE	**Temp**	**SpCond**	**Salinity**	**DO%**	**DO Conc**	**pH**
Sample Size (n)	2	2	2	2	2	2
Minimum	18.96	110	0.05	127.7	11.74	7.64
Maximum	19.77	115	0.05	128.8	11.85	7.71

Table 4. Range and median of water depths in feet measured for each pad-inspection with eggs found for each sampling site.

Depth Data	All Pad-Inspections with Eggs Found		
	Upper Site	Middle Site	Lower Site
Number of Pads	78	14	10
Minimum (ft)	3.0	0.5	6.1
Median	10.1	11.6	7.0
Maximum	24.4	13.5	13.8

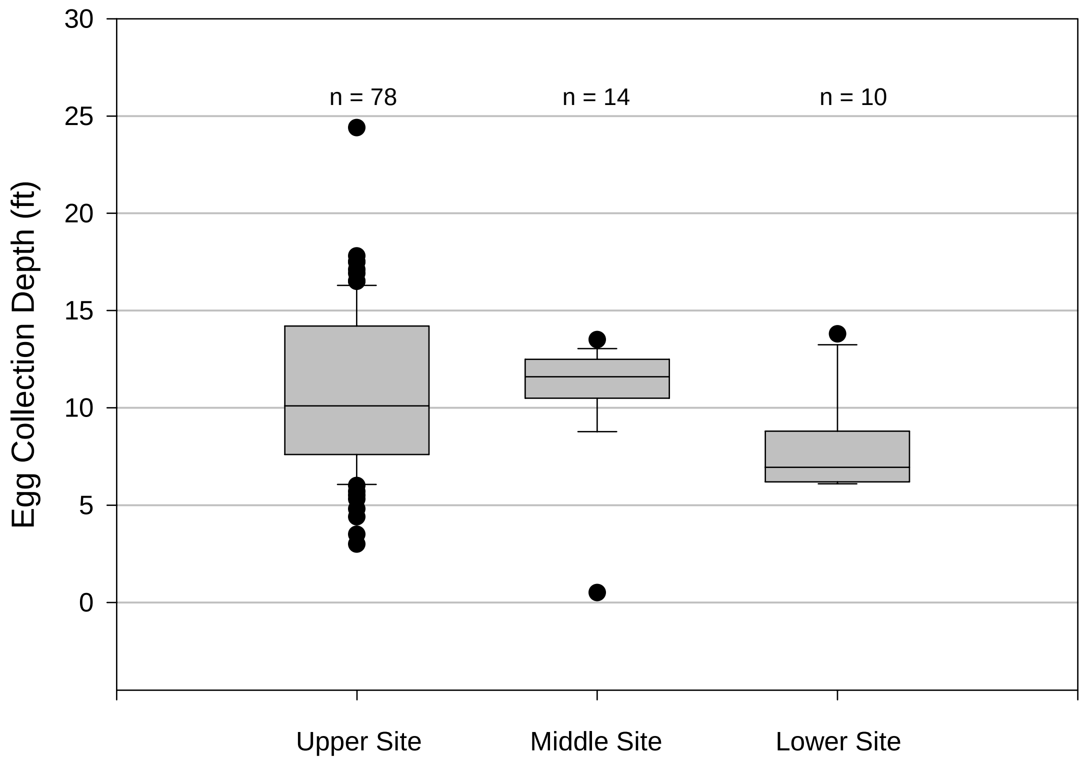

Figure 3. Box and whisker plot of depths recorded at each pad-inspection with eggs found in the upper, middle, and lower site. Whiskers represent the 10th and 90th percentiles; the box shows the 75th percentile, median, and 25th percentile; dots represent outliers.

In all three sites eggs were collected throughout the entire area sampled, as is indicated in Figures 4, 5, and 6.

Six of the eight telemetry tagged Gulf sturgeons from the Brothers River and one fish tagged in the Ochlockonee River migrated to the upper Apalachicola River during the study period as evidenced by recordings at the VR-2 remote receiver positioned at RM 101.5. A total of 2,307 detections of tagged Gulf sturgeons were recorded in the river between March 25 and May 16, 2008. In addition, four of these tagged Gulf sturgeons were manually located with a Vemco 100 eight times at the buoy line just below the JWLD from March 25 through May 5, 2008. Water temperature was 16.4°C on March 25. One fish, tag #844, was located on May 2, 2008 at the lower end of the upper spawning site. Also, on April 23, 2008, tag #1542 was located just above the middle sampling site. A fish collected and tagged in the Ochlockonee River in 2005, tag #850, was recorded at the VR-2 remote receiver from May 12 through May 18, 2008. Data was retrieved from the VR-2 on May 29, 2008. All tagged fish had left the upper river by May 18, 2008 as none were recorded at the VR-2 after that date.

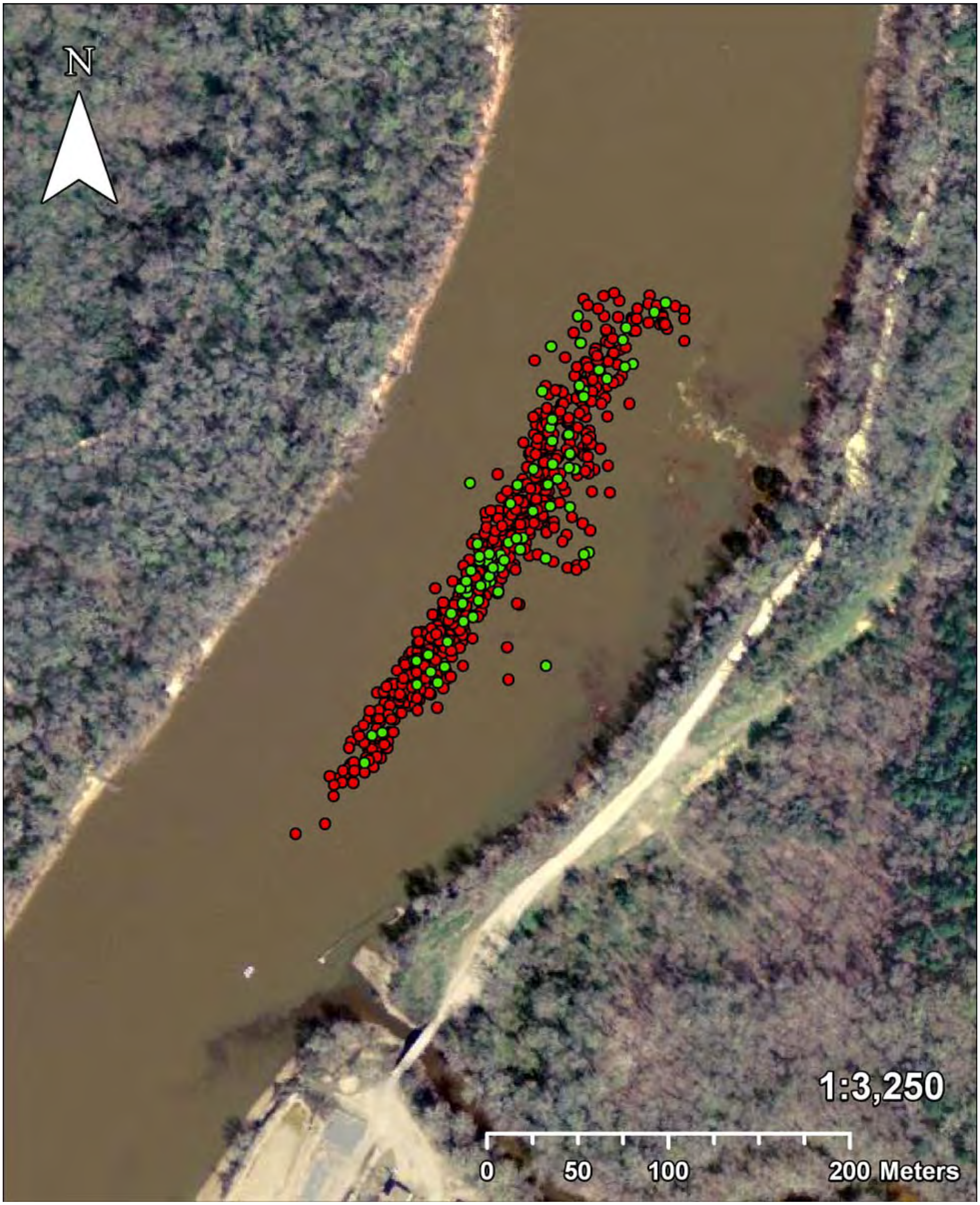

Figure 4. Locations of all egg sampler pad-inspections (n = 728) conducted in the upper site in 2008. Red dots represent pad-inspections without eggs; green dots represent pad-inspections with eggs (n = 78). Aerial imagery is from 2004.

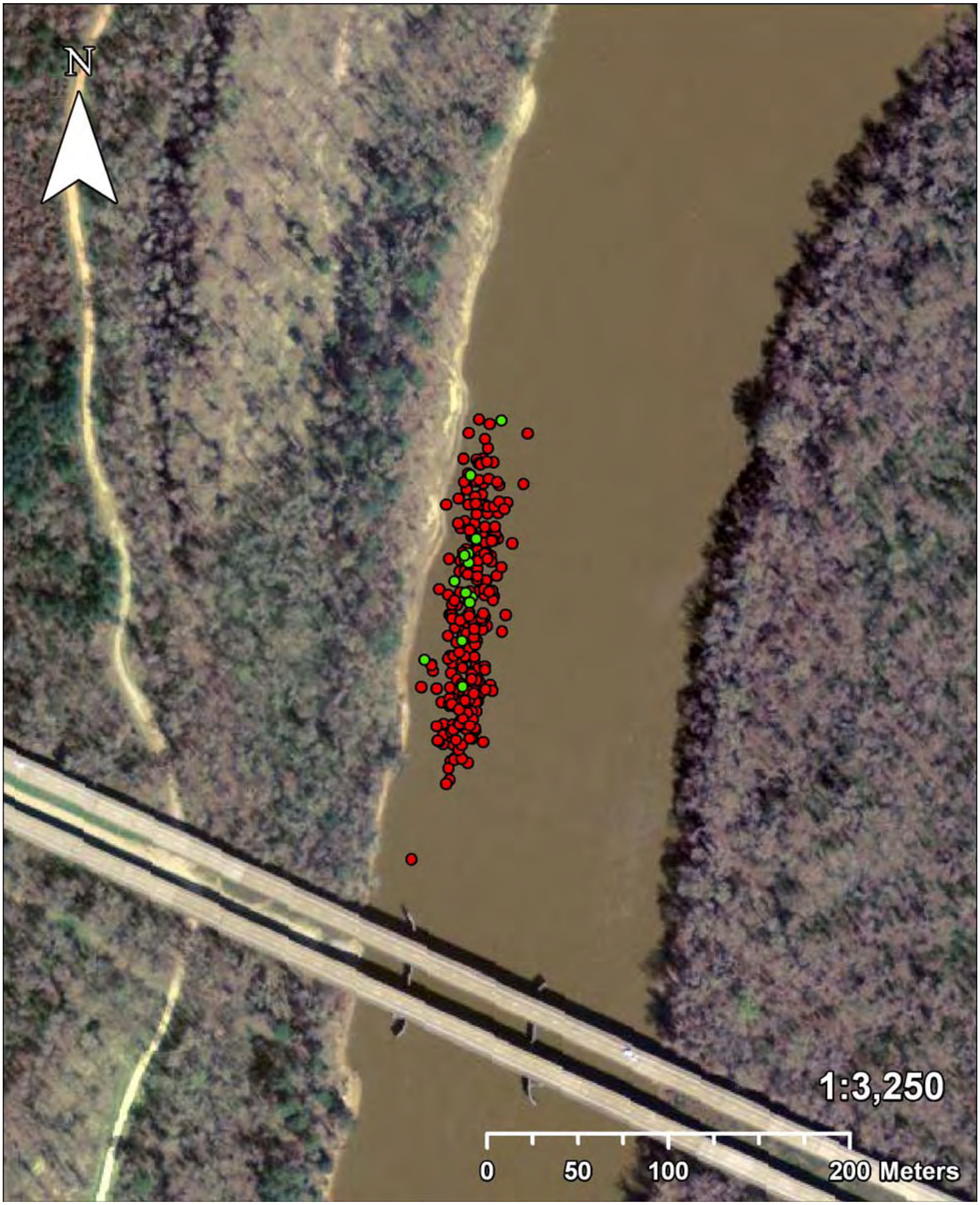

Figure 5. Locations of all egg sampler pad-inspections (n = 267) conducted in the middle site in 2008. Red dots represent pad-inspections without eggs; green dots represent pad-inspections with eggs (n = 14). Aerial imagery is from 2004.

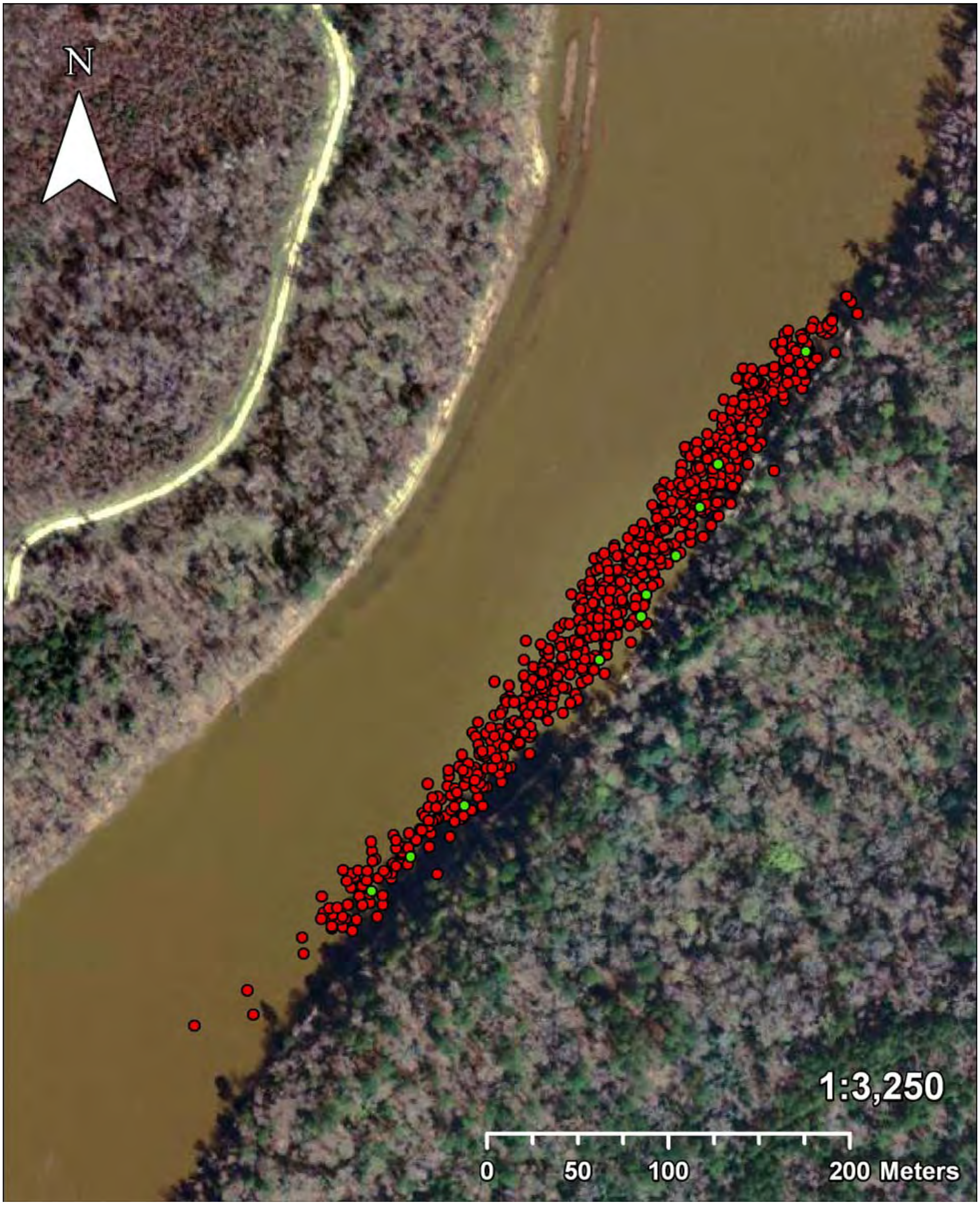

Figure 6. Locations of all egg sampler pad-inspections (n = 779) conducted in the lower site in 2008. Red dots represent pad-inspections without eggs; green dots represent pad-inspections with eggs (n = 14). Aerial imagery is from 2004.

Discussion

Gulf sturgeon eggs were collected from April 4 to May 14, 2008 at all three hard bottom locations that we sampled in the Apalachicola River. Egg collection peaked during the week of April 14 when significant numbers of Gulf sturgeon eggs were retrieved from the collection pads at all three sites (Table 1, Figure 7). During this period, Gulf sturgeon eggs collected at the upper site accounted for 40% of the total for that site, while collections at the middle and lower sites accounted for 90.5% and 100%, respectively, of the total for those sites. River discharge decreased from 35,000 cfs on April 11 to 13,500 cfs on April 14. Two other spikes in egg collections were recorded during the weeks of April 21 through April 25 and May 2 through May 5 when the river discharge decreased slightly. We also collected Gulf sturgeon eggs at the upper sampling site between April 7 and April 11 when the discharge was at its peak. Egg collection during that period amounted to 15.6% of the total; however, approximately half of the egg collection pads could not be located due to the high flows. Our data differs with what Pine *et al.* (2006) reported in that the majority of eggs they collected at the upper sampling site in the Apalachicola River in 2006 followed increases in discharge. The majority of the eggs we collected followed decreases in discharge; however, we also found eggs following increases in discharge.

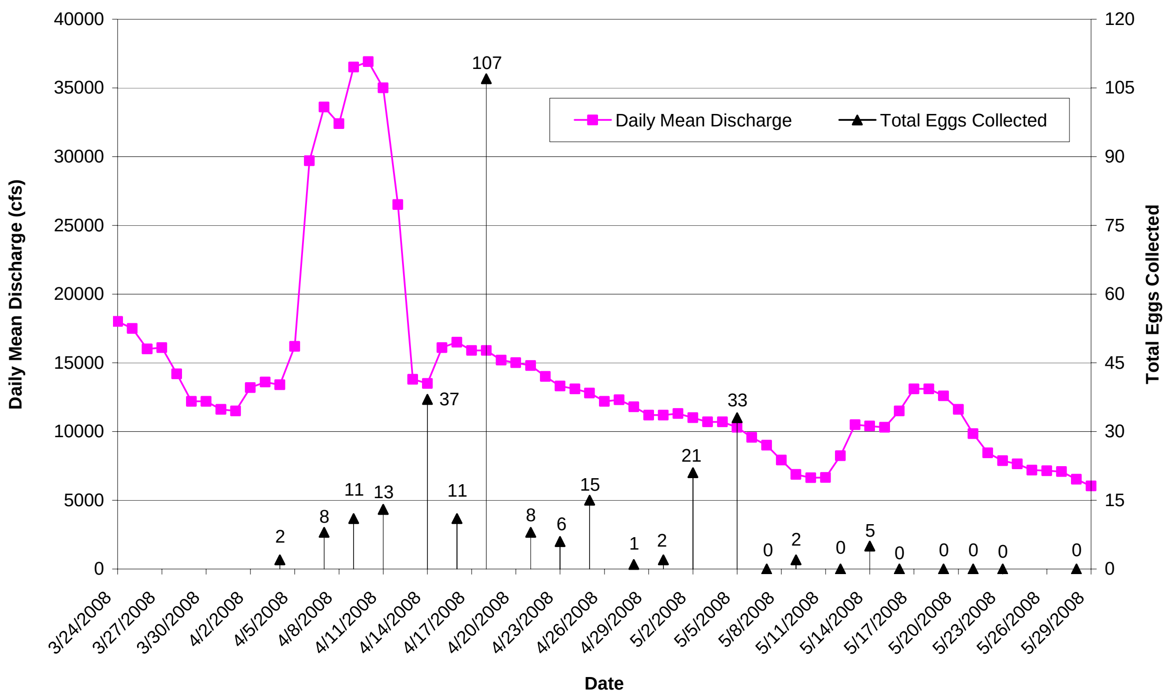

Figure 7. Plot of daily mean discharge in cfs (provisional data from USGS gauge 02358000) and the total number of eggs collected on each sampling day.

Pine *et al.* (2006) also noted that telemetered fish in the Apalachicola River moved into the spawning grounds following an increase in discharge. River discharge did not seem to influence Gulf sturgeon movement during our study. Two tagged fish, #842 and #1542, were located on March 25 just below the JWLD and at RM 101.5 prior to the discharge increase recorded on

April 6, 2008. Water temperatures decreased slightly from 20.59°C on April 11 to 19.12°C on April 16 and increased slowly throughout the remainder of the study.

We examined the range of water temperatures that occurred during the observed period of egg collection. Water temperature (averaged between sites) was recorded at 19.73°C on April 4, the first sampling day and first day of egg collection, and was recorded at 23.94°C on May 14, the final day of egg collection (Table 1, Figure 8). Temperature ranged during this period from a low of 19.12 to a high of 24.41°C. Because eggs were collected from the onset of our sampling period, it is possible that spawning occurred prior to sampling at temperatures lower than were recorded. The data collected in our study is similar to those recorded in previous studies on the Apalachicola River. In 2005 Ziewitz (2006) recorded a temperature of 20.86°C on April 27, the first day of egg collection, and recorded 23.76°C on May 13, the last day of egg collection. Temperature ranged during this period from 19.93 to 23.76°C. In 2006, Pine *et al.* (2006) reported that temperature ranged from 20.27 to 25.31°C on sampling days when eggs were collected.

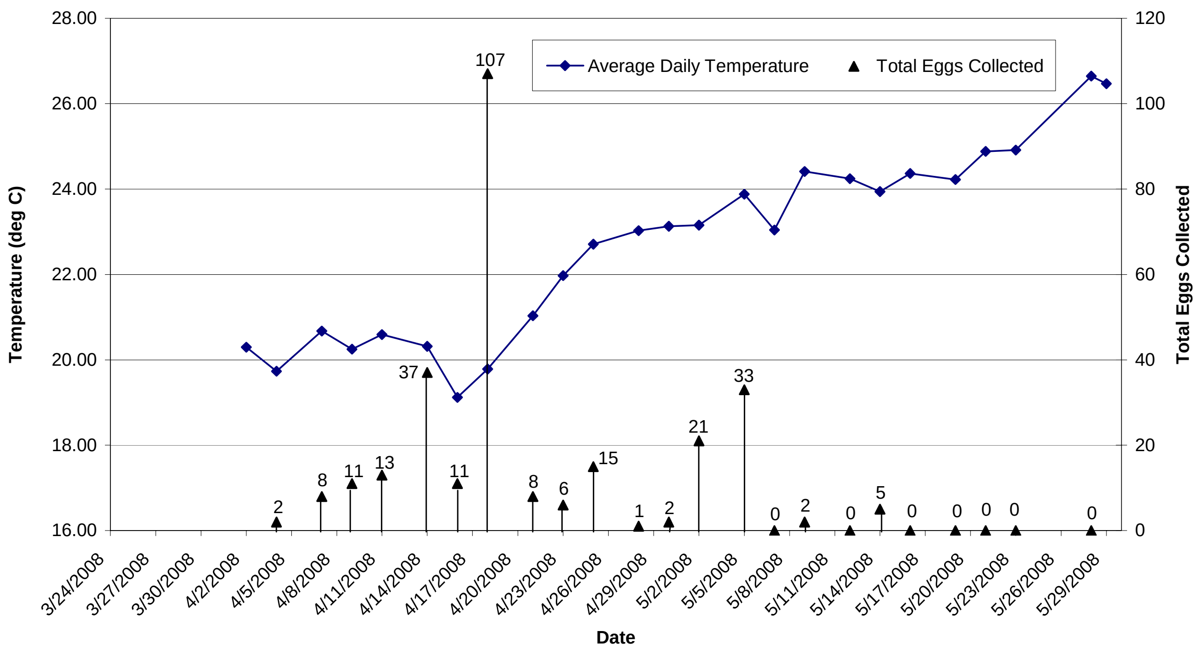

Figure 8. Plot of recorded water temperature in degrees Celsius (an average of measurements at each site) and total number of eggs collected on each sampling day.

The depth of each pad-inspection with eggs found ranged from 0.5 to 24.4 ft, with a median of 10.5 ft (n = 102) (Table 5, Figure 9). However, our depth measurements, taken only every 48-72 hours, do not necessarily represent the water depth at which spawning actually occurred. To deal with this problem, we filtered our depth data to eliminate measurements taken following the most extreme changes in discharge. Accordingly, the sampling days of April 7 and April 14 were filtered out of our dataset. Between the sampling days April 4 and April 7, daily mean gauge height changed from 43.67 to 51.58 ft. Between the sampling days April 11 and April 14, gauge height changed from 52.03 to 43.68 ft. All other differences in gauge height between sampling days were less than 2 ft. After filtering our data, the depths of pad-inspections with eggs found ranged from 3.5 to 17.8 ft, with a similar median of 10.6 ft (n = 85) (Table 5, Figure 9). The filtering process reduced the range of our data, but did not appreciably influence the median (10.5 vs. 10.6 ft). Some outliers were eliminated from the dataset as a result of filtering. For example, the egg collection at 0.5 ft from the middle site on April 14 was eliminated; since one of the two eggs collected from that pad hatched in the lab later that day, spawning may be assumed to have occurred at a much greater depth. Based on measurements of sturgeon hatching time, it is likely that spawning occurred two to three days earlier when flows were much greater. Parauka *et al.* (1991) reported that hatching time for artificially spawned Gulf sturgeon ranged from 85.5 hr at 18.4°C to 54.4 hr at about 23°C.

We compared the depths of our egg collections to previous studies on the Apalachicola River (FWS 2005, Ziewitz 2006, and Pine *et al*. 2006) (Table 5, Figure 9). In 2005, Gulf sturgeon eggs were collected on 17 pad-inspections, all at the upper site, with water depths ranging from 7.5 to 20.1 ft, with a median of 11.4 ft. In 2006, eggs were collected on 100 pad-inspections (93 from the upper site and 7 from the lower site) with a range of depths of 5.9 to 21.3 ft, and a median of 11.8 ft (Pine *et al*. 2006). Our data ranged from 0.5 to 24.4 ft, with a median of 10.5 ft (n = 102); when filtered, the range is reduced to 3.5 to 17.8 ft, with a similar median of 10.6 ft (n = 85). While the unfiltered data appears to show a much wider range of depths observed this year, the filtered data reveals that our egg collections occurred at depths generally similar to those observed in 2005 and 2006, although slightly shallower.

When the depths of egg collections from 2005, 2006, and the filtered 2008 depths are combined, the middle 80% of the data ranges from 7.2 to 17.1 ft, with a median of 11.3 ft (n = 202). This data is consistent with the range of observed egg collections obtained when using only 2005 and 2006 data, albeit slightly shallower. In that dataset, the middle 80% ranges from 8.5 to 17.8 ft, with a median of 11.8 ft (n = 117).

To examine whether Gulf sturgeon exhibit a preference for a particular range of depths when spawning, it would be necessary to compare spawning habitat use versus availability. This may be conducted in the future by comparing the range of depths available at the various river stages occurring during sampling to the range of depths in which eggs were collected.

Table 5. Range and median of water depths in feet measured for each pad-inspection with eggs in 2005 (FWS 2005 and Ziewitz 2006), 2006 (Pine *et al.* 2006), and 2008. For 2008, depth data is presented as recorded and after filtering.

Pad Inspections with Eggs	**2005**	**2006**	**2008**	
			All Data	**Filtered**
Number of Pads	17	100	102	85
Minimum	7.5	5.9	0.5	3.5
Median	11.4	11.8	10.5	10.6
Maximum	20.1	21.3	24.4	17.8

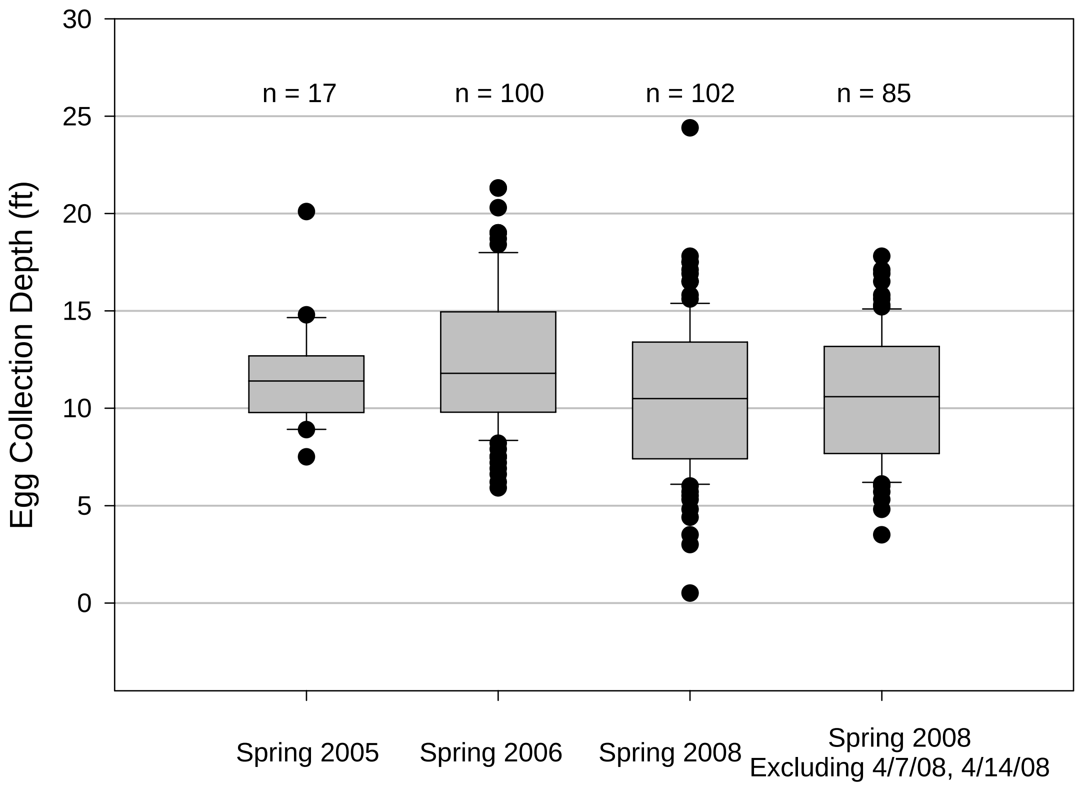

Figure 9. Box and whisker plot of depths recorded at each pad-inspection from which eggs were collected in 2005, 2006, and 2008. For 2008, depth data is presented as recorded and after filtering. Whiskers represent the 10^{th} and 90^{th} percentiles; the box shows the 75^{th} percentile, median, and 25^{th} percentile; dots represent outliers.

We compared the GPS-determined locations of egg pad collections from 2005, 2006, and 2008 (Figures 10 and 11). In the upper site, the range of the 2005 locations extends further to the east, onto the more elevated portion of the limestone shelf, which coincides with the occurrence of greater discharges in 2005 than occurred in 2006 and 2008 (Table 6). The range of locations in 2006 and 2008 are very similar; both are restricted to a narrower width of river due to the occurrence of low discharges that left much of the limestone shelf exposed or under very shallow water. The apparent greater northern extent of the 2006 data is an artifact of sampling design; in 2008 this northern portion of the site was not sampled. In the lower site, the apparent greater northern extent of the 2008 data in relation to the 2006 data is also an artifact of sampling design.

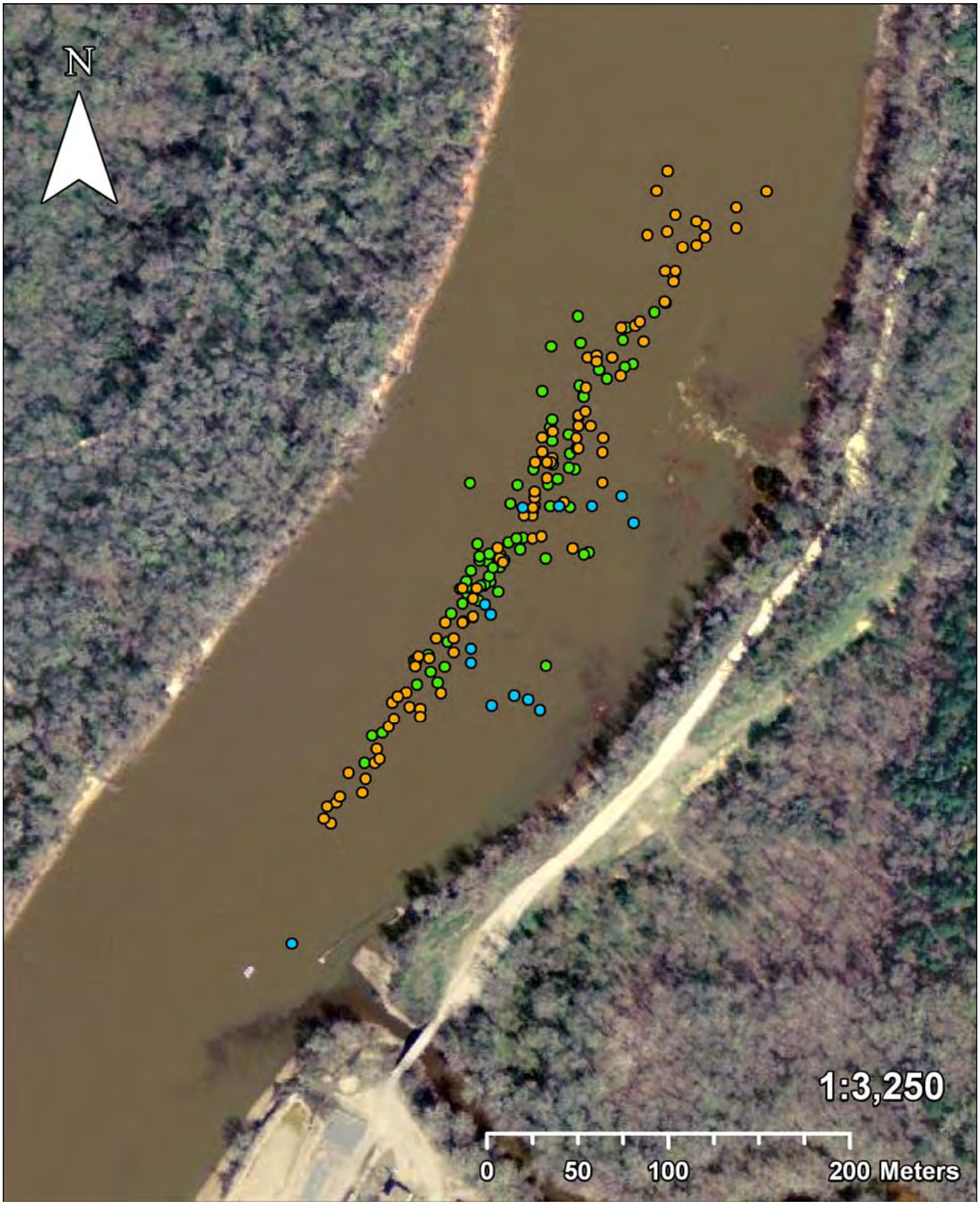

Figure 10. Locations of all egg sampler pad-inspections in which eggs were collected in the upper site in 2005 (n = 17), 2006 (n = 93), and 2008 (n = 78). Blue dots represent 2005 egg collections, orange dots 2006 egg collections, and green dots 2008 egg collections. Aerial imagery is from 2004.

Figure 11. Locations of all egg sampler pad-inspections in which eggs were collected in the lower site in 2006 (n = 7) and 2008 (n = 10). Orange dots represent 2006 egg collections; green dots represent 2008 collections. Aerial imagery is from 2004.

Table 6. A comparison of conditions and sampling effort on pertinent dates in 2005, 2006, and 2008 Gulf sturgeon egg sampling studies on the Apalachicola River. *Eggs were found on the first sampling day in the 2008 study.

Apalachicola River Studies	2005	2006	2006	2008	2008	2008
	Upper Site	Upper Site	Lower Site	Upper Site	Middle Site	Lower Site
Pads Placed						
Date	4/21/2005	3/27/2006	3/19/2006	4/2/2008	4/2/2008	4/2/2008
Temperature	21.17	No Data	No Data	20.23	20.39	20.27
Discharge	24,500	30,300	23,700	13,200	13,200	13,200
Number of Pads Placed	up to 20	20	3	30	10	30
First Eggs Found						
Date	4/27/2005	4/5/2006	4/10/2006	4/4/2008*	4/14/2008	4/16/2008
Temperature	20.86	No Data	20.3	19.29	20.62	18.96
Discharge	37,400	15,200	16,000	13,400	13,500	16,500
Number of Pads Inspected	up to 20	62	3	29	14	37
Last Eggs Found						
Date	5/13/2005	5/1/2006	4/26/2006	5/14/2008	5/2/2008	4/18/2008
Temperature	23.76	21.92	25.0	23.78	23.37	19.77
Discharge	20,400	16,300	14,100	10,400	11,000	15,900
Number of Pads Inspected	up to 20	35	9	35	14	37
Pads Last Checked						
Date	5/16/2005	5/10/2006	5/10/2006	5/28/2008	5/28/2008	5/28/2008
Temperature	24.31	24.53	24.5	26.47	26.65	26.81
Discharge	16,700	13,000	13,000	6,520	6,520	6,520
Number of Pads Inspected	up to 20	35	9	34	12	37
# of Eggs Collected	**21**	**180**	**9**	**204**	**42**	**36**

Our telemetry results indicate that three different groups of sturgeons moved upriver from March 25 through May 18, 2008 (Table 7, Table 8, and Figure 12). The following information is consistent with the Pine *et al*. (2006) finding of sturgeons moving upriver in multiple groups.

Group 1

The first group was detected on March 25; tag #842 was detected below the JWLD and tag #1542 recorded at the VR-2 located at RM 101.5. Tag #842 weighed 94.0 lbs when captured and tagged in the Brothers River in September 2005; although sex was not determined, we suspect the fish may be a female due to its size. The fish was monitored in the upper river for about 3 weeks but may have been in the area earlier since we did not begin monitoring for tagged fish until March 25. Pine *et al.* (2006) reported that the same fish (tag #842) occupied the same area from about the third week in March to mid-April in 2006. Tag #1542 was recorded with the VR-2 located at RM 101.5 on 25 separate days, March 25 through April 30, 2008. Information retrieved from the VR-2 showed that this fish (tag #1542) displayed erratic behavior; the fish was detected almost daily during the period, sometimes for a few minutes to a few hours, and then the fish moved out of the area and was not detected again until the following day. On some days, tag #1542 would be detected up to four times at the VR-2 with separations of several hours between each recording. The continual back and forth movement of tag #1542 would suggest that this fish could be a male searching for a mate. Pine *et al.* (2006) also reported that tag #1542 had an extended stay in the upper river, from mid-April to the end of May 2006.

Group 2

A group of three fish, tags #844, #1544, and #1545, recorded upstream passage at the VR-2 during the third week in April and were detected going downstream at the VR-2 during the first and second week of May 2008. All three fish exhibited a similar pattern; moving upstream with an initial detection at the VR-2 located at RM 101.5, detection below the JWLD a few days later and, downstream detection at the VR-2 several days afterward. These three fish remained in the upper portion of the river for about 2 weeks. Pine *et al*. (2006) reported that tag #844 remained in the lower and middle river during 2006. Tag #844 is a large fish, weighing 83.0 lbs at time of capture in September 2005, and we suspect that this fish may be a female that did not spawn in 2005 but could have spawned this year. Tag #1544 was reported by Pine *et al.* (2006) to occupy the upper river from mid-April to early June, 2005. We also located tag #1544 in the upper river, from March 24 through May 6, 2008. Tag #1545 was detected in the upper river from March 28 through May 13, 2008 and exhibited a similar pattern when it was recorded in 2006.

Group 3

Tags #850 and #1546 only remained in the upriver area from May 12 through May 16, 2008. Tag #850 was collected and tagged in the Ochlockonee River in September 2005. This fish was detected moving upstream at the VR-2 located at RM 101.5 on May 12 and was not located again until its downstream detection at RM 101.5 on May 18, 2008. Tag #1546 was the last fish detected at the VR-2. The fish spent two days in the upper river, arriving on May 15 (after the last egg collection on May 14) and departing on May 16, 2008. In 2006, Pine *et al*. (2006) also reported that tag #1546 was one of the last tagged fish to arrive upriver, arriving the last week in May and departing in the first week in June.

Table 7. Number of detections and time period from first to last detection of telemetered Gulf sturgeons utilizing a VR-2 at RM 101.5 and a Vemco 100 unit.

Tag Number	VR-2 and Vemco 100 Recording Period	Number of VR-2 Detections	Number of Vemco 100 Detections	Total Detections
842	03/25/08 to 04/15/08	138	1	139
1542	03/25/08 to 04/30/08	1789	1	1790
844	04/21/08 to 05/02/08	140	2	142
1544	04/24/08 to 05/06/08	40	5	45
1545	04/28/08 to 05/13/08	119	1	120
850	05/12/08 to 05/18/08	56	0	56
1546	05/15/08 to 05/16/08	25	0	25
TOTAL		**2307**	**10**	**2317**

Table 8. Data on telemetered Gulf sturgeons detected in the 2008 study utilizing a VR-2 at RM 101.5 and a Vemco 100 unit.

Tag Type	Tag Number	Date Tagged	Location Tagged	Fork Length (in)	Weight (lb)	Sex
Vemco	842	09/22/05	Brothers River	69.00	94.00	Unk
Vemco	1542	11/07/05	Brothers River	52.50	38.50	Unk
Vemco	844	09/22/05	Brothers River	64.00	83.00	Unk
Vemco	1544	11/07/05	Brothers River	39.00	14.50	Unk
Vemco	1545	11/07/05	Brothers River	67.75	94.75	Unk
Vemco	850	09/13/05	Ochlockonee River	54.00	51.75	Unk
Vemco	1546	11/07/05	Brothers River	39.00	12.00	Unk

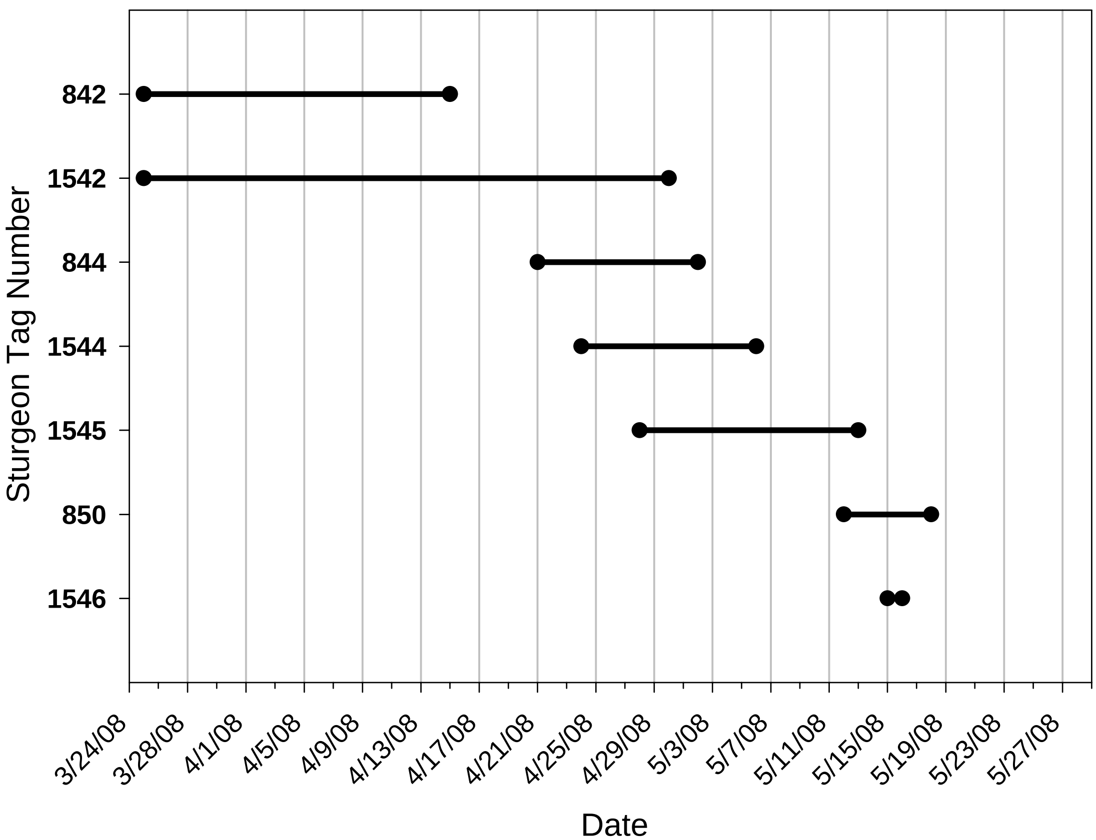

Figure 12. Time period from first to last detection of each individual telemetered Gulf sturgeon detected during study utilizing a VR-2 at RM 101.5 and a Vemco 100 unit. Three separate groups of sturgeon are indicated.

Telemetry information collected in 2008 with the VR-2 and the Vemco 100 regarding tagged Gulf sturgeon movement and length of stay in the upriver locations of the Apalachicola River is similar to what Pine *et al.* (2006) reported in 2006. We found that tagged fish had migrated to the upper river at the time the receivers were deployed, that fish were located at the spawning sites, and that all the tagged fish left the sample areas by May 18 after the last egg collection on May 14 and before the conclusion of the study on May 28, 2008. Although we can speculate that the larger fish may be females and may be using the spawning area, until the fish are sexually evaluated, equipped with tags and recorded with remote receivers placed below and above suspected and known spawning locations, we cannot be certain.

Gulf sturgeon exhibited a spawning period extending for 41 days, from April 4 to May 14, 2008 (Table 1). Furthermore, Gulf sturgeons were documented below the JWLD and at RM 101.5 on March 25, 2008. Spawning may have occurred prior to our first examination for eggs on April 4. If this was the case, it would lengthen the spawning period previously reported. FWS (2005), Ziewitz (2006), and Pine *et al*. (2006) reported that Gulf sturgeon spawning in the Apalachicola River in 2005 and 2006 lasted for 17 and 27 days, respectfully. Both studies observed a shorter spawning period; the difference in durations of the spawning periods may be related to the rate of water temperature increase. Bruch and Binkowski (2002) reported that the duration of the spawning period of lake sturgeon (*Acipenser fulvescens)* varied greatly over a 16-year study, from 2-14 days; the duration of spawning appeared to be influenced by rate of temperature rise, with a rapid increase in temperature resulting in a shortened spawning period. Although the range of temperatures observed during each spawning period (2005, 2006, and 2008) was similar (as discussed previously), the period when the temperatures were observed was shorter in duration in 2005 and 2006, indicating that temperature rose faster in 2005 and 2006 than it did in 2008. On the other hand, the efficiency of the egg samplers is unknown; it is possible that additional spawning may have occurred undetected in the sample areas. Consequently, the duration of the spawning periods could be underreported.

We suspect that multiple females likely contributed to spawning activity in the Apalachicola River during 2008 because we observed a 41-day spawning period, egg deposition at all three sample sites, and several spikes in egg collection over that period. Bruch and Binkowski (2002) reported that individual female lake sturgeons appeared to 'spawn out' after a period of 8-12 hours. Accordingly, a 41-day spawning period would most likely indicate the presence of multiple spawning female Gulf sturgeons during the period. Furthermore, we collected telemetry data indicating three groups of Gulf sturgeon located in the upriver area at different times. Egg and larval samples from each pad-inspection with eggs found (n = 102) have been preserved, and a genetic analysis of the samples is recommended to determine how many females may have contributed to the spawning in the Apalachicola River in 2008.

Conclusions

1. Gulf sturgeon spawning was documented with the collection of eggs at three sites in the Apalachicola River, one of which is newly confirmed.

2. The upper sample site accounted for the most spawning activity with 72% of the total eggs recorded during the study; the middle and lower sample sites recorded 15% and 13% of the total eggs, respectfully.

3. Telemetry indicated that three different groups of tagged Gulf sturgeon moved upstream at different times between March 25 and May 15, 2008.

4. Gulf sturgeon exhibited a 41-day spawning period. Combined with the multiple spikes in egg collection observed and evidence of three groups of sturgeon moving upriver, the information suggests that multiple females likely contributed to the spawning.

5. The majority of the eggs we collected followed decreases in discharge; however, we also found eggs following increases in discharge.

6. When the depths of egg collections from 2005, 2006, and the filtered 2008 depths are combined, the middle 80% of the data ranges from 7.2 to 17.1 ft, with a median of 11.3 ft.

7. Water temperature ranged from 19.12 to 24.41°C during the period when eggs were collected (April 4 to May 14), which is consistent with previous studies conducted on the Apalachicola River.

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