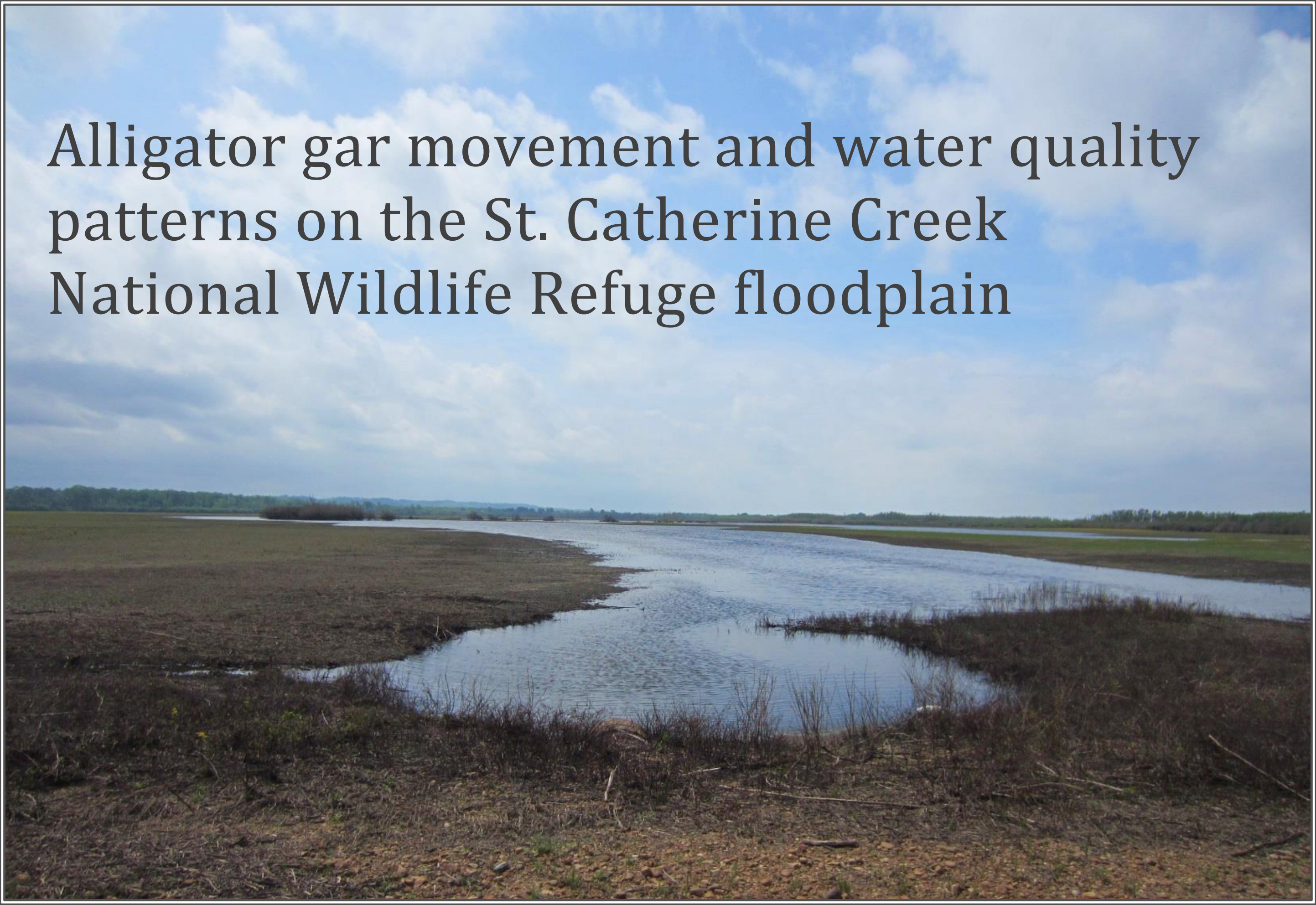
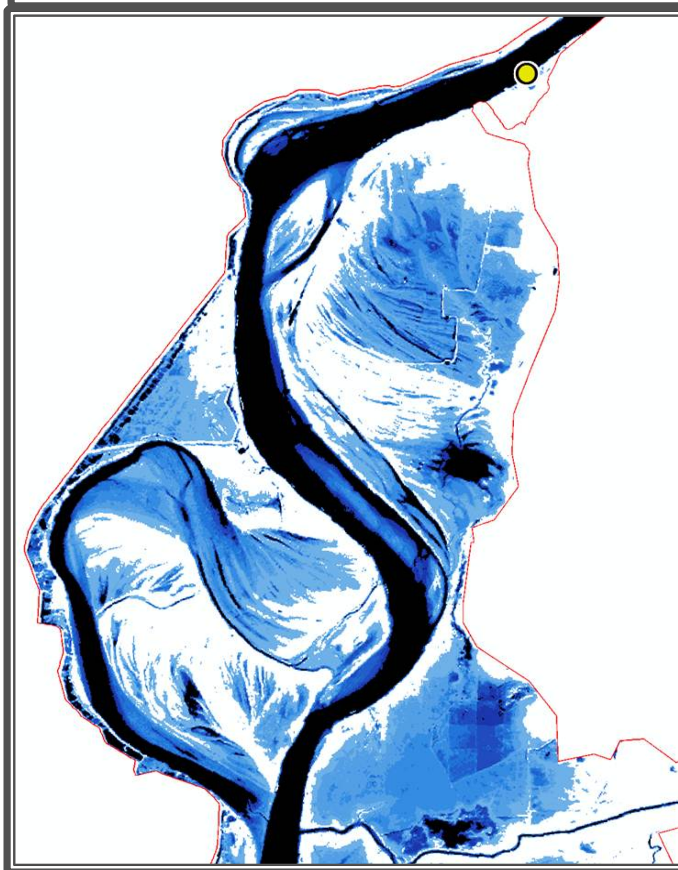
Alligator gar movement and water quality patterns on the St. Catherine Creek National Wildlife Refuge floodplain





U.S. FISH & WILDLIFE SERVICE

DEPARTMENT OF THE INTERIOR

SOUTHEAST AQUATIC RESOURCES PARTNERSHIP

SARP

GCPO

Gulf Coastal Plains & Ozarks Landscape Conservation Cooperative

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Introduction

The alligator gar (*Atractosteus spatula;* AG) is a large, long-lived, physostomous fish that prefer slow-moving rivers, bayous, and oxbows most of the year, and require access to inundated floodplains or wetland vegetation for spawning and nursery habitats (Inebnit 2009; Kluender 2011, Buckmeier 2013). Historically, AG were distributed throughout the central U.S., ranging from Oklahoma southward to the Gulf of Mexico but more recently, abundances have declined and AG is now considered vulnerable to localized extirpation (Ferrara 2001) . Several authors have cited habitat alteration and overexploitation as the most important factors in the pervasive decline in abundance (Robinson and Buchanan 1988; Simon and Wallus 1989; Etnier and Starnes 1993; Metee at al. 1996; Warren et al. 2000; Ferrara 2001; Jelks et al. 2008). Hydrologic alterations over the past century have disconnected much of the lower Mississippi River from floodplain and backwater spawning areas and this action has likely hindered reproductive success (Simmon and Wallus 1989; Etnier and Starnes 1993; Boschung and Mayden 2004). Due to concern for decreased population sizes, AG have been identified by the American Fisheries Society (AFS), the US Fish and Wildlife Service, many state fisheries programs, and the Gulf Coastal Plain Ozarks Landscape Conservation Cooperative as a species of concern in the Mississippi Alluvial Valley.

AG have frequently been observed using the floodplain on St. Catherine Creek National Wildlife Refuge (SCC) during spring spawning months and the Service's Refuge and Fisheries Programs have been engaged for many years in a partnership to collect AG from SCC for propagation at the Private John Allen NFH. In an effort to better understand the importance of SCC to AG and other floodplain-dependent species, this partnership began a tagging and telemetry effort of AG in 2010. This study was expanded in subsequent years to include an intensive telemetry array and continuous water quality monitoring coupled with a related landscape level analysis (Allen et al. 2014) of the SCC floodplain. The combination of detailed *in situ* observations coupled with landscape analysis on SCC allows for a greatly improved understanding of floodplain dynamics that would not have been possible otherwise.

Study Location

The floodplain on SCC (Figure 1) is one of the few areas of broad low-relief floodplain that is still directly connected to the lower Mississippi River. The refuge lies on a narrow corridor between the Mississippi River to the west and high elevations to the east. Federal protection levees were likely not constructed to the east of the river in this location because the relatively small protected area did not justify construction and maintenance costs. Variation in Mississippi River water level directly influences inundation extent and duration on the floodplain; however, there are several areas on the refuge that remain permanently inundated even when the Mississippi river is at a very low stand. Butler Lake is a 2.2 km^2 (547 acres) natural lake connected to the Mississippi River by St. Catherine Creek (Figure 2). During low water, a weir at the south end of the lake maintains water levels for fishing. The Bluehole is a 0.024 km^2 (6 acres) borrow pit lake that was formed after levees were constructed in an attempt to make more of the floodplain suitable for agriculture. When the levees breached during a flood, the Bluehole was reconnected to St. Catherine Creek and Butler Lake.

Methods

River Levels

Inundation extent on SCC was related to variation in the Mississippi river gage located at Natchez, MS (USACE 2012, USGS 2012), located 24 km upstream from SCC. Extent of inundation was estimated based on Landsat observations (Allen et al. 2014), telemetry data, and personal observation. Using this data, we designated 35 ft. at the Natchez gage as the average level in which flood water begins to overtop the banks and spill onto the floodplain in SCC, allowing access to floodplain habitat not available before this level.

Telemetry

AG were captured at either the Bluehole or Butler Lake on SCC (Figure 2). In March 2010, 11 AG from Butler Lake and in April 2010, 9 AG from the Bluehole were captured using 4-5 inch square monofilament gill nets. A V9 Vemco transmitter was externally attached to each fish at the base of the dorsal fin. In April 2011, 1 additional AG was captured from Bluehole and externally affixed with a V9 transmitter, but extreme flood conditions on the lower Mississippi river did not allow for any additional tagging. In January 2012, 21 AG were captured from Bluehole and a V9 transmitter was internally implanted into the abdominal cavity through the fleshy ventral side of the pelvic fin at the base of the body. In addition, 20 of these fish were internally implanted with an ATS radio transmitter to better aid in location while in the shallow waters of the floodplain. In March 2013, 20 additional AG were captured in Bluehole and internally tagged with Vemco V16 transmitters. Data from the fish tagged in 2012 and 2013 comprise the main focus of this report.

Stationary Vemco VR2W passive receivers were used to record movement detections of individual transmittered AG. In 2010, a limited array of six receivers was initially established in permanent water bodies and near the confluence with the Mississippi River to determine habitat usage. Although flood conditions in spring 2011 did not allow for a full tagging effort, receivers were still monitored and downloaded throughout the year. In spring 2012, more receivers were deployed onto the floodplain guided by inundation frequency Figure 3). In January 2013, an even broader receiver array was established to more carefully assess floodplain use. The placement of receivers was intended to represent a broad variety of habitat types across the SCC floodplain (Figure 5). "Open permanent water" and "channel" are locations that are persistently inundated. "Open field" is a broad open floodplain area having low vegetation that is intermittently inundated. "Road/ thick vegetation" habitats are also intermittently inundated but have low vegetation only along a path and higher vegetation including shrub/scrub or forest on either side. "Thick vegetation" may have small open water areas that retain water, except for the driest conditions. These small pockets of water are, however surrounded by forest. "Dense woods" locations are intermittently inundated and dominated by forest with closed canopy.

For each telemetry receiver, the average number of individual gar detected per day was calculated within six periods of coherent temperature and inundation conditions for 2013: Cool/High, Cool/Low, Spawn, Warm/High, Intermediate, and Warm/Low. During "Cool/High" (27 March - 10 April), river levels were high enough to allow broad access to most of the floodplain but temperatures were cooler than typical for spawning (less than 23 degrees C). During "Cool/Low" (12 April – 22 April), water levels fell, restricting general access to the floodplain and temperatures were less than typical for spawning. During "Spawn" (1 May – 31 May) water levels were high enough to allow broad access to most of the floodplain and temperatures were ideal for spawning (23-26 degrees C) (Inebnit 2009; R. Campbell, USFWS Hatchery Manager, Personal Communication). During "Warm/High" (1 June – 7 July) water levels were high enough to allow broad access to most of the floodplain and temperatures were above what is typical for spawning (26+ degrees C). During "Intermediate" (8 July – 31 July) water levels were variable and were temperatures above what is typical for spawning (26+ degrees C). During "Warm/Low" (1 August – 25 august) water levels restricted access to the floodplain and temperatures were above what is typical for spawning (26+ degrees C).

Water Quality

Guided by inundation frequency maps (Allen et al. 2014) and local knowledge, ten YSI 6920 V2water quality loggers were deployed throughout the SCC floodplain in 2012 and 2013 (Figure 6) to monitor floodplain water quality conditions during seasonal flooding and dewatering. Water quality parameters measured were temperature, conductivity, dissolved oxygen, pH, and turbidity at 30 minute intervals near the surface of the water column. Each logger was downloaded and recalibrated monthly. Loggers in Salt Lake, Butler Lake, Mouth of St. Catherine Creek, and Bluehole were persistently inundated and recorded information throughout most of the year. The remainder of the YSI loggers were removed after floodwaters receded. Temperature in the main channel of the Mississippi River was downloaded from the nearest USGS gaging station in Baton Rouge (USGS 07374000; USGS 2013) located 193 river kilometers downstream of SCC.

Results

River Levels

In spring 2012, floodplain inundation in SCC during the typical spring spawning season was unusually brief. Mississippi River levels at Natchez exceeded 35 feet, the water level in which fish start to have access to the floodplain, for only 67 days total from January through August (Table 2). In 2010, 2011 and 2013, river levels greater than 35 feet were all above the long-term (1983-2012) average of 116 days. In 2010, the Mississippi River was above 35 feet January through August for 197 days, in 2011 it was over for 147 days and in 2013 the river exceeded 35 feet for 163 days.

Telemetry

Telemetry data showed consistent results of repeat observation, site fidelity and movement patterns between all years. In all years, there was a high rate of repeat observation of tagged fish. Of the 20 fish that were externally tagged in spring 2010, 17 were observed at least 7 days immediately after release and 14 were observed consistently through the summer and into 2011. In the fall of 2011, after the historic Mississippi River flood in the spring of that year, only 5 of the 2010 tagged fish were still able to be tracked. Loss of tracking may have been due to death, exit from the SCC receiver array, transmitter battery failure, or transmitter shedding of these externally tagged fish. Of the 21 fish internally tagged in spring 2012, all fish were detected for at least 7 days immediately after release, 17 were observed consistently throughout the summer and fall of 2012, and 14 were also observed on the SCC floodplain through the spring and summer of 2013. Of the 20 fish that were internally tagged in spring 2013, 17 were observed for at least 7 days immediately after release, and 16 were observed on the SCC floodplain throughout the summer of 2013.

During all years, AG showed similar movement patterns but because receiver deployment was greatest in 2013, only receiver data results from 2013 are presented but will include active fish tagged from all years.

In all years, tagged AG showed a preference for remaining resident the deep water refuge of the Bluehole on SCC when water levels did not allow access to the floodplain. Other studies show the same results with different gar species (Bonvillain 2006). In early 2013 when water levels were high, but water temperatures were still too cool for spawning, AG left the deep water refuge areas and moved onto the floodplain. There did not appear to be a distinct preference for habitat type. Table 3 shows detailed results of environmental conditions and movement patterns of 32 fish tagged in spring 2012 and 2013. As water levels fell in April, AG moved from floodplain habitat back to open water and channel habitats. Figure 7 shows the movement patterns on a map with the approximate extent of inundation during each time period. When water levels rose again in May, AG dispersed broadly to all habitat types on the floodplain. As water levels remained elevated during June and into early July, AG remained dispersed on the floodplain. During May, June and even early July our tagged AG averaged more gar per receiver at habitat types considered "open field". As water levels declined in August, AG moved back to deep water refuge of the bluehole.

Using the minimum suitable inundation level of 35 feet (Natchez gage) and the ideal thermal temperature of 23-26 degrees C, we characterized the spawning conditions for AG. During 2012, the duration of both suitable inundation and thermal conditions for AG spawning lasted only about 19 days (22 March – 10 April) before river levels declined and AG moved back to the Bluehole. In 2013, thermal and inundation conditions were suitable for a minimum of 30 days (1 May - 31 May) after which temperatures rose higher than 26 degrees, but inundation still allowed AG to access the SCC floodplain for another month. The distribution of AG during the potential spawning period in each year was compared with the results from the AG spawning habitat suitability model developed in the companion document (Allen et al. 2014, Figure 8). The average number of unique individuals appeared highest at receiver locations that also had the highest suitability rank. In addition, ground observations of spawned eggs on 25 April 2013 and spawning adults in 22 April 2014 also occurred on areas that were predicted to have the highest spawning habitat suitability based on the landscape model.

Water Quality

Water quality showed clear responses to variation in location, season and river level. At this latitude, the mainstem Mississippi River is colder than the surrounding aquatic environments in the winter and spring. This was observed by both the remotely sensed data and also by water quality loggers. The connectivity to the Mississippi River and proximity from the connection dictates patterns in temperature on the floodplain. Floodplains that are more directly connected with the river will experience rapidly changing water temperature as the river rises in the spring. In general, locations higher in the SCC floodplain experienced more dampened or delayed thermal response to changes in river level compared with locations more proximate to the mainstem Mississippi. Temperatures recorded at the Bluehole during winter and spring were generally warmer compared with mainstem Mississippi River temperatures (Figure 9, Table 4). Temperatures at Butler and Salt Lakes were more frequently and rapidly influenced by rising river levels compared with locations further up in the floodplain. The temperature difference was not as great through the summer and fall. Table 5 shows the average thermal conditions at all water quality logger locations through 2013 during the same periods as those used in the telemetry analysis.

In addition to temperature variability coming from the mainstem Mississippi River, runoff from the draining floodplain can cause large increases or fluctuations in temperature. In spring 2012, large spikes in temperature were reported at the Bluehole as warm floodplain waters receded. This event also caused large variations in DO and conductivity (discussed below). This effect is most noticeable in the winter and spring at this latitude when the runoff from the land may be much warmer than the receiving waters.

Deviations in dissolved oxygen patterns appeared to be related to variation in river levels and landscape position. River rise causes temperatures to decline, but also brings highly oxygenated water (Figure 10). The landscape position of the Bluehole allows fish access to the floodplain and increases in DO with increasing river stages, but it also receives direct drainage from most of the SCC floodplain with declining river stages. The impact of extreme floodplain runoff was particularly evident in spring 2012 after an unusually brief spring high water period. As floodwaters receded from the SCC floodplain, reported DO went to zero for 18 days at the Bluehole. A similar DO decline was also seen in Butler Lake during the same time period as the floodplain water receded, but average daily values only fell below 50% saturation for 11 days. During the remainder of the summer in 2012, the Bluehole was isolated from both the floodplain and the mainstem Mississippi river and minimum DO saturation commonly fell below 20% throughout the summer and fall. Transmittered AG maintained in the bluehole despite the low dissolved oxygen and disconnect from the river.

In 2013, the flood cycle was more typical and allowed for more extensive monitoring of water quality conditions on the floodplain. During 2013, the same pattern of response was seen with varying river levels but although DO levels got quite low at the Bluehole, there was no event as extreme as that seen in spring 2012 (

Figure 12). In April 2013, a water quality logger was placed at a location high in the floodplain that could still hold water with temporarily declining river stages. As floodplain waters receded, minimum oxygen saturation values at this location were driven to near zero for most of the month. As the river rose and this location became well connected to the floodplain again, oxygen values increased, frequently becoming supersaturated during the day throughout May. As river levels began to stabilize, the daily variability in DO saturation increased and as the river began to fall, oxygen values declined again. A late season pulse in river levels repeated this same pattern. DO conditions at the Bluehole were more moderate, but showed the same pattern of being highly affected by both river stage and runoff from oxygen depleted floodplain waters.

Conductivity measurements also varied by location on the SCC floodplain (Figure 14). During high river levels, conductivity measurements were stable and primarily influenced by connectivity to the river. The extreme low DO event in spring 2012 was also reflected in high conductivity and turbidity measurements in both Butler Lake and the Bluehole as they received waters draining off the floodplain. Locally heavy rainfall events produced sharp drops in conductivity, particularly for the Bluehole which is very small relative to the amount of runoff it can receive. Water quality loggers were retrieved at the end of July in 2013 as the floodplain waters receded.

Discussion

This work documents two complete annual cycles of both floodplain water quality and AG movement on SCC. Similar to the results of Buckmeier et al (2013), Inebnit (2009) and Kluender (2011), we found that tagged AG showed strong fidelity to specific locations. In spring 2012, 85% of tagged AG remained resident in the extremely confined 6 acres of the Bluehole through the summer. In 2013, 80% of fish tagged in spring 2013 remained resident despite prolonged high connectedness with the Mississippi river from May through the end of July. Thermal condition may be one reason that adult AG show high site fidelity to SCC Bluehole and floodplain. Field observations demonstrated that temperatures at the Bluehole were, on average, 4-5 degrees C warmer than the mainstem Mississippi river throughout the winter and spring. Adult AG were detected less frequently in other permanently inundated water bodies (Butler and Salt Lakes) on SCC. These floodplain lakes are more directly connected with the mainstem Mississippi river and as a result, they more commonly experienced sharp declines in temperature with rapid increases in river level. Similarly, an intensive deployment of strategically placed continuous water quality monitors revealed that water quality variation on the floodplain can be extreme – changing dramatically depending on location in the floodplain, river stage, precipitation, season and time of day. The thermal advantage offered on the SCC floodplain may be an important factor in AG spawning habitat suitability affecting spawning success and rapid growth in young of the year.

Water quality monitors also documented extreme low oxygen conditions in waters receiving floodplain drainage. Adult AG are capable of facultative air breathing so they were able to tolerate the extreme low DO event that was recorded in the Bluehole in spring 2012 and other low oxygen events that occurred throughout the summer in both 2012 and 2013. For adult AG, therefore, thermal limits appeared to be more important than other water quality concerns and efforts to improve conservation opportunities for adult AG may be best focused on providing an appropriate thermal refuge with less concern for the impact of poor oxygen conditions. Oxygen limits for larval and juvenile AG, however are not as well understood.

Rigorous comparisons of fish distribution by habitat type are probably not justified given variable detectability of tagged alligator gar from our receivers. Vegetation density, water depth, line of sight and wind all can have a strong influence on the ability of receivers to consistently detect transmitters. There seemed to be a slight preference shown for detection at open field locations, but again, receivers at these locations also had some of the greatest probabilities of detection because there was very little obstruction from vegetation or embankments. Nonetheless, qualitative comparisons of distribution by habitat type have been very informative.

To help determine AG movement patterns, the 2013 temperature and inundation conditions were grouped into six different periods: "Cool/High" (27 March - 10 April), "Cool/Low" (12 April – 22 April), "Spawn" (1 May – 31 May) (23-26 degrees C), "Warm/High" (1 June – 7 July), "Intermediate" (8 July – 31 July), and "Warm/Low" (1 August – 25 August). These time periods were based on an optimal range of temperature and inundation for AG. It is unclear if there is an exact range of temperature and inundation in which AG can and cannot spawn. It is likely that AG are more flexible in temperature selection than we report and may be able to spawn in temperatures higher than 26 degrees and lower than 23 degrees. It is also unclear if AG will choose to spawn at suboptimal inundation conditions. There is a gradient of AG presence on the floodplain between 30 and 40 feet at the Natchez gage (Allen et al. 2014), but it is possible that gar may be able to spawn in suitable habitat directly adjacent to permanently inundated open water bodies when the floodplain is unavailable. In addition, the six analysis time periods define coherent time periods of at least ten days having similar conditions of temperature and inundation. AG may take advantage of brief transition periods of only a few days that may also have suitable conditions. For instance, ground observations of spawned eggs were found on 25 April 2013 at 23.8 degrees. Conditions of inundation and temperature on this date were changing rapidly and therefore were not included into one of the six periods of coherent temperature and inundation. It fell just outside of “cool/low” and before “spawn”. This observation of AG eggs means spawning occurred within the prior 3 days where localized conditions for spawning may have been suitable, but they were not broadly available throughout the SCC floodplain. An additional observation of AG spawning occurred high on the floodplain on 25 April 2014 when broad floodplain conditions were suitable: the river level at Natchez was 46 feet and floodplain water temperature was 24^{o}C. Temperature on the mainstem Mississippi river on that same date was 15^{o}C.

Challenges and Future Research

Stationary receivers and more powerful transmitters have helped make collecting telemetry data easier and less time consuming. Smaller transmitters with longer battery life are also more ideal for internal tagging, the method found to work best in this study. That technology coupled with repeated water quality data, satellite imagery and spatial analysis resulted in a more powerful interpretation of results compared with studies where each of these components was completed in isolation. There are, however, some important questions that remain to be addressed. In this study, the highest number of tagged adult AG were found near telemetry receivers that were located in “open field” habitats when water levels allowed open access to the whole floodplain. Likewise, AG were seen spawning in suitable open field habitats on SCC in April 2014. What remains somewhat unclear is whether this open canopy physical habitat is *required* for AG spawning. There are many forested areas on the Mississippi river floodplain and it is unclear whether these habitats are, in fact, unsuitable for AG spawning. Spawning was observed in open canopy habitats, but such habitats are relatively easy to access and there was no complementary effort to determine whether spawning also occurred in habitats that were more densely wooded.

In addition, the highest numbers of AG were detected in open canopy habitats, but they were also detected in lower numbers at receivers located in all other habitat types (

Table 3). Receivers located in “open field” habitats may have simply recorded more individuals because they had an increased range to detect tagged AG compared with receivers located in more densely vegetated habitats. Many receivers that were classified as “open field” habitat were also actually directly adjacent to forested areas. Habitats that were classified as a specific single type for analysis purposes are very complex and are directly adjacent to other habitat types. It may be that AG prefer this ecotone between two differing habitat types. More data will be analyzed for upcoming reporting and hopefully future studies will address some of these pending questions.

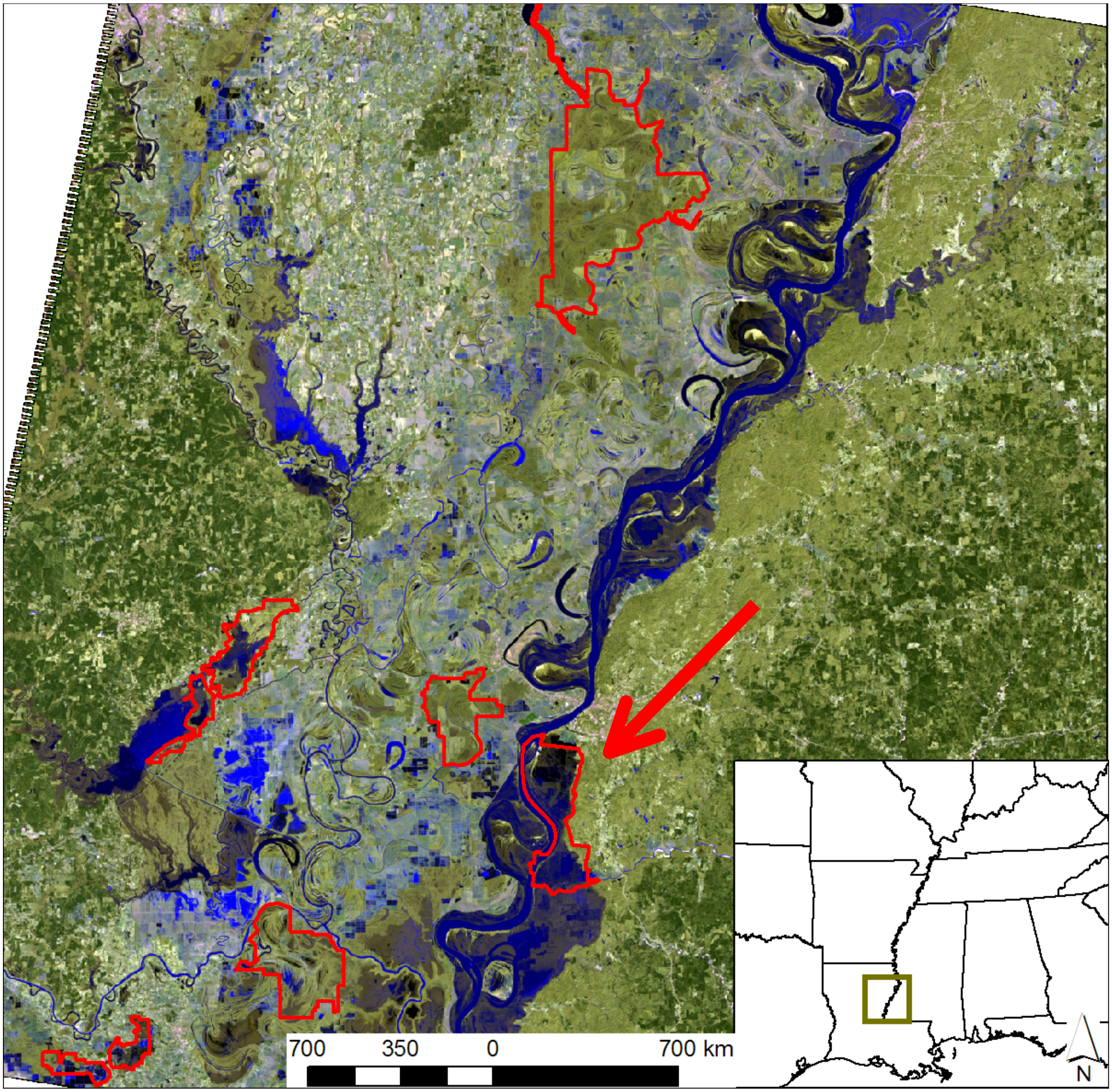
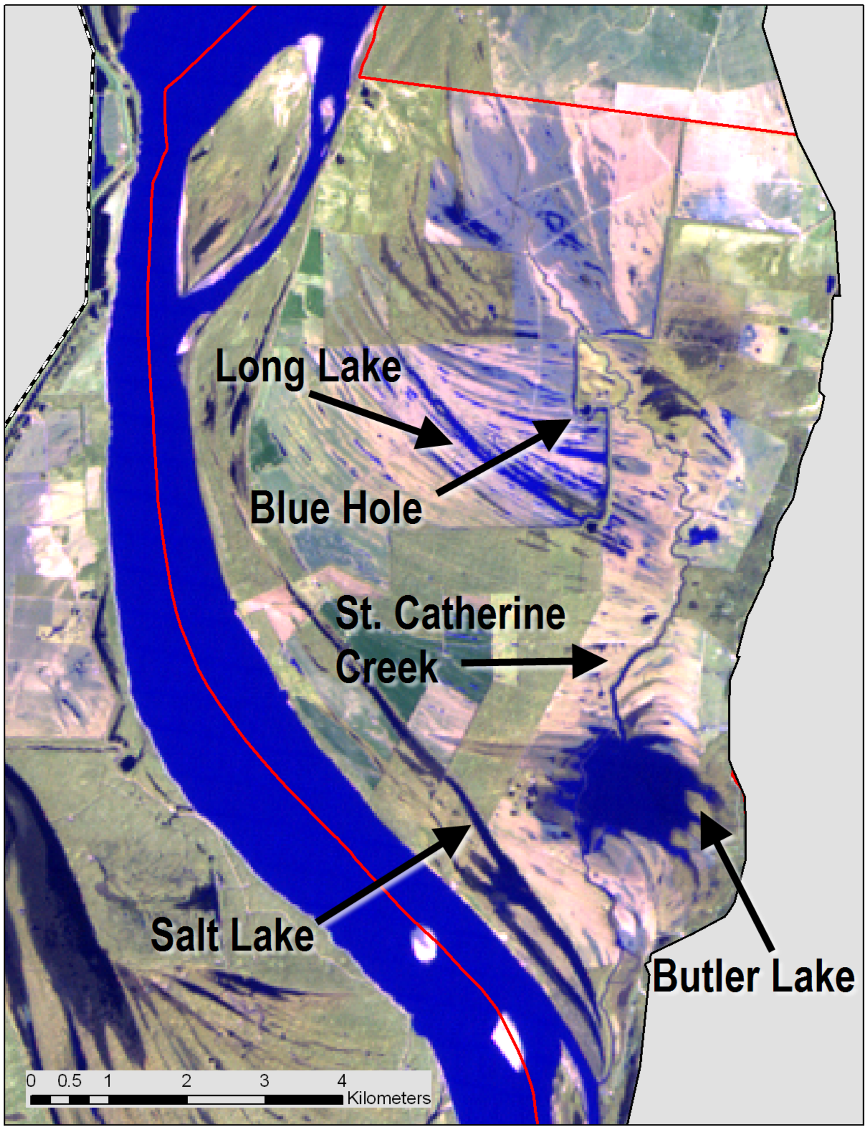


Figure 1. National Wildlife Refuge (NWR) boundaries are outlined with red. The location of the St. Catherine Creek (SCC) NWR is indicated with an arrow. Background Landsat imagery is from 16 Feb 2010 and shows extensive inundation (darker areas) on the SCC floodplain.


Long Lake
Blue Hole
St. Catherine
Creek
Salt Lake
Butler Lake
0 0.5 1 2 3 4
Kilometers

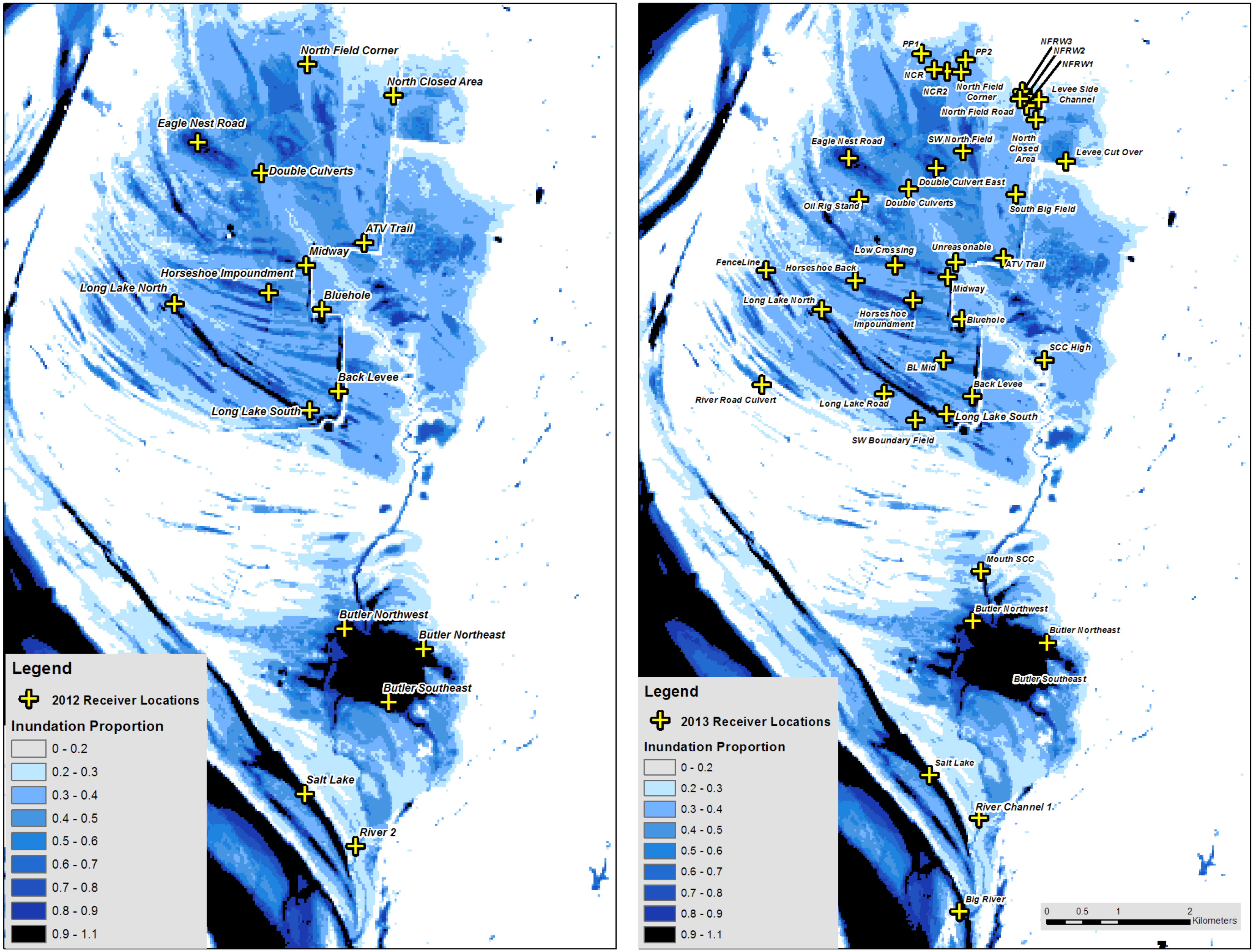


Figure 3. Telemetry receiver locations in St. Catherine Creek NWR.

Figure 5. Selected receiver locations and habitat types within St. Catherine Creek National Wildlife Refuge. Upper left: North Closed Area – open field; Upper right: North Field Road – open field; center left: ATV Trail - channel; center right: North Cut Road – road/thick vegetation; lower left: Oil Rig Stand – thick vegetation; Lower right: NFR - dense woods.

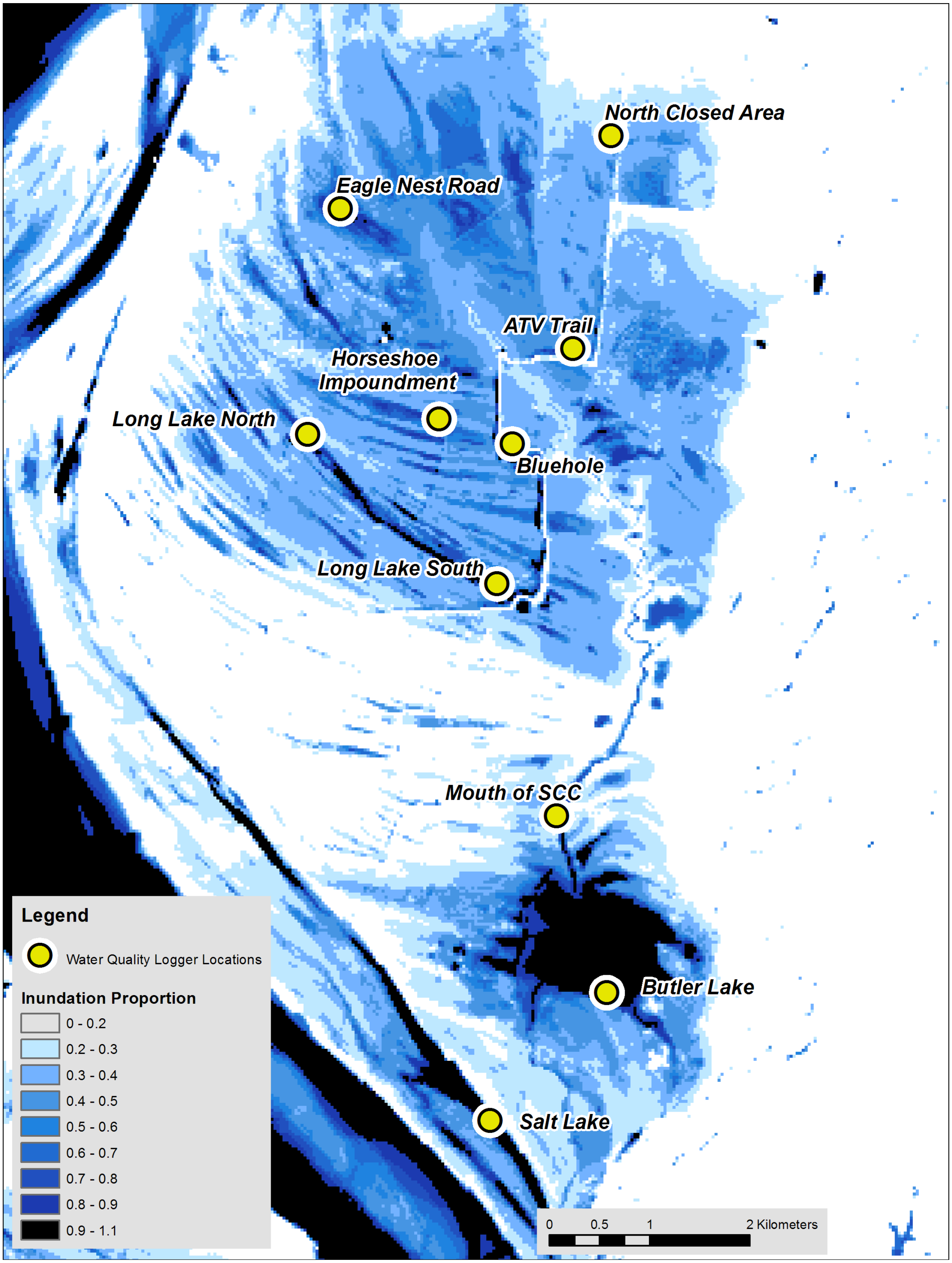


Figure 6. Location of YSI water quality loggers on St. Catherine Creek NWR floodplain.

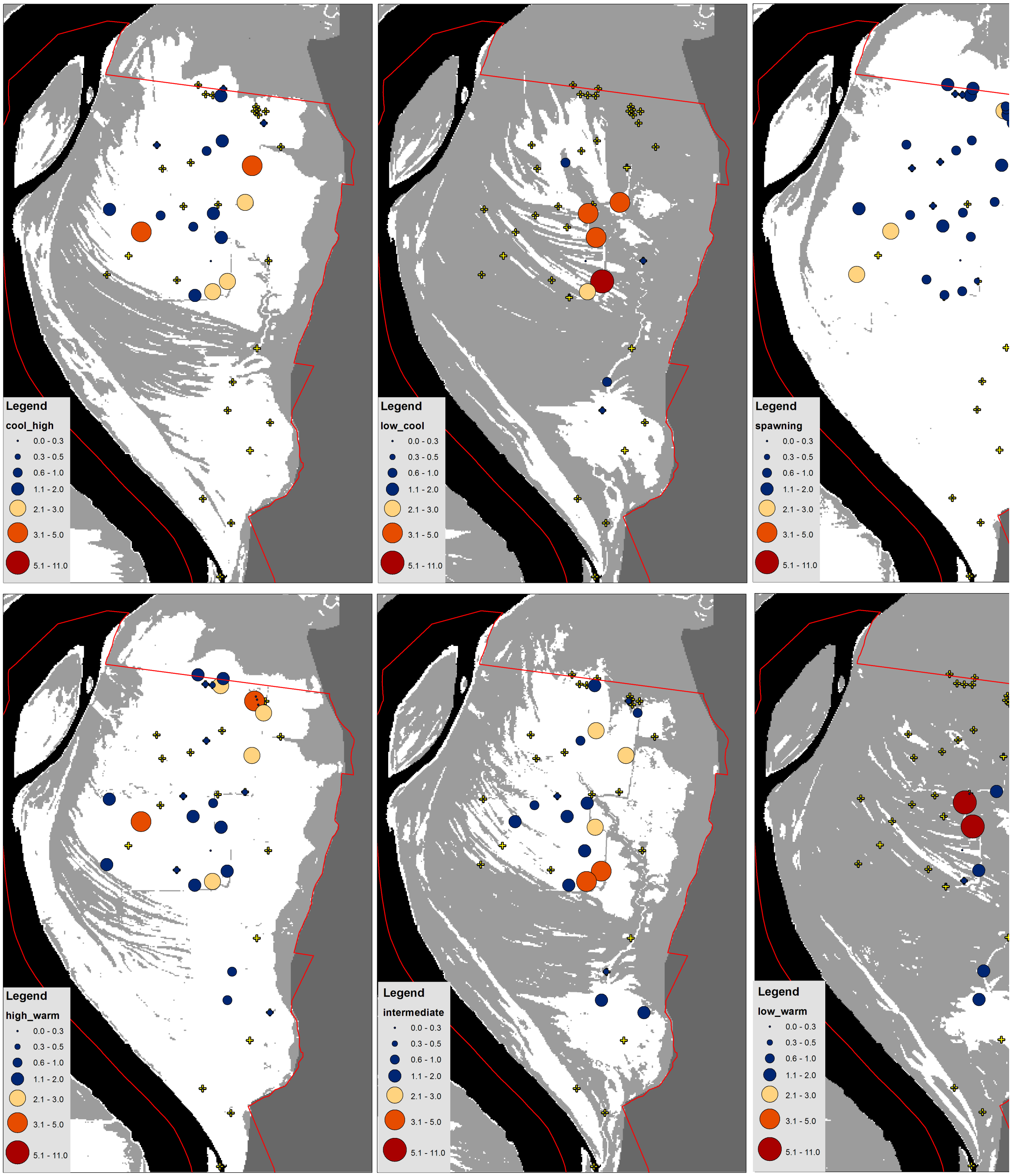


Figure 7. Patterns of alligator gar movement on St. Catherine Creek National Wildlife Refuge floodplain during spring and summer of 2013. Each panel depicts the average number of individuals observed at each telemetry receiver during six time periods of coherent temperature and water level conditions. Cool-High: 27 March – 10 April; Low-Cool: 12 April – 22 April; Spawning: 1 May – 31 May; High-Warm: 1 Jun-7 July; Intermediate: 8 July-31 July; Low Warm: 1 Aug – 25 Aug. The estimated extent of floodplain inundation during each time period is shown as a white background. Receivers that were deployed but did not report any detections are shown as a yellow cross.

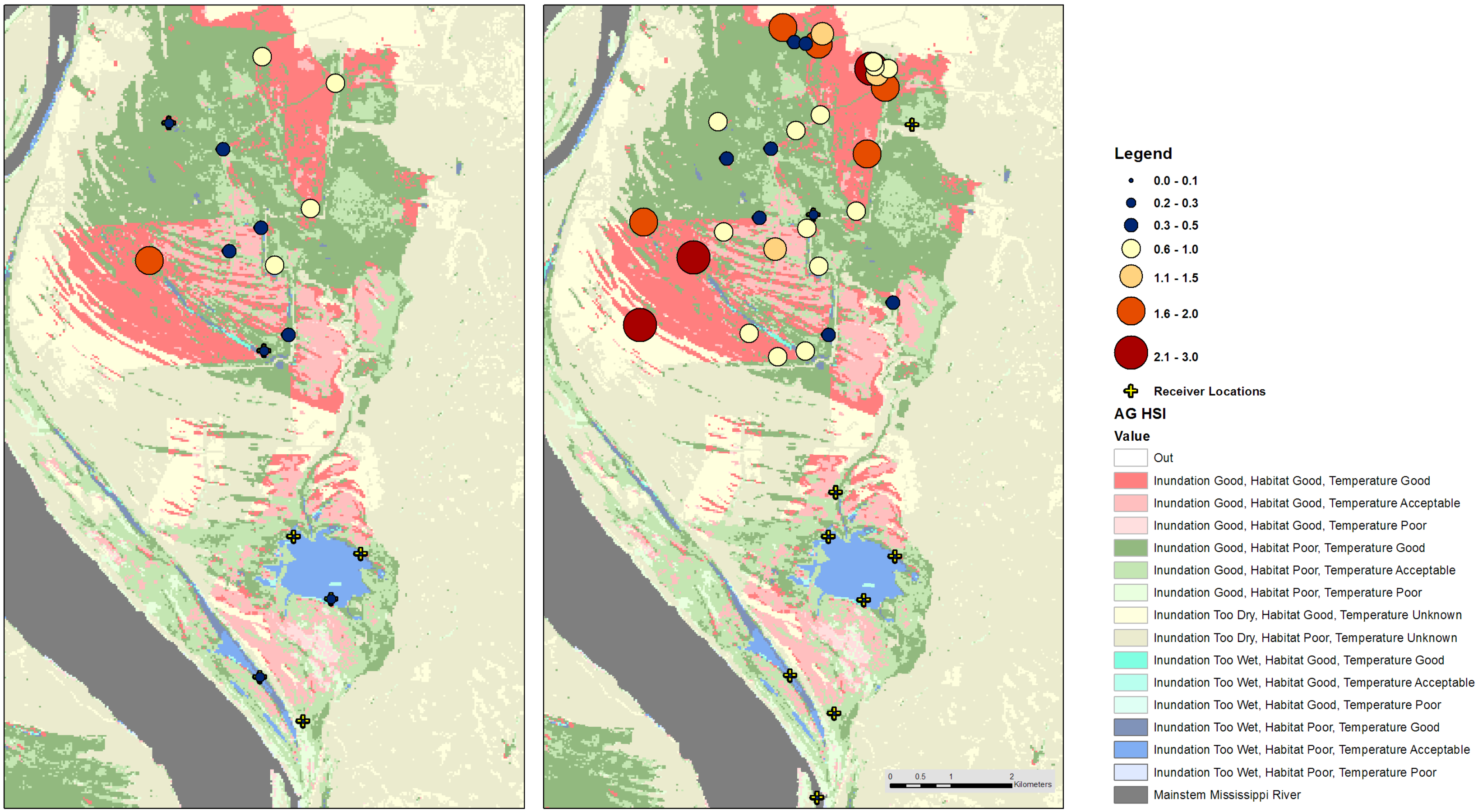


Figure 8. AG habitat suitability rank in St. Catherine Creek National Wildlife Refuge in 2012 (left panel) and 2013 (right panel). The size and color of each dot relates to the average number of unique AG recorded at each receiver during the spawning season (defined as 22 March – 10 Apr 2012 and 1 May - 31 May 2013).

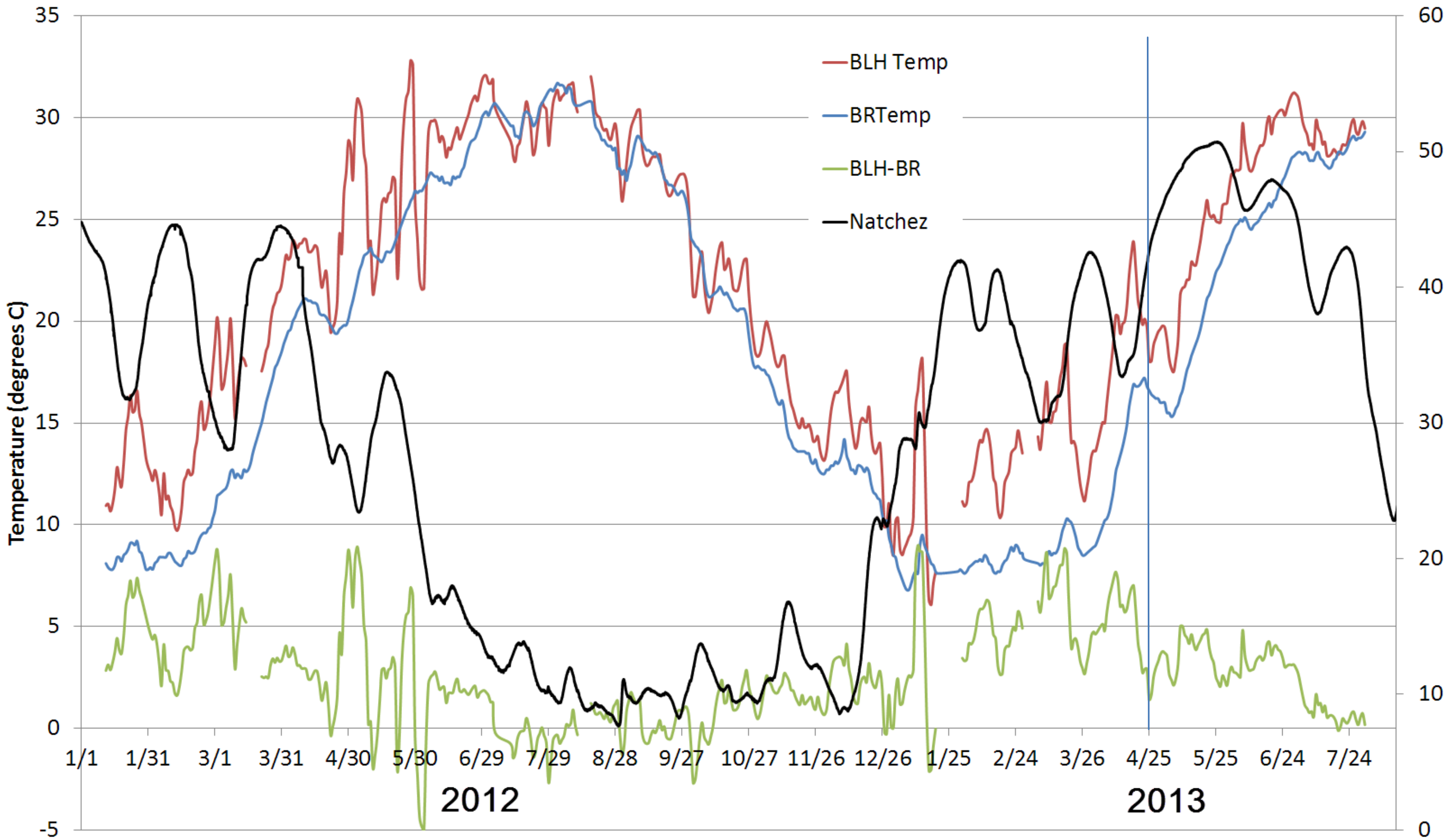


Figure 9. Comparison of temperature reported at the Bluehole (BLH) on St. Catherine Creek National Wildlife Refuge and mainstem river temperature at Baton Rouge, LA (BR). Green line indicates the temperature difference (temperature at Bluehole minus temperature of the mainstem Mississippi River at Baton Rouge, LA). Mississippi River stage at Natchez, MS is indicated with a black line.

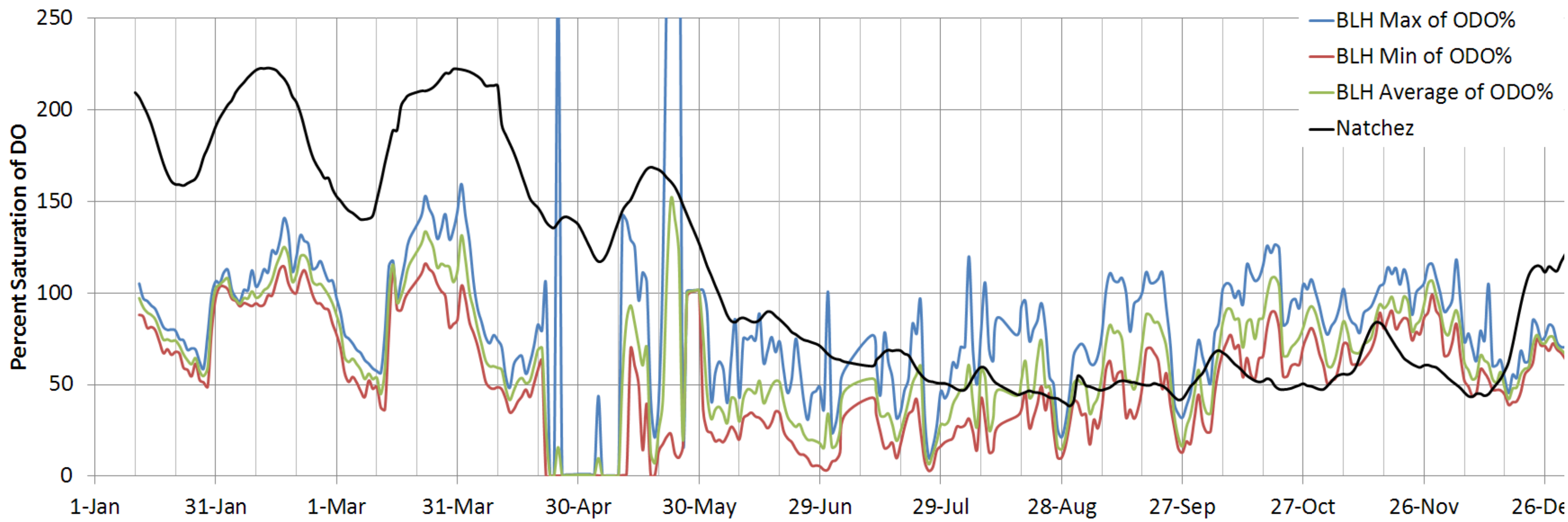


Figure 10. Patterns in maximum, minimum and average daily dissolved oxygen saturation at the Bluehole related to changes in river stage in 2012. Mississippi River stage at Natchez, MS is indicated with a black line.

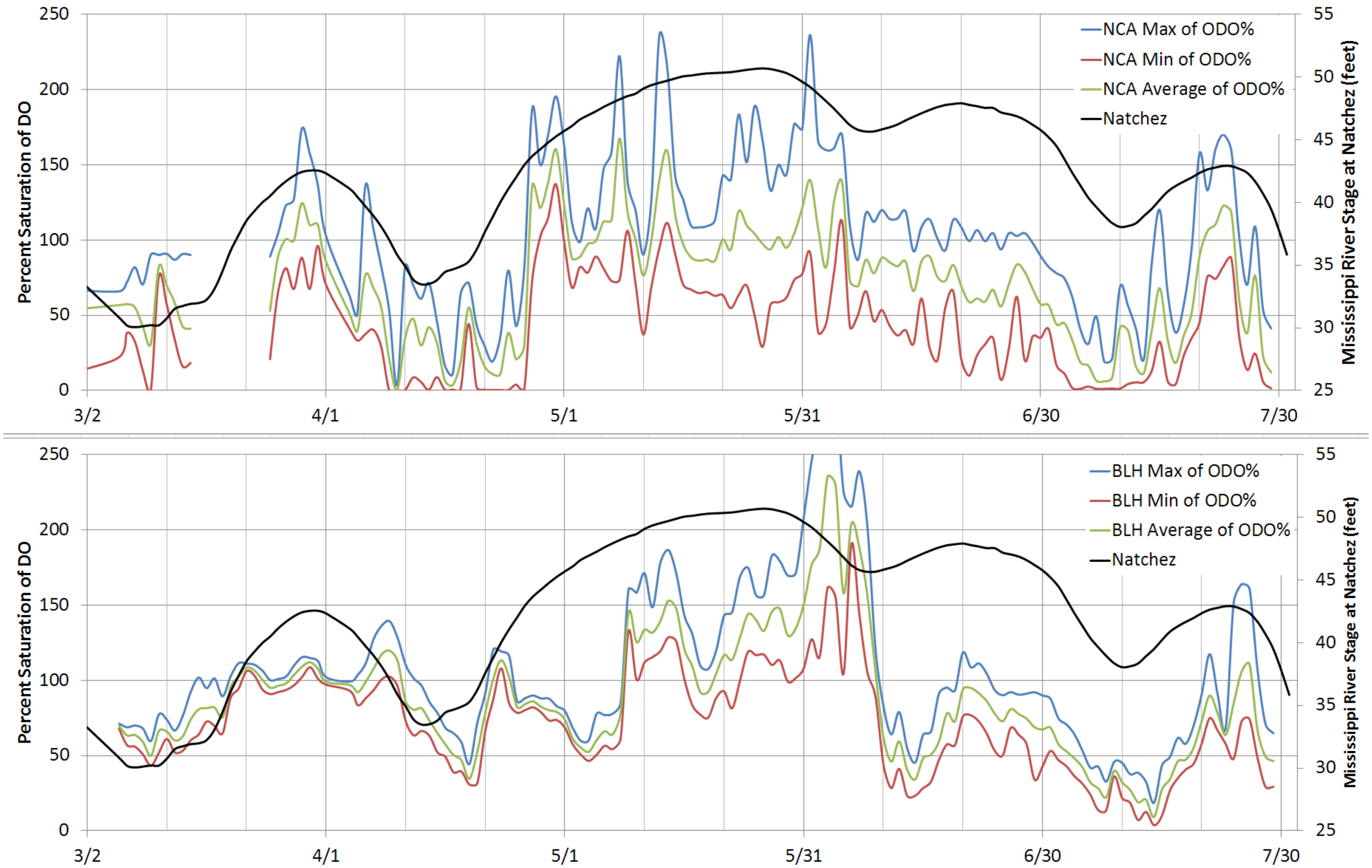


Figure 12. Patterns in maximum, minimum and average daily dissolved oxygen saturation at the North Closed Area (upper panel) and at the Bluehole (lower panel) related to changes in river stage in 2013. Mississippi river stage at Natchez is indicated with a black line.

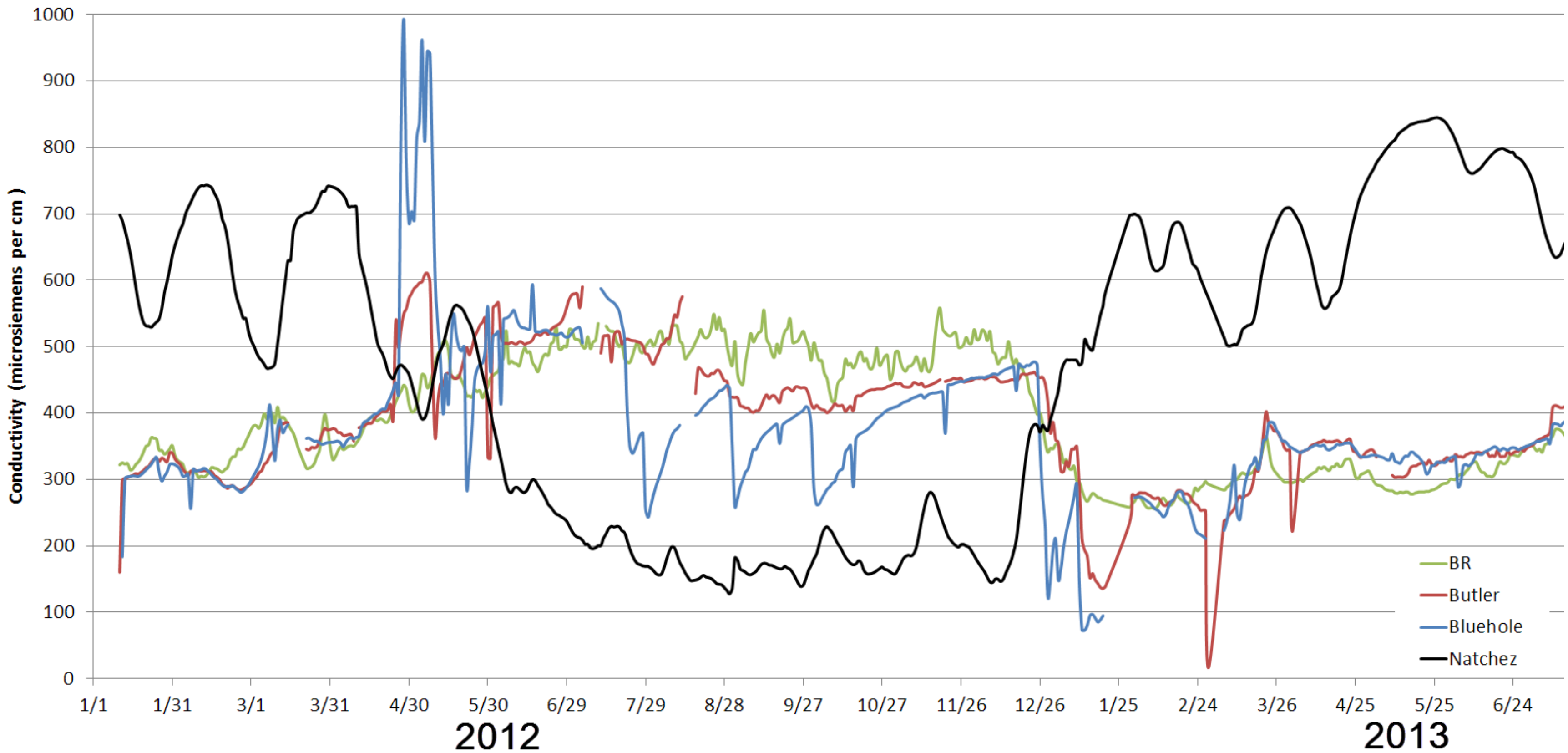


Figure 14. Average daily conductivity measurements in 2012 and 2013 at the Bluehole and Butler Lake on the St. Catherine Creek National Wildlife Refuge and in the mainstem Mississippi River at Baton Rouge. Mississippi River stage at Natchez, MS is indicated with a black line.

Table 1. Locations, dates, and type of transmitters implanted into alligator gar (AG) at St. Catherine Creek NWR.

Capture/Tag Date	Capture Location	Transmitter	Total AG Tagged
9-Mar-10	Butler Lake	Vemco V9	10
23-Mar-10	Butler Lake	Vemco V9	1
26-Apr-10	Bluehole	Vemco V9	9
25-Apr-11	Bluehole	Vemco V9	1
18-Jan-12	Bluehole	Vemco V9	10
19-Jan-12	Bluehole	Vemco V9	11
13-Mar-13	Bluehole	Vemco V16	17
14-Mar-13	Bluehole	Vemco V16	3

Table 2. Number of days in each month from 2010-2013 where Mississippi River stages at Natchez exceeded 35 feet. Long term average from 1983-2012 is provided for comparison.

Month	2010	2011	2012	2013	Average (1983-2012)
Jan	23	0	20	12	12
Feb	28	0	22	25	15
Mar	25	28	15	13	21
Apr	27	30	10	22	21
May	28	31	0	31	20
Jun	30	30	0	29	18
Jul	26	28	0	31	9
Aug	10	0	0	0	1
Total	197	147	67	163	116

Table 3. Location and description of alligator gar observations by telemetry receivers deployed in spring 2013. Observations of alligator gar at each receiver are reported by coherent thermal and hydrologic time periods. Observations are the average numbers of individual fish detected per day at each receiver during each coherent time period. The highest values are shaded in red and zeros are shown in light grey. Grey shading indicates that the receiver was not functional during that time period.

2012 and 2013 Tagged Fish				Average Number of Individuals Per Day in 2013					
				27 Mar – 10 Apr	12 Apr – 22 Apr	1 May – 31 May	1 Jun – 7 Jul	8 Jul – 31 Jul	1 Aug – 25 Aug
Natchez River Stage (feet)				40-42	33-39	46-50	46-48	35-42	23-34
Receiver Location	Habitat Category	Latitude	Longitude	Cool/High	Cool/Low	Spawn	Warm/High	Intermed	Warm/Low
Big River	open perm water	31.39241	-91.45963	0.00	0.00	0.03	0.00	0.04	0.00
Bluehole	open perm water	31.47139	-91.45803	1.87	7.18	1.23	1.92	3.04	19.44
Butler NW	open perm water	31.43114	-91.45697	0.27	1.18	0.03	0.70	2.58	2.12
Butler NE	open perm water	31.42810	-91.44550	0.13	0.36	0.26	0.46	1.96	1.52
Butler SE	open perm water	31.42222	-91.45093	0.33	0.55	0.06	0.54	2.63	
Long Lake North	open perm water	31.47296	-91.47978	5.00	0.18	2.94	5.54	1.42	0.00
Salt Lake	open perm water	31.41066	-91.46400	0.00	0.00	0.00	0.05	0.08	0.00
Back Levee	channel	31.46113	-91.45651	4.60	8.00	0.68	1.86	5.17	2.48
ATV Trail	channel	31.47945	-91.45143	3.87	10.82	1.19	0.70	0.13	2.28
Double Culverts	channel	31.48890	-91.46603	0.00	0.00	0.48	0.00	0.38	0.32
Levee Cut Over	channel	31.49222	-91.44151	0.00	0.00	0.23	0.00	0.00	0.00
Levee Side Channel	channel	31.50056	-91.44549	0.00	0.00	2.10	0.51	0.08	0.00
Long Lake South	channel	31.45878	-91.46059	3.67	2.45	1.19	3.03	4.42	0.64
Midway	channel	31.47702	-91.46007	2.93	10.73	1.29	1.16	3.33	10.36
Mouth SCC	channel	31.43774	-91.45559	0.07	1.27	0.06	0.68	1.21	1.20
River Channel 1	channel	31.40487	-91.45644	0.00	0.00	0.00	0.00	0.00	0.00
SCC High	channel	31.46580	-91.44527	0.07	0.82	0.52	0.27	0.38	0.24
Unreasonable	channel	31.47901	-91.45879	0.00	0.00	0.39	0.00	0.00	0.00
Double Culvert East	open field	31.49155	-91.46170	1.67	0.09	0.97	1.00	1.46	0.36
Fenceline	open field	31.47829	-91.48833	1.73	0.00	2.16	2.35	0.17	0.00
North Closed Area	open field	31.49781	-91.44603	1.33	0.00	2.61	3.76	1.58	0.00
North Field Corner	open field	31.50434	-91.45759	3.27	0.00	2.58	4.19	2.13	0.00
North Field Road	open field	31.50065	-91.44849	0.07	0.00	4.45	6.97	0.63	0.00
PP1	open field	31.50690	-91.46371	0.13	0.00	2.03	1.65	0.13	0.00
PP2	open field	31.50594	91.45686	0.40	0.00	1.74	1.95	0.21	0.00
River Road Culverts	open field	31.46304	-91.48923	0.00	0.00	3.06	1.95	0.00	0.00
South Big Field	open field	31.48796	-91.44938	6.93	0.00	2.32	4.49	4.67	0.04
SW Boundary Field	open field	31.45798	-91.46542	1.60	0.00	1.35	1.68	1.29	0.00
SW North Field	open field	31.49383	-91.45741	3.67	0.00	1.23	0.00	0.00	0.00
Horseshoe Back	road / thick veg	31.47669	-91.47444	0.80	0.00	0.77	0.24	1.17	0.04
Long Lake Road	road / thick veg	31.46158	-91.47025	0.00	0.00	0.81	0.57	0.00	0.00
Low Crossing	road / thick veg	31.47872	-91.46821	0.00	0.00	0.39	0.30	0.83	0.28

NCR2	road / thick veg	31.50445	-91.45974	0.07	0.00	0.45	0.59	0.08	0.00
North Cut Road	road / thick veg	31.50470	-91.46174	0.60	0.00	0.55	0.73	0.13	0.00
BL MID	thick vegetation	31.46595	-91.46095					2.21	0.64
Eagle Nest Road	thick vegetation	31.49306	-91.47521	0.53	0.18	1.32	0.22	0.21	0.00
Horseshoe Impoundment	thick vegetation	31.47399	-91.46558	1.67	0.00	1.65	1.92	3.92	0.24
Oil Rig Stand	thick vegetation	31.48756	-91.47377	0.20	0.00	0.55	0.03	0.04	0.00
River Road Culvert East	thick vegetation	31.46737	-91.48327	0.00	0.00	0.00	0.00	0.00	0.00
NFRW1	dense woods	31.49976	-91.44748	0.00	0.00	1.26	0.00	0.00	0.00
NFRW2	dense woods	31.50094	-91.44779	0.00	0.00	1.10	0.00	0.00	0.00
NFRW3	dense woods	31.50166	-91.44808	0.00	0.00	0.90	0.00	0.00	0.00

Table 4. Average thermal difference between Butler Lake and the mainstem Mississippi River at Baton Rouge and between the Bluehole and the mainstem Mississippi River at Baton Rouge.

Temperature Difference (deg C) 1 Jan – 1 Jun	Butler-Baton Rouge	Bluehole-Baton Rouge
2012	2.8	4.0
2013	2.5	4.4

Table 5. Average thermal conditions (degrees C) at all water quality logger locations through 2013 using the same periods as those used in the telemetry analysis.

Average Temperature in 2013										
	Salt Lake	Butler Lake	Mouth of SCC	Bluehole	ATV Trail	Long Lake South	Long Lake North	Horseshoe Imp.	Eagle Nest Road	North Closed Area
Cool/High 3/27 - 4/10	12.5	13.9	15.2	15.2	17.3	17.4	19.1	17.7	16.4	17.8
Cool/Low 4/12-4/22	N/A	20.6	21.2	21.2	20.6	21.7	21.7	21.4	19.7	20.2
Spawn 5/1-5/30	N/A	22.1	22.4	22.8	22.2	22.2	22.7	23.1	23.4	23.2
Warm/High 6/1-7/7	N/A	28.0	28.3	29.2	28.8	29.6	29.8	29.2	28.4	29.2
Intermed 7/8-7/31	28.9	28.7	28.9	28.9	28.7	29.4	29.6	28.6	28.5	28.7
Warm/Low 8/1-8/25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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