Fisheries Technical Session

Movement Patterns of Coastal Largemouth Bass in the Mobile-Tensaw River Delta, Alabama: A Multi-approach Study

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Abstract: Largemouth bass (*Micropterus salmoides*) is a popular recreational sport fish in estuarine environments like the Mobile-Tensaw Delta. However, catch rates of large largemouth bass are often low in these coastal systems. Larger largemouth bass (≥2,268 g) are sometimes thought to move upstream to less saline locations when salinity increases. We combined three approaches to explore movement of adult largemouth bass in relation to salinity and angler displacement: external tagging, acoustic telemetry, and fish releases at tournaments. Movement patterns were more varied at downstream sites than upstream sites. Behaviors of downstream fish included remaining in protected channels near the release location, moving upstream as salinity increased (<2‰), or moving into the main river channel. Fish upstream generally remained near the release site. Recaptures of largemouth bass tagged externally during regular sampling were typically found in the original tagging site (86%–100% across years), while largemouth bass from a tournament tagging effort dispersed from the release point in <23 days. Effects of angling were observed for each approach, and angler recaptures of tagged fish indicated effects on the largemouth bass fishery including movement of fish to other systems, and the re-distribution of fish from tournament release sites. We found no evidence of broad-scale upstream movement of largemouth bass, particularly when salinity increased in the lower Mobile-Tensaw Delta.

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Study of largemouth bass *(Micropterus salmoides)* has been quite extensive in a wide array of freshwater systems, due in large part to their popularity as a recreational sport fish (Nack et al. 1993, Markham et al. 2002). This research has produced a large volume of information regarding both the ecology and management of largemouth bass (hereafter referred to as bass) in freshwater systems (Garvey et al. 2000, Philipp and Ridgway 2002). However, little is known about bass in the numerous coastal systems they inhabit.

The bass present in the oligohaline and upstream portions of estuarine systems along the mid-Atlantic and Gulf coasts can be exposed to periodic salinity (Meador and Kelso 1990*b;* Peterson and Meador 1994). Throughout their range in coastal systems, reduced size and low catch rates of large bass have been documented both scientifically (Tucker 1985, Meador and Kelso 1990*b*) and by anglers. For instance, 1,743 angler-hours were required to catch a bass ≥2,268 g in 2002, and no bass of this size were caught in 3,498 angler-hours in 2003 in the Mobile-Tensaw Delta. This was substantially more effort than the Alabama statewide average of 519 angler-hours to catch a bass this large (Nichols and McHugh 2002, Haffner et al. 2003). Linking these population trends to coastal influences has motivated many studies (Colle et al. 1976; Guier et al. 1978; Hallerman et al. 1986; Meador and Kelso 1990*a, b;* Susanto and Peterson 1996; Peer 2004). However, the degree to which salinity directly or indirectly (e.g., marine/estuarine derived prey and predators) affects coastal bass habitat choice and movement remains unclear. As in other coastal systems, this question is made more complex by anglers moving bass (Richardson-Heft et al. 2000, Krause 2002).

The openness and increased spatial scale of coastal systems relative to most lentic, freshwater systems potentially allows individuals to represent one well-mixed population or several distinct sub-populations. Numerous studies on bass movement in small lakes or reservoirs (Savitz et al. 1983, Mesing and Wicker 1986, Bain and Boltz 1992, Wildhaber and Neill 1992) indicate localized, seasonal movements (<1 km) corresponding with spawning or changing temperature. The more diverse, interconnected habitats found in riverine systems, especially coastal systems with salinity in downstream areas, may cause fish to move more readily; however, our understanding of the effects of such coastal influences on population mixing remains limited. When salinity reached 5‰ in a Louisiana study and no fish were found, the suggestion was that bass moved upstream to freshwater areas (Meador and Kelso 1989). Experimental evidence has indicated that bass prefer salinities ≤3‰ (Meador and Kelso 1989) and experience mortality when held at salinities ≥12‰ for prolonged periods of time (Meador and Kelso 1990*a*). While an individual bass was collected at 17.5‰ (Swingle and Bland 1974), freshwater fish typically dominate catches at lower salinities (<1‰, Swingle and Bland 1974; <2.63‰, Keup and Bayless 1964). Therefore, the absolute salinity needed to initiate movement to upstream freshwater locations remains unconfirmed and may depend on processes affecting movement of salinity within systems. In addition, the rate of salinity fluctuations combined with the interaction of salinity with other variables (e.g., temperature, etc.) is likely to affect the physiological tolerances of organisms to salinity (Wheatley 1988, Meador and Kelso 1989).

In this study, we hypothesized that the movement of adult bass in the Mobile-Tensaw Delta would be affected by salinity. We expected movement of adult bass to be greater in downstream areas than in upstream areas as the salinity gradient developed. We used three approaches to assess movement of bass related to increasing salinity; external tagging of bass to identify movement within and among sample sites, acoustic telemetry to identify movement at one downstream and one upstream location, and acoustic and external tagging of bass at two tournament release sites to evaluate dispersal from tournament release areas.

Study Site

The Mobile-Tensaw Delta (hereafter referred to as the Mobile Delta) comprises 8,224 ha between the confluence of the Alabama and Tombigbee rivers and the head of Mobile Bay and forms a network of rivers, creeks, bays, lakes, wetlands, and bayous (Armstrong et al. 2000). It is the fourth largest river delta in the United States (Tucker 1985) and spans a length of nearly 55 km and a width up to 15 km. During our study, salinity peaks (1 m depth) in the Mobile Delta reached as high as 9.3‰ in the most downstream portions, while upstream portions remained fresh. Tidal influence (average tidal range <0.5 m) on saltwater intrusion is minimal, except at maximum amplitude (Schroeder 1978). Habitat ranges from tidal freshwater marshes downstream to hardwood forests upstream.

Methods

External Tagging

We sampled a downstream-upstream salinity gradient using six fixed sites along the lower, eastern portion of the Mobile Delta (Fig. 1a). Sites extended approximately 33 km from just south of I-10 and the US 90/98 Causeway north to I-65. Monthly electrofishing (pulsed-DC) at each site, starting in July 2002 and ending in December 2004, included boom and prod-pole electrofishing (Smith-Root DC Electrofisher, 7.5 GPP, 7,500 W). Boom electrofishing consisted of two 15-min transects in nearshore waters <2 m deep, while prod-pole electrofishing consisted of three 10-min transects associated with shoreline areas.

Bass (≥200 mm) were measured (nearest mm TL), weighed (nearest g), externally tagged (N = 1,025; Guy et al. 1996) with T-bar anchor tags (FD-68B; Floy Tag, Inc.), and released where they were collected. Individually numbered tags also included a phone number to enable anglers to report their recaptures. Although no

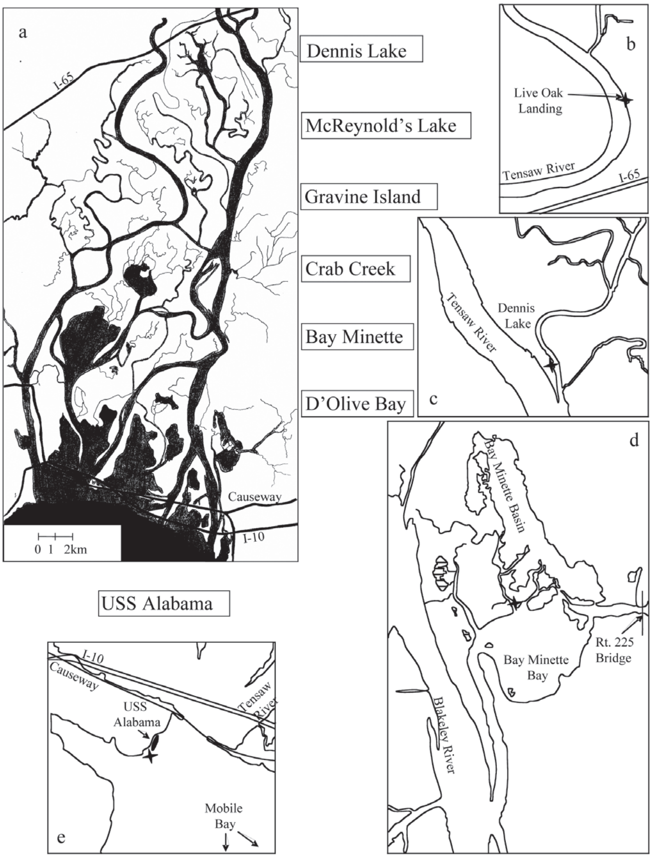

Figure 1. (a) Map of the Mobile Delta with locations of monthly sample sites (D'Olive Bay, Bay Minette, Crab Creek, Gravine Island, McReynold's Lake, and Dennis Lake). (b) Map of the upstream tournament release site (Live Oak Landing) on the Tensaw River 4.8 river-km upstream of I-65. (c) Map of Dennis Lake, upstream acoustic telemetry site. (d) Map of Bay Minette, downstream acoustic telemetry site. (e) Map of the area surrounding the downstream tournament release site (USS Alabama). All release sites are denoted by a ✦.

reward system was used, there is an active bass fishery in the Mobile Delta with anglers voluntarily reporting tagged bass.

Acoustic Telemetry

One upstream site (Dennis Lake; Fig. 1c) and one downstream site (Bay Minette; Fig. 1d) were selected for the release of acoustic transmitter tagged bass. The primary habitat in Bay Minette was a shallow, heavily vegetated bay about 3 km from the nearest main river channel, while the dominant habitat in Dennis Lake consisted of a smaller river channel with sparse aquatic vegetation about 0.6 km to the nearest main river channel. In previous years, the salinity at 1 m depth approached 5‰ at Bay Minette and never reached detectable concentrations at Dennis Lake.

Bass ($N = 40$) were tagged and released in a spring (March 2003) and fall (October 2003) phase. For larger individuals ($N = 32$), a 16 by 63 mm, 8 g, 14-month minimum tag (CT-82-2, Sonotronics, Inc.) was implanted, and a 9.5 by 28 mm, 2.5

g, 60-day minimum tag (IBT-96-2, Sonotronics, Inc.) was implanted for smaller bass (*N* = 8). Tags never weighed more than 2% of bass wet weight in air (Winter 1996).

Each individual was measured, weighed, and externally tagged as described previously. Surgery and anesthesia techniques for tag implantation were similar to Winter (1996). Each surgery was completed within 5 minutes, and the gills were irrigated during surgery. Tagged bass recovered for at least 30 minutes and were released at a central location in each site (Fig. 1c,d).

Fish were located using a hand-held, DH-2 directional hydrophone and USR-5W digital receiver (30–85 kHz; Sonotronics, Inc.) approximately monthly during day hours. Spring-released fish were sampled from March 2003–December 2004, and fall-released fish were sampled concurrently with spring-released fish from October 2003–December 2004. Although the approximate expected ranges for the smaller tags were 500 m and the larger tags were 1,000 m in seawater, locations were selected conservatively to compensate for habitat complexity (i.e., bends in channels, channel or embayment mouths, or aquatic vegetation). The hydrophone was rotated three times, with each rotation at a different frequency (low, medium, and high) within the range of tag frequencies (70–80 kHz). If a tag signal was detected, the individual tag code was first identified and then the receiver frequency was adjusted to within 1–2 kHz of the tag frequency to maximize the signal received. Specific locations were isolated by triangulation. An equally loud signal in all directions indicated a fish location, and a GPS coordinate (GPS 12 Personal Navigator, Garmin, Inc.), surface temperature, salinity, and total depth were recorded for each fish.

Tournament Release Site

Acoustic Telemetry.—A downstream location (USS Alabama; Fig. 1e) previously used for tournament releases was selected as a release site, where the potential return of bass above the Causeway could be identified. Bass (*N* = 5) were electrofished in April 2004 from Bay Minette, located upstream of the Causeway, and implanted with acoustic transmitter tags. After surgery and recovery, tagged bass were transported to the USS Alabama and released (Fig. 1e). Salinity was recorded at the release point. Two days after release, we returned to the USS Alabama and surrounding area and listened for the presence of signals. Fish were tracked for three months following release, which corresponded with the monthly tracking for Bay Minette and Dennis Lake.

External tagging.—Bass weighed-in at a tournament (15 May 2004) at Live Oak Landing on the Tensaw River (Figure 1b) were placed in large holding tanks adjacent to tagging teams. Salt was added to all tanks to reduce osmotic stress on fish. All tournament caught bass (*N* = 362) were measured, weighed, externally tagged, and placed in recovery tanks. All fish were processed in less than 3 hours and were released directly into the Tensaw River immediately adjacent to the weigh-in and tagging location (Fig. 1b).

We electrofished (as described above) 4, 13, and 23 days post-release covering the downstream and upstream shorelines of the Tensaw River adjacent to the release location (total distance radius = 1 km; total pedal time = 100–120 min). Total numbers of tagged and untagged bass and GPS coordinates and tag numbers of recaptured individuals were also recorded.

Data Analysis

For bass relocated with the acoustic telemetry approach, monthly means for abiotic variables were calculated. Individual distances moved for bass relocated using acoustic telemetry or recaptured individuals from the tournament tagging were calculated using Terrain Navigator software (Maptech, Inc.) with GPS coordinates taken in the field. Mean distances by month were also calculated for bass relocated at Bay Minette and Dennis Lake and by post-release sampling date for tournament recaptures. Two-way ANOVAs with interaction effects ($P < 0.05$) were used to test for statistical differences both spatially and temporally. Due to limited data on smaller adults through time, data from both size categories were combined for analysis.

Results

External Tagging

During three years of standard sampling at six sites, we tagged and released a total of 1,025 bass (Table 1). Of these, 62 were recaptured (49 in our sampling; 14 reported by anglers), with total recaptures at any one site generally <10 bass. While most recaptured bass were released (77%–100% across years), the remainder were kept for age-and-growth analysis. Only two bass were recaptured more than once (both released and recaptured in Crab Creek). Most bass (86%–100% across years) were recaptured where they were released. Only two bass were found to move between sampling sites. Both of these fish were originally tagged and released at Crab Creek in April 2003 and recaptured in Bay Minette in May 2003, representing an estimated movement (minimum total distance) of 15.8 km in ≤37 days.

Though most bass (63%–100% across years) were recaptured within three months following release, recaptures of bass tagged in previous years increased during the study. Months since initial release ranged from 1–18 months for recaptured bass across years, with six individuals recaptured in 2004 between 10–18 months after initial release. No bass released in 2002 were recaptured in later years, but seven bass recaptured in 2004 were initially released in 2003. Most fish were recaptured during February through May, which included months just prior to or during spawning in both 2003 (64%) and 2004 (66%).

Although angler reporting of tagged bass remained low throughout the study (Table 1), these reports included one fish caught in McReynold's Lake (May 2004) and released in a private fishing pond and another fish tagged and released at D'Olive Bay in August 2003 and recaptured in the vicinity of Pascagoula, Mississippi, in January 2004. No movement between sample sites was found through angler reporting.

Table 1. Numbers of bass externally tagged, released, and recaptured in sampling (labeled "AU recapture" within the table) and by anglers for all sample sites and years.

	Numbers of Bass			
Sites	2002	2003	2004	Site total
Dennis Lake				
Tagged/Released	12	73	80	165
AU recapture	0	3	3	6
Angler recapture	0	1	1	2
McReynold's Lake				
Tagged/Released	38	82	74	194
AU recapture	0	0	5	5
Angler recapture	0	2	2[a]	4
Gravine Island				
Tagged/Released	29	7	64	120
AU recapture	0	1	5	6
Angler recapture	0	0	3	3
Crab Creek				
Tagged/Released	48	66	75	189
AU recapture	1	4[b]	8[b]	13
Angler recapture	0	0	0	0
Bay Minette				
Tagged/Released	35	99	122	256
AU recapture	0	4[c]	8	12
Angler recapture	0	3	1	4
D'Olive Bay				
Tagged/Released	28	27	46	101
AU recapture	0	2	3[a]	5
Angler recapture	0	1	1[d]	2
Combined Site Total				
Tagged/Released	190	374	461	1,025
AU recapture	1	14	32	47
Angler recapture	0	7	8	15

a. For one bass, only recapture location known. Release location was unknown, because complete tag number not available.

b. Two bass were recaptured twice each ($N = 1$ in 2003, $N = 1$ in 2004).

c. Two recaptured bass counted in Bay Minette were initially released in Crab Creek.

d. One bass was recaptured in Pascagoula, Mississippi, but initially released in D'Olive Bay where it was counted.

Acoustic Telemetry

Total lengths of larger bass released at Bay Minette in spring 2003 ($N = 8$) ranged from 320 to 452 mm (mean ± 1 SD = 378 mm ± 48.8), and in fall 2003 they ranged from 340 to 530 mm ($N = 8$, mean ± 1 SD = 425 mm ± 60.8). Larger bass tagged at Dennis Lake in spring 2003 ($N = 8$) ranged in size from 359 to 448 mm (mean ± 1 SD = 388 mm ± 28.7) and from 352 to 425 mm (mean ± 1 SD = 380 mm ± 29.0) in fall 2003 ($N = 8$). Smaller bass released at Bay Minette in spring 2003 ($N = 2$) were 265 mm and 272 mm (mean ± 1 SD = 269 mm ± 4.9) and 299 mm and 304 mm (mean ± 1 SD = 302 mm ± 3.5) in fall 2003 (N = 2). Smaller bass tagged at Dennis Lake in spring 2003 (N = 2) were 240 mm and 241 mm (mean ± 1 SD = 241 mm ± 0.7) and 285 mm and 290 mm (mean ± 1 SD = 288 mm ± 3.5) in fall 2003 (N = 2).

A total of 155 individual relocations were made during April 2003 through December 2004 (Dennis Lake = 84, Bay Minette = 71). We relocated all bass from each site and release phase at least one time, except for fall-released fish at Bay Minette. Only 70% of these fish were relocated at least once. Essentially, all bass were relocated at least once in Dennis Lake, and 86% were relocated at least once in Bay Minette. Relocations during any one monthly sample varied from 0%–70% in Bay Minette and Dennis Lake. In Bay Minette, the percent of relocations by month were highest in the months immediately after the spring-release (70% in April 2003) and the fall-release (40% in December 2003 and February 2004). Highest percentages of relocations by month (50%) from the spring release were not isolated to a specific time (9 April, 26 April, October, and December 2003) in Dennis Lake, while the highest percentage (70%) of monthly relocations occurred immediately after the fall release (October 2003). Although the percentage of relocations decreased to 0% during May 2003 at both Dennis Lake and Bay Minette, percentages rebounded in the following months at both sites.

Salinity peaked at our downstream site, Bay Minette, in August 2002 (4.9‰), November 2003 (1.5‰), and September 2004 (1.7‰) and remained fresh at our upstream site, Dennis Lake. In March 2003, bass were released at Bay Minette in freshwater at a surface water temperature of 19.7 C, and bass were released at Dennis Lake in freshwater at 18.7 C. In October 2003, bass were released at Bay Minette in 1.4‰ salinity and 26.2 C, while bass in Dennis Lake were released in freshwater at 24.9 C.

Spring-released bass (Fig. 2a) were relocated at Bay Minette when salinity was present in October (N = 3) and November (N = 4) of 2003. Mean salinities for spring-released bass in Bay Minette were 1.0‰ (range = 1.0‰–1.1‰) in October 2003 and 1.4‰ (range = 0.3‰–1.9‰) in November 2003. Only one spring-released bass (0.3‰) was relocated in October 2004 during increased salinities. Similarly, fall-released bass (Fig. 2b) were relocated during increased salinities at Bay Minette in October 2003 (N = 3) at mean salinities of 0.7‰ (range = 0.2‰–1.0‰) and in November 2003 (N = 2) at mean salinities of 1.6‰ (no range). In October 2004, only one fall-released bass (0.2‰) was present with increased salinity.

Only two bass were found to move to areas with lower salinity when ambient salinity increased. As salinities increased in Bay Minette during 2003, one spring-released bass moved 1.1 km upstream toward Bay Minette Creek, the main freshwater inflow. This fish moved from 1.1‰ salinity in October 2003 to 0.3‰ salinity in Bay Minette Creek by November 2003 (month of peak salinity). After salinity declined, this fish returned to its previous location and remained there. The other fish moved 1.3 km toward Bay Minette Creek immediately after its fall release when salinities were 1.4‰ to a salinity of 0.2‰ at its relocation site. This bass was relocated only one other time in February 2004 moving farther upstream into Bay Minette Creek.

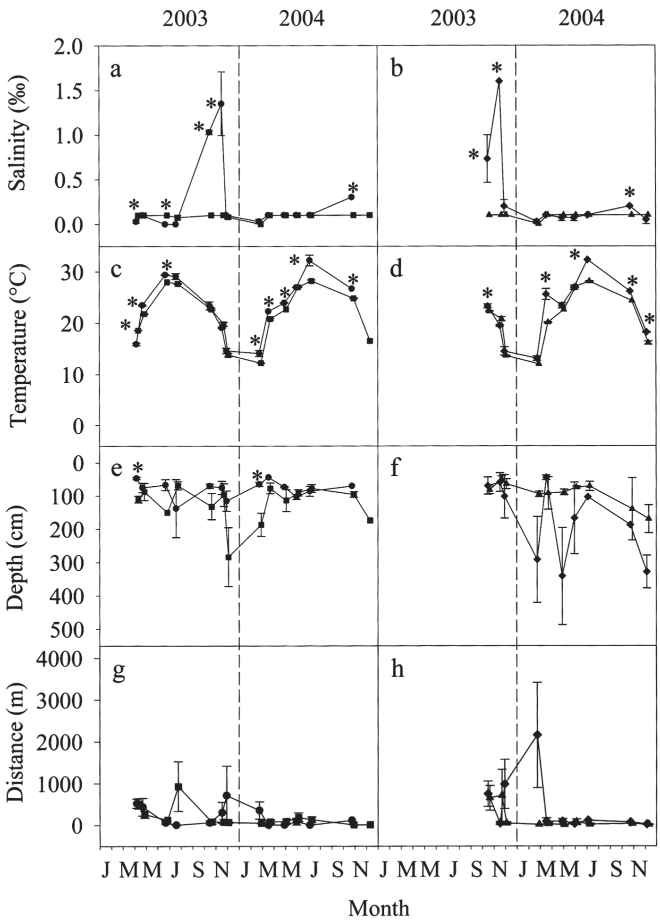

Figure 2. Mean salinity (a), mean surface water temperature (c), mean total depth (e), and mean total distance (g) for relocations of acoustically tagged bass from spring release in Bay Minette (•) and Dennis Lake (■). Mean salinity (b), mean surface water temperature (d), mean total depth (f), and mean total distance (h) for relocations of acoustically tagged bass from fall release in Bay Minette (◆) and Dennis Lake (▲). Significant differences ($P < 0.05$) are indicated by a *.

Peak temperatures ranged from 30.7 C (August 2003) to 32.7 C (August 2002, July 2004) in Bay Minette, and peak temperatures were 28.9 C (September 2003), 31.8 C (July 2004), 32.4 C (August 2002) in Dennis Lake. Peak surface water temperatures were lowest at both sites in 2003 and occurred one month later in Dennis Lake than in Bay Minette.

A significant month x site interaction ($F = 13.32$, $P < 0.01$) indicated that mean temperatures at relocation points for spring-released bass were significantly higher in Bay Minette than Dennis Lake during April, June, and July of 2003 (Fig. 2c). In

2004, mean temperatures at relocation points for spring-released bass were significantly higher in Bay Minette during February, March, May, July, and October than in Dennis Lake. Likewise, a significant month x site interaction (F = 7.68, $P < 0.01$) indicated that fall-released bass were found in significantly higher temperatures at Bay Minette than Dennis Lake during October 2003 and March, July, October, and December 2004 (Fig. 2d).

Although no significant month x site interaction (F = 1.41, $P = 0.18$) was found for mean total depth, both the month (F = 1.90, $P = 0.047$) and site effects (F = 6.53, $P = 0.01$) were significant for spring-released bass (Fig. 2e). Spring-released bass in Bay Minette (mean = 76.8 cm) were relocated in shallower water than in Dennis Lake (mean = 125.2 cm). Conversely, significant differences (F = 4.39, $P = 0.045$) between sites for fall-released fish (Fig. 2f) indicated that bass were relocated in Dennis Lake (mean = 87.5 cm) at shallower depths than in Bay Minette (mean = 178.6 cm).

While the Bay Minette habitat type was primarily represented by a shallow, heavily vegetated bay, all locations of bass at this site occurred along the edges of the less vegetated, deeper side channels. In general, dense vegetation is minimal at Dennis Lake, and bass in Dennis Lake tended to be associated with fallen trees, submerged brush piles, or root wads immediately adjacent to the deeper channel.

Although mean total distances did not differ by site [spring (F = 0.82, $P = 0.66$); fall (F = 0.77, $P = 0.65$)] or month [spring (F = 0.01, $P = 0.94$); fall (F = 0.91, $P = 0.35$)] for largemouth bass released in the spring (Fig. 2g) or fall (Fig. 2h) and despite a greater distance to the main river channel at Bay Minette (3 km) than Dennis Lake (0.6 km), a subset ($N = 3$) of bass from Bay Minette moved to the Blakeley River (Fig. 1d), the nearest main river. One spring-released fish was relocated three times as it progressed into the main river (November 2003 – February 2004) and was last relocated moving downstream in the Blakeley River (3.6 km from release). The second fish (fall-released) moved upstream upon reaching the Blakeley River (5.3 km from release) and was relocated there two times (February, May 2004). A third fish (fall-released) moved toward the Blakeley River (December 2003; 2.4 km from release), then returned upstream, and crossed Bay Minette Bay (Fig. 1d) to a location in Bay Minette Creek (February 2004; 3.5 km from previous location) where it remained for the duration of the study. Only one fish (spring-released), from Dennis Lake (Fig. 1c) moved to the Tensaw River (2.7 km from release), the nearest main river, and was not found there until July 2003 where it stayed for the remainder of the study.

Three fish were also relocated by Scott Mettee (Geological Survey of Alabama, personal communication) during June 2004. Of the fish not in our routine sampling path, one fish, originally released in Dennis Lake, was relocated 21.3 km upstream, and the other fish, originally released in Bay Minette, was relocated upstream in the Blakeley River (8.7 km from the release site). The third of these fish was previously located during our routine sampling and was described above as the only fish moving into the Tensaw River from Dennis Lake.

An effect from angling was also indicated by this approach. One angler reported recapturing a spring-released bass in Bay Minette. A fall-released fish at Dennis Lake appeared to be in the live well of an angler while we were tracking it in October of 2003. October was the first tracking trip after the fall release, and no other relocations for this fish were obtained after this.

Tournament Release Site

Five bass ranging in size from 354 to 404 mm TL (mean ± 1 SD = 370 mm ± 19.9) were tagged and released at a downstream site, the USS Alabama Battleship Memorial Park. Surface and bottom salinity levels in Bay Minette at the time of capture were both 0.1‰, while surface and bottom salinity levels at the USS Alabama release site were 4.5‰ and 10.4‰, respectively. Two days post-release, three bass were detected in the area of the battleship downstream of the 90/98 Causeway and I-10 overpass. One fish was detected near the release site, a second fish was detected downstream, and a third fish was detected in an easterly direction across the Tensaw River. In the following months, no fish were located upstream or downstream of the battleship until a final attempt in April 2005 resulted in the relocation of one bass 451 m upstream of the release point but still downstream of the 90/98 Causeway and I-10 overpass. This fish was first relocated moving downstream of the release location in April 2004.

At the Team Jesus bass tournament 15 May 2004 at Live Oak Landing, upstream of Dennis Lake and I-65, we tagged and released 362 bass. In our post-tournament electrofishing, 36, 13, and 2 tagged bass were collected 4, 13, and 23 days respectively after the tournament. Although mean distance moved by bass did not differ significantly, a general trend toward increasing distance (mean minimum distance) away from the release location through time (mean ± 1 SE; day 4 = 402 m ± 44.33; day 13 = 349 m ± 70.82, and day 23 = 610.5 m ± 158.8) occurred. While distance moved by bass was significantly ($F = 8.01$, $P < 0.01$) greater in the upstream direction (mean ± 1 SE = 533 m ± 60.21) than in the downstream direction (mean ± 1 SE = 328 m ± 41.53) from the release point, a greater proportion of bass moved downstream (67%) than upstream (33%) of the release location.

Subsequently, anglers reported recapturing eight bass from this tournament. Two anglers recaptured bass around the release location while fishing for another tournament. One released their recaptured bass at another tournament weigh-in location 14.2 km downstream of the release location. The other released a bass 32.5 km upstream at another tournament release location. Another bass was recaptured by an angler ~20 days post-release in the mouth of Dennis Lake (10.2 km from the release location). Two other fish were also recaptured near the tournament release, but no involvement in a tournament was indicated. Another three fish were recaptured in nearby water bodies though movements to these locations would have been larger in terms of river miles.

Discussion

Coastal bass exhibit an apparent reduced growth rate with few individuals reaching large size (Tucker 1985, Meador and Kelso 1990*b*). To understand the mechanisms that cause this pattern, it is necessary to determine movement patterns of bass in response to environmental stress (e.g., increasing salinity) associated with coastal systems and identify if movement could affect observed patterns via mixing of sub-populations (Copeland and Noble 1994, Jackson et al. 2002).

Bass move among habitats in response to many environmental factors including food availability (Fish and Savitz 1983, Savitz et al. 1983), avoidance of low dissolved oxygen (Wildhaber and Neill 1992), temperature preferences (Warden and Lorio 1975), and vegetation density (Killgore et al. 1989, Savino and Stein 1989). Previous studies suggest that bass also move to preferred spawning areas that may differ from their choice of habitat during other periods (Mesing and Wicker 1986, Nack et al. 1993, Richardson-Heft et al. 2000).

Unlike smaller, freshwater systems, where one movement pattern tends to predominate in relation to an environmental stress, bass populations in the Mobile Delta were found to exhibit three different movement patterns at downstream sites, (1) remain in deeper side channels directly connected to shallow bay; (2) move upstream with increasing salinity; (3) move into or toward main river channel. While salinity remained low throughout the telemetry study, other coastal influences associated with downstream sites (e.g., habitat variation, greater influence from marine/estuarine prey or predators) may also influence bass movement at downstream sites in the absence of high salinity.

Rather than migrating to spawning locations in embayments and creek mouths as shown for bass in the tidal freshwater portions of the Hudson River and the Chesapeake Bay (Nack et al. 1993, Richardson-Heft et al. 2000), one subset of the acoustic tagged fish at Bay Minette and most of the tagged fish at Dennis Lake remained in these protected habitats (i.e., channels) throughout the year, instead of moving strictly during the spawning season. As has been suggested in freshwater systems, longer residence by bass in these channels may be due to a combination of protection from wind and wave action (Mesing and Wicker 1986), immediate access to deeper water during increased temperatures (Warden and Lorio 1975), higher quality or more abundant food resources concentrated within a smaller area (Fish and Savitz 1983, Savitz et al. 1983), or less dense aquatic vegetation allowing increased foraging access (Killgore et al. 1989, Savino and Stein 1989) lacking in the shallower and heavily vegetated, but predominant bay habitat.

It has been hypothesized that bass move upstream to freshwater during increased salinity (Swingle and Bland 1974, Meador and Kelso 1989, 1990*b*). Although we were able to relocate bass during increased salinity at Bay Minette, peak salinities only approached 2‰ and may not have been high enough to initiate movement to lower-salinity waters. Only a small subset of tagged bass (one from each release phase) made upstream movements (but only 1.1–1.3 km) as salinity increased at Bay Minette. While one bass returned to its previous location after salinity declined, the other bass continued moving upstream until February 2004, when it was relocated for the last time. Other studies also indicated reduced catches of freshwater fish at low salinities (Keup and Bayless 1964, Swingle and Bland 1974). Therefore, future work during years of higher salinity should continue to identify whether a salinity threshold exists to initiate bass movement in the Mobile Delta.

Despite the increased distance to a main river channel at Bay Minette (3 km) relative to Dennis Lake (0.6 km), a third subset of bass (2/release phase) moved to the main river channel at Bay Minette. Distances moved by bass from the Bay Minette release point ranged from 2.4–8.7 km. Because distances moved for this subset of tagged fish were greater than the typical distances moved (<1 km) by bass in freshwater systems, angler displacement may be a possible explanation. However, only one bass moved to the closer main river channel at Dennis Lake, indicating either differences in angler use of areas in the Mobile Delta or other factors driving this movement pattern for a portion of the population. Hence, separating the effects of anglers from other environmental factors would be useful in advancing our understanding of movement patterns of bass in coastal systems.

The lack of relocations both downstream and upstream during high water levels in May 2003 suggested movement by bass outside of the detection area. Our ability to relocate bass among the fallen trees, submerged brush piles, and root wads along the channel edges and along vegetated channel edges during normal water levels in the months immediately prior to and after high water levels suggested that bass had indeed moved out of the channels, but their quick return indicated a lack of any extensive movements away from the area. Unfortunately, our ability to detect the sonic tags in the forested shallows was greatly limited by lack of access to these areas and the obstruction of signals by the forested or vegetated edges.

Higher temperatures at downstream relative to upstream sites may be due to the shallow bay habitat found at Bay Minette and the shaded riverine habitat in Dennis Lake—habitats typical of downstream and upstream locations in this system. With temperatures above 27 C for 4–5 months of the year at Bay Minette and 3–4 months of the year at Dennis Lake, restricted activity, particularly during foraging, may contribute to reduced growth rates of adult bass (Rice et al. 1983). Less efficient conversion of food to growth at smaller sizes was found in age-0 bass from the Mobile Delta and Florida populations compared to Wisconsin populations at higher temperatures as indicated through bioenergetics modeling and was thought to be the result of local adaptation to the extreme high temperatures they experience at southern latitudes (Slaughter et al. 2004). Innovative bioenergetics modeling including habitat choice, movement, and salinity as parameters along with food and temperature in simulations will permit a better energetic understanding of how these variables interact to effect growth differences.

While salinities never reached the level needed to force bass to move at sites above the Causeway, surface salinity did approach 5‰ when we released acoustically tagged bass at the USS Alabama release site. Initial movements of these fish (two days post-release) did not indicate movement upstream of the release location. Because none of the fish were relocated >2 days post-release, this indicated that bass had moved out of the area, but upstream movement was not confirmed. One fish was relocated one year after release just upstream of the release site but below the I-10/Causeway overpass. A study of tournament displacement by Ridgway (2002) found few bass transplanted >8 km from their capture sites in Rideau Lake, Ontario, returned and those displaced within that range could take up to one year to return to their original capture site. However, another study of bass movement in the tidal freshwater and oligohaline portions of the Chesapeake Bay indicated a return to capture sites over distances of 21 km (Richardson-Heft et al. 2000). None of the tagged bass released at the battleship site returned to the site of their capture (16 km) up to one year after release. Further research is needed on the effects (e.g., mortality or movement away from salinity) of release into areas of increased salinity for bass originating from upstream freshwater areas. Improved knowledge of common capture locations relative to tournament release locations is needed to address the potential for return to a capture site in the Mobile Delta and the potential localized effect of release site distance from capture site on bass populations in this system.

Although most recaptured bass concentrated within a 0.5 km radius of the upstream tournament release longer (4 days = 58%; 13 days = 77%) than a study of post-tournament stockpiling (<7 days) of bass in the Chesapeake Bay (Richardson-Heft et al. 2000), complete dispersal outside this radius occurred by 23 days post-release. This may indicate an increased length of time for stockpiling of bass as a result of tournament activity in the Mobile Delta. In addition, relative to the potential effects of angler displacement, our externally tagged bass were generally recaptured at their release sites. Given the time range (1–18 months) between release and recapture and the high rate of recaptures during spawning, these fish may be making localized movements out of the range of our sampling methods. Compared with recaptures of externally tagged bass that were originally captured, released, and typically recaptured in the same local area, bass transplanted by tournament activity generally moved away from the release site indicating an attempt to either return to an old home range or establish a new home range. Therefore, continued research on the effects of tournament practices in concentrating bass around release sites may further assist our understanding of the population effects of these potentially extensive redistributions of fish throughout this system.

It was evident from each of our research approaches that fish are often displaced by anglers. External tags were reported by anglers from bass that were released in other systems (e.g., freshwater fishing pond, coastal waters surrounding Pascagoula, Mississippi). Acoustic telemetry provided evidence for the presence of a tagged fish in an angler live-well. Both acoustic telemetry (21.3 km) and tournament tagging (32.5 km) indicated large-scale movements outside of our routine sampling areas. Some anglers reported the use of recent tournament release locations as favorite fishing sites for later tournaments, which lends further support to the potential for continuous re-distribution of concentrations of fish to various tournament release locations throughout the Mobile Delta.

Conclusions

Several types of movement patterns were observed in bass in downstream portions of the Mobile Delta, while movement patterns of bass in the upstream portions remained less variable throughout the study. Although increasing salinity appeared to directly influence bass movement in only a couple of instances, likely due to low salinity experienced during this study, other coastal influences (e.g., habitat variation, marine/estuarine derived prey and predators) may have contributed to these downstream-upstream differences in movement patterns. Our results suggest that some potential for population mixing exists within downstream areas, while bass populations from upstream areas remained relatively isolated from downstream areas. As angler effects were evident for all approaches, more research is needed to separate the effects of coastal influences and angler displacement on bass and to improve our understanding of the contribution these factors may have in isolating or mixing bass populations within such coastal areas.

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