Changes in Behavior, Movement, and Home Ranges of Largemouth Bass Following Large-scale Hydrilla Removal in Lake Seminole, Georgia

STEVE M. SAMMONS¹, MICHAEL J. MACEINA¹, AND DAVID G. PARTRIDGE²

ABSTRACT

About 1,200 ha of hydrilla (Hydrilla verticillata L.f. Royle) was eliminated in the Spring Creek embayment of Lake Seminole, Georgia, using a drip-delivery application of fluridone (1-methyl-3-phenyl-5-[3-(trifluoromethyl) phenyl]-4(1H)-pyridinone) in 2000 and 2001. Two groups of 15 and 20 largemouth bass (Micropterus salmoides Lacepede) were implanted with 400-day radio tags in February 2000 and 2001 to determine changes in movement and behavior before and after hydrilla reduction. Fish were located approximately every 10 days beginning two weeks after tag insertion; beginning in May 2000 diel movement was assessed once a month, and on each sampling date the fish were located every 4 hours for 24 hours (six locations per sampling date). Only fish that were at large in the lake for at least 200 days and with at least 35 locations were used for analysis; 19 fish met these criteria. Locations were grouped into two treatment levels based on the amount of hydrilla present in the system, a pre-treatment period (May to August 2000) when hydrilla coverage in Spring Creek was 72%, and a post treatment period (June to Octo-

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Received for publication August 28, 2002 and in revised form October 27, 2002.
ber 2001) when coverage was 22%. Most largemouth bass remained in the treatment area and maintained similar home range sizes during both treatment periods. However, fish exhibited greater movement, inhabited greater depths, and switched from using hydrilla to large woody debris after hydrilla was reduced. Fish may have responded to better foraging conditions by changing feeding strategies from ambush to searching, which should increase foraging success. Decreased water clarity and increased threadfin shad abundance may have precipitated the increased daytime movement we observed in this study. Our data demonstrated that while largemouth bass do not leave an area when hydrilla is reduced with fluridone, their behavior does change. Lake managers involved in aquatic plant removal programs can exchange this information with anglers concerning the effects of hydrilla treatment and potential impacts to the fishery.

**Key words:** reservoir, herbicide, aquatic plants, management, radio tracking.

**INTRODUCTION**

The presence and abundance of aquatic plants have been associated with fish community structure and population characteristics in a wide variety of systems (reviewed by Dibble et al. 1996). Although much of the early work on fish-aquatic plant interactions was conducted in north-temperate natural lakes (Weaver et al. 1996), with the invasion and spread of more robust and competitive exotic plants such as hydrilla, aquatic weed management has increased in public reservoirs and has fueled many of the major controversies that have arisen on these systems in recent years (e.g., Wilde et al. 1992, Wrenn et al. 1996).

Largemouth bass typically dominate reservoir sport fish communities and are the most important fish sought by anglers in southeastern impoundments (Durocher et al. 1984). High levels of aquatic plants often affect largemouth bass populations by enhancing recruitment, but can delay the onset of piscivory in age-0 fish and reduce growth rates of all ages of fish (Durocher et al. 1984, Moxley and Langford 1985, Bettoli et al. 1992, Maceina et al. 1995, Hoyer and Canfield 1996, Wrenn et al. 1996, Brown and Maceina 2002). Abundance and angler catch rates of largemouth bass often increase with aquatic plant coverage (Durocher et al. 1984, Maceina and Reeves 1996, Wrenn et al. 1996); however, mean size of fish tends to decrease as vegetation levels increase (Smith and Orth 1990, Dibble et al. 1996, Maceina 1996, Slipke et al. 1998).

Most researchers have found that moderate (15 to 30%) submersed vegetation coverages maximize age-0 largemouth bass production while still allowing adequate adult growth (Wiley et al. 1984, Moxley and Langford 1985, Maceina 1996). Economic analysis of the fishery at Lake Guntersville, Alabama, projected that the greatest positive impact on the local economy from recreation would be achieved at 20% plant coverage (Henderson 1996). This amount of coverage allowed the highest levels of angling and nonangling recreation without being hindered by excessive plant growth, and resulted in a projected value of $122 million annually to the surrounding areas (Henderson 1996). However, the estimated value of the fishery would decline by 82% and 57% at plant coverages of 50% and 0%, respectively. Clearly, weed management in reservoirs involves balancing the needs of many user groups and can have serious economic consequences (Colle et al. 1987, Henderson 1996, Wrenn et al. 1996, Slipke et al. 1998).

Lake Seminole was once a widely renowned largemouth bass fishery; however, catch rates of largemouth bass ≥305 mm TL in Lake Seminole declined by almost 50% between 1985 and 1996, while hydrilla coverage increased from 40% to 50% (Slipke et al. 1998). Annual visitation at Lake Seminole declined steadily from a high of 4.2 million visitor days in 1984 to a low of 0.9 million visitor days in 1997, consonant with the increase in hydrilla (USACE 1998). Spring Creek (Figure 1) is a 2,189-ha tributary of Lake Seminole that has been the epicenter of aquatic vegetation problems in the lake (USACE 1998). An areal survey in 1997 indicated that coverage of submersed aquatic plants, primarily hydrilla, was 76% in Spring Creek, compared to 26% in the Chattahoochee River and 32% in the Flint River arms (USACE 1998). Growth rate, relative weight, and fecundity of largemouth bass in Lake Seminole were considerably lower in Spring Creek than in the other two embayments of the lake (Brown and Maceina 2002).

As part of an overall hydrilla management plan for Lake Seminole, the U.S. Army Corps of Engineers (USACE) constructed a drip delivery fluridone system in Spring Creek...
caused the USACE to restart the system in October 2000 and (D. Morgan, USACE, pers. comm.). Hydrilla regrowth when most of the hydrilla canopy collapsed in about a week lapsed by the end of the 60-day period, and the USACE ppb of fluridone. However, the hydrilla canopy had not col-

The system was initiated in late May 2000 and was planned to 253 bridge on the upper end of Spring Creek (Figure 1).

Vegetation dominated by hydrilla peaked in the early 1990s outcompeting most other submersed plants (USACE 1998). The reservoir is operated primarily for navigation, although hydropower and water supply are also major uses (USACE 1998). Stable water levels (<1 m annual fluctuation) and the shallow depths of this reservoir have re-

Some common native plants found in the lake include vari-

able-leafed milfoil (Myriophyllum heterophyllum Michaux), Illinois pondweed (Potamogeton illinoensis Morong), muskgrass (Chara sp. L.), stonewort (Nitella sp. L.), tape-grass (Vallisneria americana Michaux), and coontail (Ceratophyllum demersum L.). Exotic plants include Eurasian milfoil (Myriophyllum spicatum L.) and hydrilla. Hydrilla was discovered in Lake Semi-

The drip-delivery system was constructed at the Highway 253 bridge on the upper end of Spring Creek (Figure 1). The system was initiated in late May 2000 and was planned to be in operation for 60 days while maintaining a dose of 15 ppb of fluridone. However, the hydrilla canopy had not collapsed by the end of the 60-day period, and the USACE maintained the drip system until mid to late August 2000, when most of the hydrilla canopy collapsed in about a week (D. Morgan, USACE, pers. comm.). Hydrilla regrowth caused the USACE to restart the system in October 2000 and maintain it until early December 2000. The drip system was initiated again in May 2001 and remained on until September 2001, thereafter it was operated on biweekly intervals through the end of the year. Hydrilla coverage in the Spring Creek embayment declined from 72% to 22% when the hydrilla canopy collapsed in late August 2000; total control of hyd-

A total of 35 largemouth bass greater than 1.5 kg were sur-

Tracking

A total of 35 largemouth bass greater than 1.5 kg were surgical-

Materials and Methods

Study Area

Lake Seminole is a 13,919-ha impoundment on the Chattahoochee and Flint Rivers located on the Florida-Georgia border. Impounded in 1957, the reservoir has a mean depth of 3.0 m, a maximum depth of 10.7 m, and 155 km of shore-

Data Analysis

Only diel locations were used for these analyses because single locations 10 days apart were not representative of largemouth bass behavior. However, determination of these single locations were used to describe fish movement out of the Spring Creek area. For diel locations, only fish that were at large in the lake for at least 200 days and with at least 35 lo-

post-treatment period (June to October 2001), when vegetation coverage in the Spring Creek embayment was 22% and coverage in the main study area was less than 15%. In each period, mean movement, mean depth, and home ranges were calculated for each fish. Primary habitat for each location was grouped into one of seven categories: hydrilla, large woody debris, submersed (native) aquatic plants, floating-leaved plants, emergent vegetation, bare (no plant material on the bottom), and other. Percent occurrence of fish in each of these habitat categories was compared between the pre and post-treatment periods.

Movement (m/h) was estimated as the distance moved divided by the number of hours between locations in a 24-hour tracking period. Home ranges were calculated for each fish in each treatment using a kernel estimator (Seaman and Powell 1996). This method was shown to be the least-biased estimate of home range, and can be used to identify high use areas (Seaman and Powell 1996). For this study we used the 95% density estimate to represent overall home range of the fish, and the 50% density estimate to represent high-use core area of the fish (Hooge et al. 2001). Site fidelity of tagged largemouth bass ranged from 0.4 to 5.3 m before hydrilla reduction (Table 2). Movement was typically low (<50 m/h) in both treatment periods; however, frequency distributions were different between treatments (Figure 2). Depths of tagged largemouth bass ranged from 0.4 to 5.3 m before hydrilla reduction and 0.4 to 6.0 m afterwards. Mean depth and movement were compared between the two treatments in each time period using a t-test (SAS 1999). All comparisons were considered significant at P < 0.10.

**RESULTS**

Nineteen largemouth bass were tracked long enough and had enough locations to be used for these analyses. These fish were at large for 212 to 560 days and were located 36 to 117 times (Table 1). Of the other 16 fish, nine died, one tag malfunctioned, four fish left the study area, and two fish disappeared and were never located again. Of the four fish that left the study area in 2001, two were suspected to have been moved by anglers into the Flint River, as these fish were found twice near a popular fishing camp that hosts bass fishing tournaments. Another fish moved more than 10 km upstream into Spring Creek above the reservoir (Figure 1). Two fish, one in the pre-treatment period and one in the post-treatment period, did not exhibit site fidelity and were excluded from home range analysis.

Movement of largemouth bass ranged from 0 to 324 m/h before hydrilla reduction and 0 to 465 m/h afterwards, and mean movement of largemouth bass was greater after hydrilla reduction (Table 2). Movement was typically low (<50 m/h) in both treatment periods; however, frequency distributions were different between treatments (Figure 2). Depths of tagged largemouth bass ranged from 0.4 to 5.3 m before hydrilla reduction and 0.4 to 6.0 m afterwards. Mean depth of largemouth bass was greater after hydrilla reduction (Table 2), and depth distribution was deeper (Figure 3). Home range size ranged from 0.9 to 200 days and with at least 35 locations were used in this study.

**TABLE 1. Total length, weight, date tagged, days at large, number of locations, and fate of 19 of 35 largemouth bass implanted with radio tags in Lake Seminole, Georgia. Only fish at large for more than 200 days and with at least 35 locations were used in this study.**

<table>
<thead>
<tr>
<th>Tag</th>
<th>Total Length (mm)</th>
<th>Weight (g)</th>
<th>Date Tagged</th>
<th>Last Date Found</th>
<th>Days at Large</th>
<th>Number Locations</th>
<th>Fate</th>
</tr>
</thead>
<tbody>
<tr>
<td>013</td>
<td>471</td>
<td>1740</td>
<td>09 Feb 2000</td>
<td>22 May 2001</td>
<td>468</td>
<td>95</td>
<td>Tag Expired</td>
</tr>
<tr>
<td>023</td>
<td>511</td>
<td>2240</td>
<td>09 Feb 2000</td>
<td>05 Apr 2001</td>
<td>421</td>
<td>80</td>
<td>Tag Expired</td>
</tr>
<tr>
<td>044</td>
<td>444</td>
<td>1535</td>
<td>09 Feb 2000</td>
<td>08 Sep 2000</td>
<td>212</td>
<td>43</td>
<td>Fish Died</td>
</tr>
<tr>
<td>054</td>
<td>539</td>
<td>2205</td>
<td>09 Feb 2000</td>
<td>21 May 2001</td>
<td>467</td>
<td>92</td>
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<td>2515</td>
<td>09 Feb 2000</td>
<td>05 Apr 2001</td>
<td>421</td>
<td>81</td>
<td>Tag Expired</td>
</tr>
<tr>
<td>095</td>
<td>546</td>
<td>2533</td>
<td>09 Feb 2000</td>
<td>26 Apr 2001</td>
<td>442</td>
<td>89</td>
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</tr>
<tr>
<td>114</td>
<td>609</td>
<td>4108</td>
<td>09 Feb 2000</td>
<td>22 Aug 2001</td>
<td>560</td>
<td>117</td>
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</tr>
<tr>
<td>124</td>
<td>525</td>
<td>2150</td>
<td>09 Feb 2000</td>
<td>25 Apr 2001</td>
<td>441</td>
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<tr>
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<td>1688</td>
<td>09 Feb 2000</td>
<td>05 Apr 2001</td>
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<td>571</td>
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<td>25 Apr 2001</td>
<td>441</td>
<td>86</td>
<td>Fish Died</td>
</tr>
<tr>
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<td>579</td>
<td>3150</td>
<td>25 Feb 2001</td>
<td>13 Dec 2001</td>
<td>291</td>
<td>42</td>
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<tr>
<td>503</td>
<td>434</td>
<td>1670</td>
<td>25 Feb 2001</td>
<td>13 Dec 2001</td>
<td>291</td>
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<tr>
<td>544</td>
<td>598</td>
<td>2110</td>
<td>25 Feb 2001</td>
<td>13 Dec 2001</td>
<td>291</td>
<td>50</td>
<td>Study Ended</td>
</tr>
</tbody>
</table>

core use area ranged from 0.3 to 9.6 ha after hydrilla removal. However, mean home range and core use areas of the fish did not change after hydrilla was reduced (Table 2). Large-mouth bass movement did not change after hydrilla reduction in the crepuscular and night periods; however, movement during the day more than doubled (Figure 4). Mean depth of largemouth bass increased in the crepuscular and daytime periods, but was not different at night (Figure 4). Habitat use of largemouth bass was primarily hydrilla and large woody debris before hydrilla reduction; large woody debris were the primary habitat used afterwards (Figure 5).

**DISCUSSION**

Hydrilla reduction in Spring Creek was associated with changes in largemouth bass movements and depth distributions, but had little effect on home ranges. Similar to our study, home ranges reported for largemouth bass generally ranged from <0.1 to 50 ha (Lewis and Flickinger 1967, Warden and Lorio 1975, Fish and Savitz 1983, Mesing and Wick-er 1986, Wanjala et al. 1986, Colle et al. 1989, Bain and Boltz 1992, Lyons 1993, Furse et al. 1996, Woodward and Noble 1997). Rapid hydrilla loss in late summer 2000 did not cause fish to leave the area in search of hydrilla. Unlike those tagged in 2001, the first group of tagged largemouth bass were subjected to widely disparate abundances of hydrilla. Only two fish from the group tagged in 2000 became missing, and one of those was almost certainly the result of tag failure, since contact was lost during a 24-hour tracking period. The fate of the other fish remained unknown; however, contact was lost 2 months before the hydrilla canopy collapsed in August 2000. All the other fish remained in the study area and in most cases home ranges before and after hydrilla removal were broadly overlapping.

**TABLE 2. MEAN MOVEMENT, DEPTH, AND HOME RANGES OF LARGEMOUTH BASS BEFORE AND AFTER HYDRILLA REMOVAL IN SPRING CREEK, LAKE SEMINOLE, GEORGIA, IN 2000 AND 2001.**

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
<th>t-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diel Movement (m/h)</td>
<td>Mean (N)</td>
<td>Standard Error</td>
<td>Mean (N)</td>
<td>Standard Error</td>
</tr>
<tr>
<td></td>
<td>39.8 (10)</td>
<td>5.4</td>
<td>54.3 (9)</td>
<td>8.2</td>
</tr>
<tr>
<td>Depth (m)</td>
<td>2.4 (10)</td>
<td>0.2</td>
<td>3.0 (9)</td>
<td>0.3</td>
</tr>
<tr>
<td>95% Kernel Home Range (ha)</td>
<td>18.9 (9)</td>
<td>0.4</td>
<td>19.1 (8)</td>
<td>0.3</td>
</tr>
<tr>
<td>Core Use Area (ha)</td>
<td>3.40 (9)</td>
<td>0.9</td>
<td>3.82 (8)</td>
<td>1.2</td>
</tr>
</tbody>
</table>

**Figure 2.** Frequency distributions (10-m/h increments) of diel movement observed for largemouth bass before and after hydrilla reduction in Spring Creek, Lake Seminole, Georgia, in 2000 and 2001. Distributions were different between treatments (Kolmogorov-Smirnov Test, KS_a = 1.30, P = 0.07).

**Figure 3.** Frequency distributions (0.2-m increments) of depth observed for largemouth bass before and after hydrilla reduction in Spring Creek, Lake Seminole, Georgia, in 2000 and 2001. Distributions were different between treatments (Kolmogorov-Smirnov Test, KS_a = 3.48, P = 0.0001).
Largemouth bass movement increased following hydrilla reduction. Movement of largemouth bass has been found to be influenced by light levels (Messing and Wicker 1986, Colle et al. 1989), and large reductions of aquatic plants can result in decreased water clarity (Canfield et al. 1983, Leslie et al. 1983, Maceina et al. 1992). Similarly, Secchi disk depths decreased in Spring Creek, following hydrilla reduction. Before the decline in hydrilla, Secchi depths were unable to be taken because of the dense vegetation. However, in a few bare places the bottom could be clearly seen in water depths up to 5 m. In contrast, mean Secchi transparency in summer 2001 was 2.7 m. Thus the reduction in water clarity may have accounted for the large increase in daytime movement observed after hydrilla removal.

The change in habitat complexity may also have contributed to the increase in largemouth bass movement. Largemouth bass in experimental systems have been found to change predation tactics in response to decreases in aquatic plant densities, switching from active searching to ambush hunting (Savino and Stein 1982). Dense vegetation provides abundant cover for prey fishes, which decreases feeding efficiency by predators such as largemouth bass (Savino and Stein 1982, Dibble et al. 1996), leading to reduced growth and poor body condition (Colle and Shireman 1980, Maceina and Shireman 1985, Maceina et al. 1991, Bettoli et al. 1992), which Brown and Maceina (2002) observed in Spring Creek prior to hydrilla reduction. Also, dense vegetation can also depress dissolved oxygen levels, leading to more concentrated prey fish in oxygenated refugia (Miranda et al. 2000); whereas, dissolved oxygen and prey distributions can be more uniform in absence of aquatic plants (Miranda and Hodges 2000). Thus largemouth bass in Spring Creek may have began actively searching for prey after hydrilla reduction, leading to higher movement rates.

Vegetation losses can also affect species abundance and composition (Bettoli et al. 1991, 1993). Top predators such as largemouth bass may be confronted by an entirely new fish fauna community with drastic changes in plant abundance, causing them to change prey selection and feeding strategies, causing differences in behavior. Pelagic fish species, such as gizzard shad (Dorosoma cepedianum Lesueur), and threadfin shad (D. petenense Günther), generally increase in abundance following plant reduction (Maceina and Shireman 1985, Bettoli et al. 1993), and threadfin shad appeared to be increasing in Spring Creek as hydrilla decreased. Switching from a more littoral prey species such as bluegill (Lepomis macrochirus Rafinesque) to shad should change behavior, and may contribute to the increase in daytime movement we observed, since shad tend to congregate near the surface during the day and may be more vulnerable to predation (Vondracek and Degan 1995; Sammons and Bettoli 2002).

As hydrilla was reduced in Spring Creek, largemouth bass switched from using primarily hydrilla to large woody debris

Figure 4. Mean diel movement and depth of largemouth bass at three diel periods before and after hydrilla reduction in Spring Creek, Lake Seminole, Georgia, in 2000 and 2001. Means with the same letter within each diel period were not different (t-test, P > 0.10).

Figure 5. Habitat use of tagged largemouth bass before and after hydrilla reduction in Spring Creek, Lake Seminole, Georgia, in 2000 and 2001. Habitat categories are: bare (no plants or other cover), emergent vegetation, floating-leaved plants, SAV (submersed native aquatic plants), hydrilla, LWD (large woody debris), and other (e.g., docks).
Largemouth bass are a structurally-oriented fish (Schlagenhaft and Murphy 1985, Colle et al. 1989, Lyons 1993, Annett et al. 1996), and when aquatic vegetation is present, these fish will usually use this habitat more often than other available habitats (Betsill et al. 1986, Mesing and Wicker 1986, Smith and Orth 1990, Lyons 1993). In a lake where all the vegetation had been removed, Colle et al. (1989) found that largemouth bass in inshore areas preferred emergent weedy areas, avoiding bare areas, while fish that stayed offshore were closely associated with piers. Largemouth bass in Spring Creek would occasionally be found in shallow shifty flats or in bare areas that formerly harbored hydrilla, but usually they would be associated with some form of cover. The general increase in depth distribution by largemouth bass after hydrilla removal may have been a response to the loss of shallow cover by shifting to using large woody debris such as stumps, which were generally found in deeper water.

**MANAGEMENT IMPLICATIONS**

Largemouth bass anglers prefer fishing submerged vegetation such as hydrilla, and are generally not supportive of vegetation removal or reduction programs, believing that any such programs will reduce largemouth bass abundance and negatively affect the fishery (Klussman et al. 1988, Wilde et al. 1992, Slipke et al. 1998). Our results indicated that largemouth bass did not abandon areas where vegetation was reduced, but they did respond differently to habitat changes. Our data showed largemouth bass tended to inhabit deeper water, exhibit greater movement within their home ranges, and used woody structure and not other vegetation such as emergent or floating-leaved that was present following hydrilla reduction.

Fisheries such as Lake Seminole are extremely valuable to surrounding communities, and changes in the plant community of a system, along with the corresponding changes in fish communities, whether real or perceived, can have economic impacts. Angling effort on Lake Guntersville, Alabama declined 63% over a 3-year period when vegetation levels decreased, causing a drop of $1.4 million in angling expenditures over that time (Wrenn et al. 1996). Anglers at Lake Conroe, Texas, remain convinced that the fishery was negatively impacted by total removal of hydrilla from the system in the early 1980s, despite data to the contrary (Wilde et al. 1992). Clearly balancing the needs of and perceptions of various user groups is vital for success of any vegetation management project. Our study showed some impacts to largemouth bass behavior by vegetation reduction did occur, but most fish did not migrate away from the fluridone application and the decline in hydrilla. When large-scale vegetation reduction occurs similar to those we observed in Spring Creek, anglers will have to alter their fishing behavior to remain successful.

**ACKNOWLEDGMENTS**

Funding for this project was provided by the Georgia Department of Natural Resources through Federal Aid to Sportfish Restoration Project F-64. Support was also provided to S. M. Sammons with student scholarships provided by the Midouth Aquatic Plant Management Society and the Reservoir Committee of the Southern Division of the American Fisheries Society, and with a fellowship provided by Auburn University. Mike Mitchell, Alabama Cooperative Fishery and Wildlife Research Unit at Auburn University provided technical advice on kernel home range estimations.

**LITERATURE CITED**


