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Effect of Aquathol K Treatments on Activity Patterns of Largemouth Bass in Two Coves of Lake Seminole, Georgia

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ABSTRACT

Thirty largemouth bass (*Micropterus salmoides* Lacepde) were implanted with radio tags in late October 2003 in two coves of Lake Seminole, Georgia, and tracked over a 24-hour period about every 10 days to determine their response to herbicide application. After five weeks of tracking, hydrilla (*Hydrilla verticillata* Royle) in each cove was treated in early December 2003 with dipotassium salt of endothall (Aquathol K; 7-oxabicyclo [2.2.1] heptane-2,3-dicarboxylic acid) at a rate of 3.5 ppm. Largemouth bass were tracked during application and tracking continued for three months post treatment to assess effects of herbicide treatment on activity patterns. The treatment in Desser Cove successfully reduced hydrilla in approximately half the cove. However, the treatment in Peacock Lake completely eliminated all submersed aquatic vegetation (SAV) by April 2004. Movement and activity centers remained similar between treatment periods in Desser Cove, but increased after treatment in Peacock Lake. Depth occupied by telemetered fish decreased after Aquathol K treatment in both coves. In general, behavior of largemouth bass did not change appreciably during treatment, and only minor changes were observed in the post-treatment period in Peacock Lake, where all SAV was eliminated. Fish showed little attraction to or movement away from treatment areas, and fish migration from either cove was nil after treatment. Application of Aquathol K and subsequent reduction of SAV had little effect on largemouth bass behavior or movement.

Key words: telemetry, herbicide, endothall, activity patterns.

INTRODUCTION

Submersed aquatic vegetation (SAV) influences fish populations by enhancing reproductive success of many sportfish, increasing abundance of prey such as macroinvertebrates and smaller fishes, and by controlling access to this prey through predation efficiency (Savino and Stein 1982, Dibble et al. 1996, Trebitz and Nibbelink 1996, Unmuth et al. 1999). High SAV abundance (>50% percent area covered [PAC]) also restricts access of anglers (Colle et al. 1987) and can affect angler success (Maceina and Reeves 1996). Intermediate coverage of SAV (20% to 40% PAC) has been found to provide a trade-off between prey production and predation efficiency, leading to increased growth, condition, and abundance of sportfish such as largemouth bass (e.g., Wiley et al. 1984, Dibble et al. 1996, Brown and Maceina 2002).

Most largemouth bass anglers prefer to fish in or near SAV and often oppose control of aquatic macrophytes (Wilde et al. 1992). More than 40% of bass tournament anglers in Texas opposed or strongly opposed any type of SAV control (Wilde et al. 1992). Greater than 70% of largemouth bass anglers preferred the same amount or more SAV in the heavily-vegetated Lake Seminole, Georgia; whereas, >50% of anglers targeting other species preferred less SAV coverage (Slipke et al. 1998). All categories of anglers preferred increased SAV densities in two South Carolina reservoirs (Henderson et al. 2003).

Although herbicide treatments are the most common way to control abundant SAV in the southeastern U.S. (Bates and Smith 1994), obviously reduction of SAV using herbicides is not without controversy (Henderson 1996). Although numerous largemouth bass population-level studies have been conducted in relation to changes in SAV abundance (reviewed by Maceina 1996, Sammons et al. 2005), few studies have examined largemouth bass behavioral responses to herbicide applications (Bain and Boltz 1992, Boyer and Cichra 1994, Sammons et al. 2003). Since the responses of largemouth bass likely depends on many factors, including treatment protocol and herbicide used, more studies of this topic are needed. The objective of this study was to examine changes in behavior and activity patterns of largemouth bass in response to small-scale herbicide treatments using dipotassium salt of endothall (Aquathol K; 7-oxabicyclo [2.2.1] heptane-2,3-dicarboxylic acid) in two coves of Lake Seminole, Georgia.

MATERIALS AND METHODS

Study Areas, Herbicide Treatment, and Plant Surveying

The study was conducted in two coves adjacent to the Chattahoochee River arm of Lake Seminole, Georgia. Desser Cove was a 39-ha shallow (<2 m) slough approximately 100 m wide and 5 km long (Figure 1). Before herbicide treatment, the cove was approximately 100% covered with a monoculture of hydrilla, with a narrow fringe of alligator weed (*Alternanthera philoxeroides* G.), water hyacinth [*Eichhornia crassipes* (Mart.) Solms.], and giant cutgrass [*Zizaniopsis miliacea* (Michx.) Doell. + Asch.]. In contrast, Peacock Lake was a 23-ha discrete lake connected to the main channel of the Chat-

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tahoochee River by a narrow stream (Figure 1). Approximately 52% of the cove was covered with hydrilla, 10% with American lotus [*Nelumbo lutea* (Willd.) Pers.], and the remainder was mostly open and deeper, with depths up to 6 m. Some limited standing timber was located in deeper water, along with some scattered coontail (*Ceratophyllum demersum* Lacepde). A narrow fringe of alligatorweed, water hyacinth, and giant cutgrass encircled the cove.

Both coves were treated with 3.5 ppm (total of 2,388 L) of Aquathol K on December 4, 2003. Desser Cove was treated in one long continuous strip beginning at the western bank and extending halfway across the cove for its entire length (total of 17.8 ha). Peacock Lake was treated in a series of 31.25-m strips placed approximately 100 m apart (6 strips in all); approximately 11 ha were treated. In both coves, herbicide was applied to create vegetative edge habitat that was expected to provide SAV-open water interface habitat for largemouth bass (Engel 1995, Trebitz and Nibbelink 1996).

In 2001, SAV was mapped reservoir-wide using remote-sensing imagery that recorded differences in reflectance of light for each vegetation type (D. Morgan, USACE, pers. comm.). Reflectance values for each type (floating, emergent, submersed, topped) were determined in the field and assigned for the entire area. Coverage of each type was then

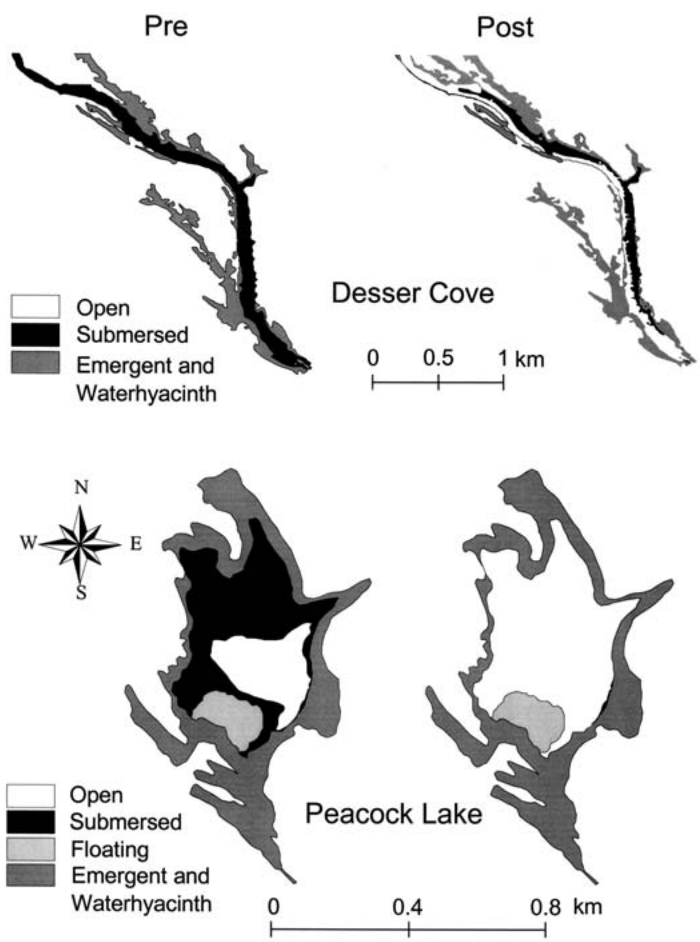

Figure 1. Map showing plant coverages in the two coves of Lake Seminole, Georgia, used in this study before (pre) and after (post) application of Aquathol K herbicide.

determined using ArcMap/ArcInfo software (ESRI, Inc., Redlands, CA). Aquatic plant coverage did not change appreciably in either cove between 2001 and 2003 (D. Morgan, USACE, pers. comm.), thus this survey was used to approximate conditions in each cove before treatment. Aquatic plants were mapped in each cove in April 2004 using a recording fathometer (Maceina and Shireman 1980) and a global position system (GPS) by the USACE. At each waypoint taken with the GPS unit, a simultaneous fix mark was taken with the fathometer to determine whether SAV was present or absent at each waypoint. Periodically, a vegetation rake was used to determine species composition of SAV. Waypoints and their associated vegetation attributes were imported into ArcView software (ESRI, Inc., Redlands, CA) to create vegetation polygons and estimate percent areal coverage in each cove.

Largemouth Bass Telemetry

Fifteen largemouth bass greater than 500 g were implanted with radio tags (Advanced Telemetry Systems, Inc., Isanti, MN) using the methods of Maceina et al. (1999) in each cove on October 28, 2003. We followed the recommendation of Winter (1996) of not implanting a tag greater than 2% of body weight to ensure that behavior and movement will not be affected. Tags had a 180-day life expectancy and were fitted with a mortality sensor. If the tag was motionless for at least 24 hours due to death or expulsion, then the signal rate doubled. All fish were collected using electrofishing. Immediately upon capture, fish had a radio tag implanted and were released at the site of capture.

Fish were tracked in a 4.2-m boat equipped with a 30-hp go-devil motor approximately every 10 days beginning approximately 2 weeks after tag insertion. On each sampling date, fish were found every 4 to 6 hours for a 24-hour period to assess movement patterns. The precise location (within 5 m) of each fish was mapped using a GPS receiver. The primary habitat type and water depth were recorded at each location.

Only fish that were at large in the coves for at least 140 days and with at least 50 locations were used for analysis (Table 1). Fish locations were divided into two time periods: a pre-treatment period (November 14, 2003 to December 16, 2003), before SAV responded to the herbicide, and a post-treatment period (January 8, 2004 to March 30, 2004), after SAV declined from the treatment. Primary habitat for each location was grouped into one of eight categories: hydrilla, water hyacinth, alligatorweed, large woody debris (Peacock Cove only), American lotus (Peacock Cove only), giant cutgrass, open (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. Activity centers were calculated for each fish in each treatment using a 20% kernel estimator (Seaman and Powell 1996, Sammons et al. 2003). Site fidelity of each fish in each treatment period was tested using the Monte Carlo random walk test developed by Spencer et al. (1990), modified by Hooge et al. (2001). Movement and depth were further subdivided in each treatment period into diel time periods: dawn, two hours before and after sunrise, dusk, two

Table 1. Tag number, total length, weight, last date found, days at large, number of locations, and fate of 30 largemouth bass implanted with radio tags on October 28, 2003, in Desser Cove and Peacock Lake in Lake Seminole, Georgia.

Cove	Tag	Total length (mm)	Weight (g)	Last date found	Days at large	No. locations	Fate
Desser	155	465	1685	30 Mar 04	154	54	Study ended
	173	490	1700	30 Mar 04	154	55	Study ended
	193	430	1092	30 Mar 04	154	50	Study ended
	213	426	1091	30 Mar 04	154	54	Study ended
	234	372	725	30 Mar 04	154	54	Study ended
	253	367	680	30 Mar 04	154	54	Study ended
	273	379	758	14 Nov 03	17	2	Fish died
	294	525	2400	30 Mar 04	154	55	Study ended
	313	446	1250	30 Mar 04	154	55	Study ended
	334	399	925	30 Mar 04	154	55	Study ended
	354	440	1442	30 Mar 04	154	55	Study ended
	374	372	785	30 Mar 04	154	55	Study ended
	394	395	910	30 Mar 04	154	55	Study ended
	414	340	510	10 Dec 03	43	19	Fish died
	434	356	600	2 Dec 03	35	9	Fish died
Peacock	453	535	2350	30 Mar 04	154	54	Study ended
	475	360	686	18 Mar 04	142	50	Lost
	495	338	500	30 Mar 04	154	55	Study ended
	514	365	650	30 Mar 04	154	55	Study ended
	534	343	600	30 Mar 04	154	55	Study ended
	555	459	1556	17 Dec 03	50	26	Fish died
	573	604	3900	13 Nov 03	16	2	Fish died
	594	448	1400	30 Mar 04	154	55	Study ended
	614	444	1299	30 Mar 04	154	55	Study ended
	633	376	794	30 Mar 04	154	54	Study ended
	654	616	4128	30 Mar 04	154	55	Study ended
	674	455	1565	30 Mar 04	154	55	Study ended
	694	380	812	30 Mar 04	154	55	Study ended
	714	534	2530	30 Mar 04	154	55	Study ended
	732	464	1558	30 Mar 04	154	55	Study ended

hours before and after sunset, day, and night (Sammons et al. 2003). Movements were assigned to the time period in which the majority of the movement occurred.

Movement and depth distributions in each treatment period were compared using a Kolmogorov-Smirnov Test (SAS 2000). Mean movement and depth were compared between treatments in each area using a repeated measures analysis of variance with each fish being considered as a randomly-chosen fixed subject and sample week used as the time function (Maceina et al. 1994). Activity centers were compared between treatments in each area using a t-test (SAS 2000). Movement and depth data were non-normally distributed and were loge-transformed prior to analysis. Mean depth and movement were compared between the two treatments in each diel time period using a t-test (SAS 2000). Differences in proportions of fish locations occupying the treatment area and non treatment area in Desser Cove were tested using chi-squared analyses (SAS 2000). This analysis was not done for Peacock Lake, because all SAV was eliminated and there were no distinct treated and untreated areas. All comparisons were considered significant at $P < 0.10$.

RESULTS AND DISCUSSION

Application of Aquathol K in Desser Cove reduced hydrilla along the entire western bank of the slough, creating definite edge habitat throughout much of the cove (Figure 1). Available habitat shifted from a monoculture of hydrilla to large open areas with a scattered patchwork of hydrilla clumps. In contrast, application of Aquathol K in Peacock Lake eliminated all SAV in the cove by April 2004 (Figure 1). Available habitat changed from 52% coverage of hydrilla to mostly open water, except for scattered stems of American lotus. In both coves, the fringe of water hyacinths, alligatorweed, and giant cutgrass was unaffected by herbicide treatment.

Twelve largemouth bass in Desser Cove and 13 in Peacock Cove were tracked long enough and had enough locations to be used for these analyses. These fish were at large for 142 to 154 days and were located 50 to 54 times (Table 1). The other 5 fish died within two months of tag implantation. No fish left Desser Cove during this study; however one fish in Peacock Lake was unable to be found on the last sample date. This fish may have left the cove, been removed by angling, or the tag signal may have terminated prematurely. Since none of the other fish left the coves during this study, it is unlikely that the absence of this fish was due to the herbicide treatment.

Movement did not change in Desser Cove after herbicide application; however, it increased 38% in Peacock Lake (Table 2). In Desser Cove, movements were skewed low (<20 m/h) both before and after herbicide treatment; however, incidence of movements >80 m/h increased slightly after Aquathol K application (Figure 2; Kolmogorov-Smirnov Test; $P < 0.10$). In contrast, movements in Peacock Lake were more evenly distributed, although movements > 80m/h were

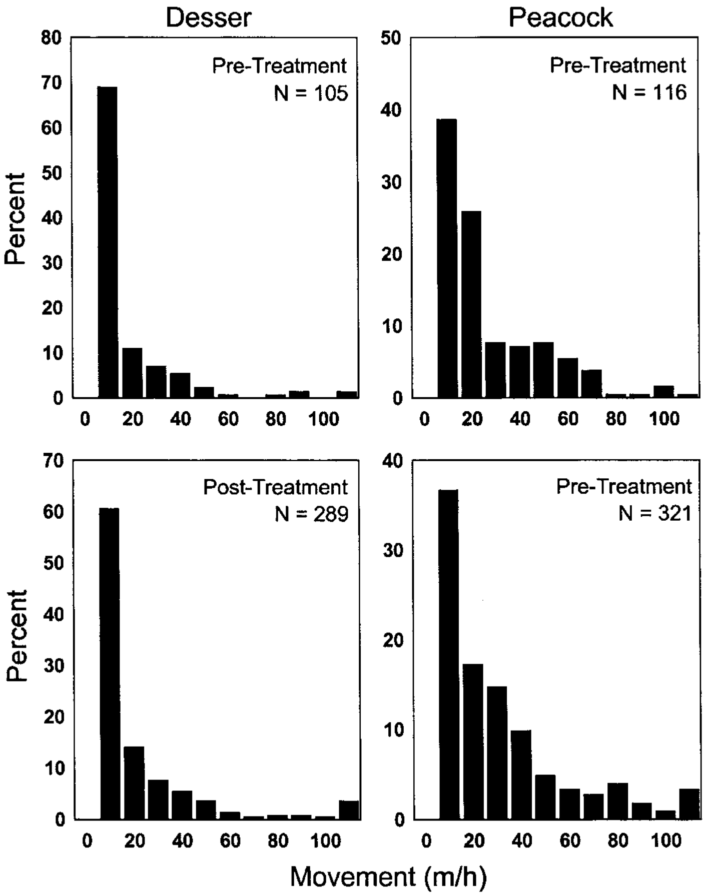

Figure 2. Frequency distribution (10-m/h increments) of diel movement observed for largemouth bass before and after treatment with Aquathol K herbicide in Desser Cove and Peacock Lake of Lake Seminole, Georgia. Distributions were different between treatment periods in both coves (Desser; KSa = 1.41; P < 0.10; Peacock; KSa = 1.21; P < 0.10).

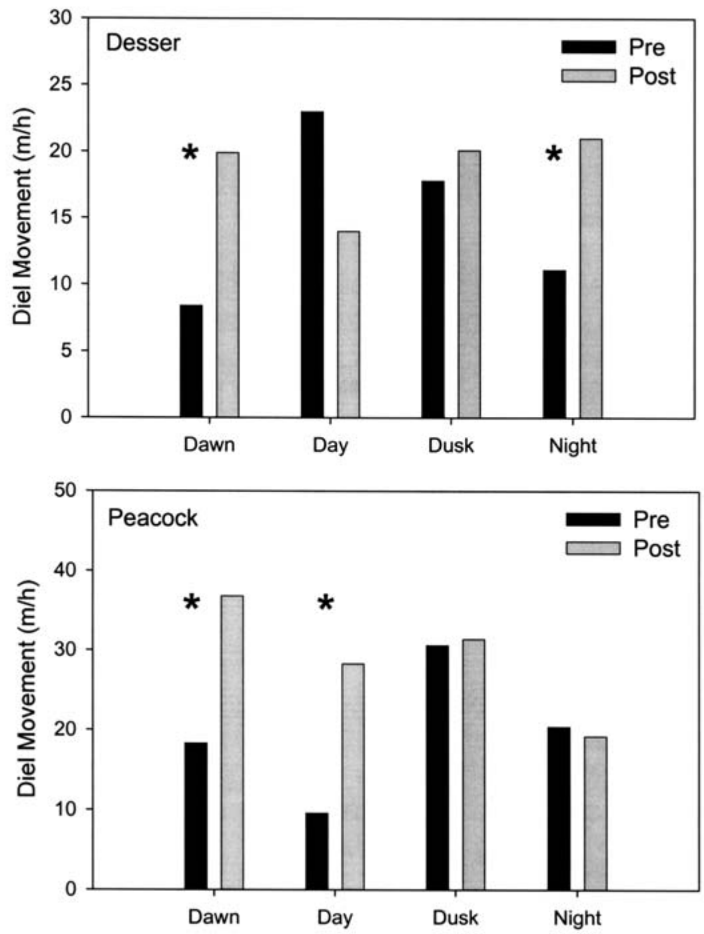

Figure 3. Mean movement in four diel periods of telemetered largemouth bass in two areas of Lake Seminole, Georgia, before and after treatment with Aquathol K herbicide. Asterisks denote significant differences in movement between treatment in each diel period (t-test, P < 0.10).

more common after herbicide treatment (Figure 2; Kolmogorov-Smirnov Test; P < 0.10). Movement increased after herbicide treatment in Desser Cove in the dawn and night periods, but remained similar in day and dusk periods (Figure 3). However, movement increased during the dawn and day periods, but remained similar in dusk and night periods in Peacock Lake after treatment (Figure 3). Activity center size significantly increased after herbicide treatment in Peacock Lake, but appeared to decline in Desser Cove, although the change was not significant (Table 2).

Mean depths occupied by telemetered largemouth bass declined slightly after herbicide treatment in Desser Cove (Table 2). A similar decline appeared for fish in Peacock Lake, but was not statistically significant. However, depth distribution shifted dramatically after Aquathol K treatments in Desser Cove, with most fish being found in water <1.2 m deep (Figure 4; Kolmogorov-Smirnov Test; P < 0.10). A similar shift was observed in Peacock Lake after elimination of SAV; however, fish occupied a wider range of depths after SAV elimination than they had before treatment (Figure 4; Kolmogorov-Smirnov Test; P < 0.10). Depths significantly declined in the dawn, day, and night periods in Desser Cove, and in the day, dusk, and night periods in Peacock Lake after herbicide treatment (Figure 5).

Habitat use in Desser Cove shifted from almost exclusively hydrilla before herbicide treatment to a mixture of hydrilla, water hyacinth, giant cutgrass, and open water afterwards (Figure 6). However, almost 50% of all fish locations were in hydrilla after herbicide treatment, indicating little movement away from hydrilla towards open water or treated areas. The proportion of all fish locations occupying the treatment area and nontreatment area did not change following Aquathol K application in Desser Cove (Chi-square; P > 0.10). Chi-squared analyses revealed that 7 of 12 fish did not move away from or towards the treatment area (P > 0.10); however, 3 fish decreased their use of the treatment area and two fish increased their use of the treatment area following herbicide application (Chi-squared, P < 0.10). In contrast, habitat use in Peacock Lake shifted from primarily hydrilla to open water following SAV elimination (Figure 6). Largemouth bass continued to be found in hydrilla while some still remained in the cove; however, all hydrilla was eliminated by one month into the post treatment period. Water hyacinth use almost tripled, and use of giant cutgrass and alligator-

Table 2. Mean movement, depth, and activity center of largemouth bass before and after herbicide treatment in two coves of Lake Seminole, Georgia, in 2003 and 2004.

Cove	Measure	Pre-treatment mean (N)	Post-treatment mean (N)	Test statistic	P
Desser	Movement (m/h)	7.15 (105)	8.17 (289)	F = 0.27	0.62
	Depth (m)	1.45 (181)	1.13 (371)	F = 3.34	0.09
	Activity Center (ha)	1.56 (12)	0.89 (12)	t = 1.20	0.25
Peacock	Movement (m/h)	10.83 (116)	14.96 (321)	F = 5.80	0.03
	Depth (m)	1.78 (206)	1.50 (404)	F = 1.29	0.28
	Activity Center (ha)	0.29 (13)	0.45 (13)	t = 1.79	0.09

weed also increased after treatment. However, use of American lotus remained similar between treatments (Figure 6).

Aquathol K has been shown to be effective in controlling hydrilla (Skogerboe and Getsinger 2001), and is commonly applied in a transect pattern to create edge habitat for fish such as largemouth bass (G. Adrian, Cerexagri, Inc., pers. comm.). Largemouth bass have been found to be associated with edge habitat (Engel 1986), presumably because it enhances predation success (Pothoven et al. 1999). Creating channels in dense SAV has been shown to increase growth of some age classes of largemouth bass (Pothoven et al. 1999, Unmuth et al. 1999). The treatment in Desser Cove was successful at opening a long channel in the formerly dense monoculture of hydrilla in that cove. However, the same treatment in Peacock Lake resulted in complete elimination of all SAV in that cove.

Variable effectiveness of herbicide treatment is not unusual, but the difference in results between the two coves was puzzling. Skogerboe and Getsinger (2001) reported that exposure time of plants to Aquathol K was important in determining overall effects of the treatment. Desser Cove had some water flow resulting from several springs located within

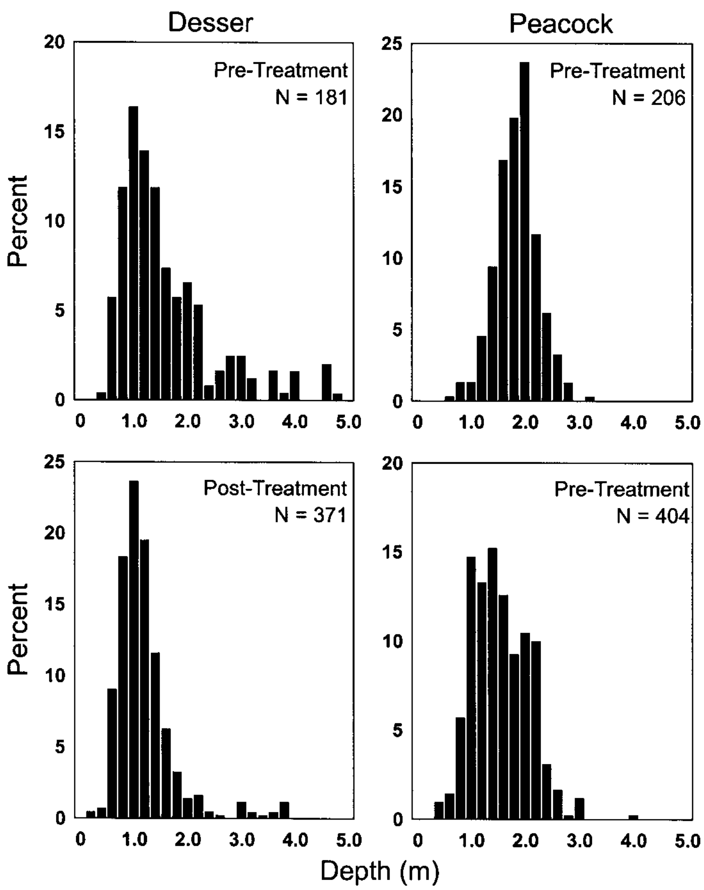

Figure 4. Frequency distribution (0.2-m increments) of depths occupied by telemetered largemouth bass before and after treatment with Aquathol K herbicide in Desser Cove and Peacock Lake of Lake Seminole, Georgia. Distributions were different between treatment periods in both coves (Desser; KSa = 3.14; P < 0.10; Peacock; KSa = 4.59; P < 0.10).

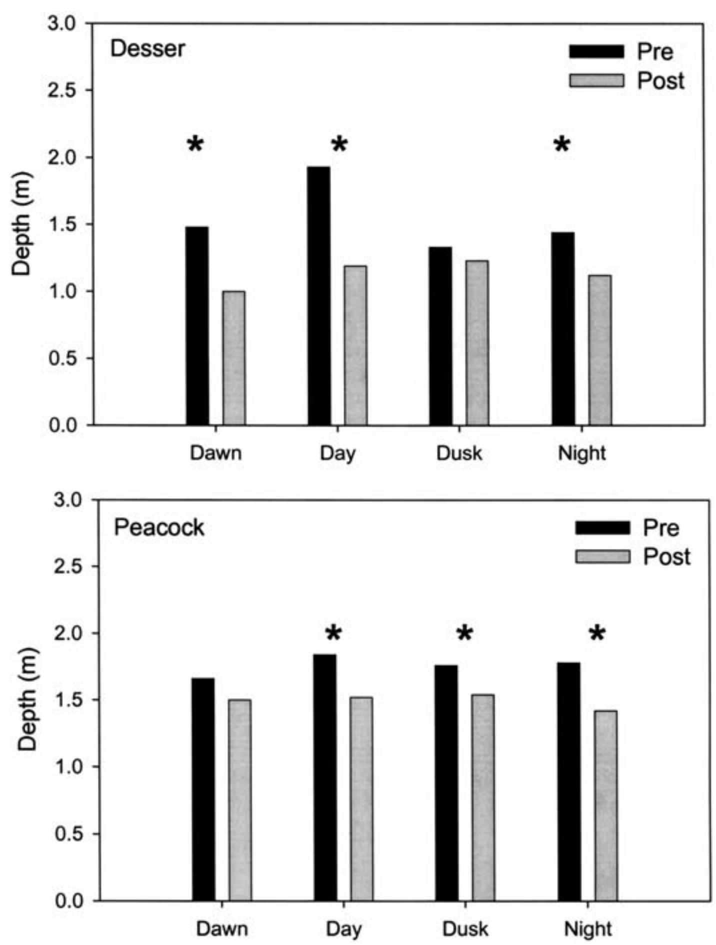

Figure 5. Mean depth in four diel periods of telemetered largemouth bass in two areas of Lake Seminole, Georgia, before and after treatment with Aquathol K herbicide. Asterisks denote significant differences in depth between treatment in each diel period (t-test, P < 0.10).

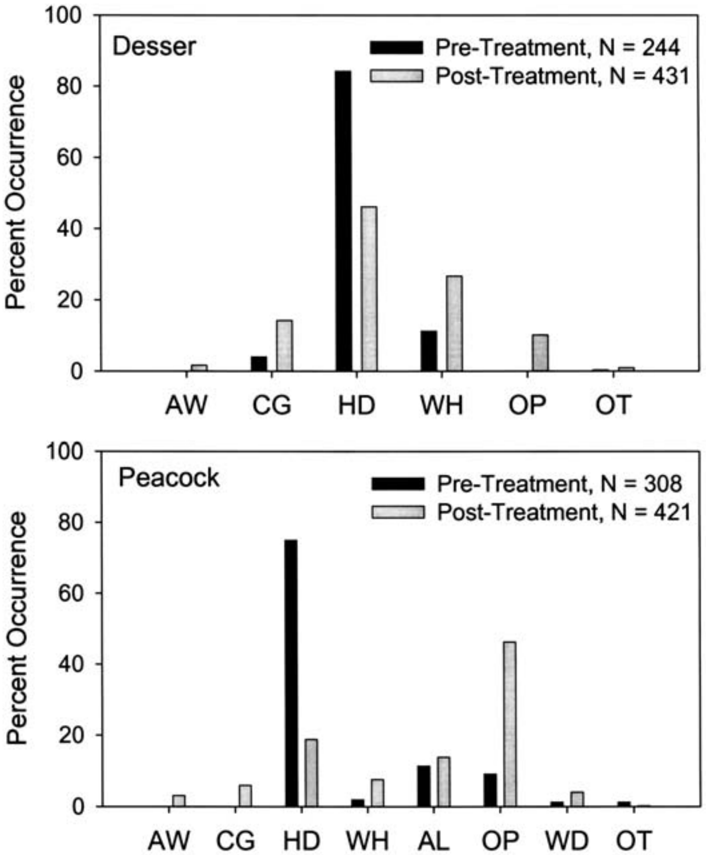

Figure 6. Percent occurrence of tagged largemouth bass in habitat categories before and after Aquathol K treatment in two coves of Lake Seminole, Georgia. Habitat categories were: alligatorweed (AW), giant cutgrass (CG), hydrilla (HD), waterhyacinth (WH), American lotus (AL), open, no plant material (OP), woody debris (WD), and other (e.g., native submersed vegetation; OT).

it, which may have limited the effects of the herbicide. In contrast, Peacock Lake was almost completely isolated from the main Chattahoochee River channel, and thus SAV may have had a longer exposure time to the herbicide in Peacock Lake than in Desser Cove, leading to more effective control. The two areas were treated on the same day with the same batch of herbicide at similar water temperatures, so environmental conditions and herbicide effectiveness was assumed to be similar between the two coves (D. Morgan, U.S. Army Corps of Engineers, pers. comm.). Regardless, Aquathol K treatment resulted in changes in SAV in both coves.

After herbicide treatment, largemouth bass movement increased in Peacock Lake, but not in Desser Cove; whereas, depth distribution decreased in both coves. However, activity center size appeared to decrease in Desser Cove, but increased in Peacock Lake after treatment. Sammons and Maceina (2003) found that home range size was related to fish movement in the Spring Creek arm of Lake Seminole, which we observed in Peacock Lake. However in Desser Cove, fish movement increased slightly after treatment (14%), but activity center size declined 43%. The divergence in results between the two coves may have been related to the continued presence of hydrilla after herbicide treatment in Desser Cove. Similar to the results in Peacock Lake, largemouth bass movement in the Spring Creek arm of Lake Seminole increased after a large reduction of hydrilla occurred (Sammons et al. 2003). However, hydrilla remained abundant in Desser Cove after herbicide treatment, and fish were often located in it. Thus, treatment in Desser Cove may not have removed enough SAV to affect largemouth bass movement patterns.

Largemouth bass in this study were found in shallower areas following herbicide treatment in both coves. However, in a similar study Sammons et al. (2003) found that largemouth bass used deeper areas following a large-scale reduction of hydrilla in the Spring Creek arm of Lake Seminole. The decrease in depth distribution after treatment in this study may have been confounded by the spawning season, which occurred in the post-treatment period. Largemouth bass typically spawn in shallow (<0.5 m) protected areas clear of SAV or other complex habitats (Allan and Romero 1975, Hunt and Annett 2002). Many locations in Desser Cove continued to contain dense SAV or floating and emergent vegetation, which would not seem to represent quality spawning habitat. However, no attempt was made to determine whether or not fish were in fact spawning, so it is likely that spawning movements did somewhat confound the results of this study.

Largemouth bass shifted from using hydrilla to open water habitats as hydrilla disappeared in Peacock Lake. Use of American lotus did not change, and only a slight increase in the use of giant cutgrass, alligatorweed, and water hyacinths was observed. Fish did not appear to change the area that they had used in Peacock Lake before SAV elimination, despite the dramatic change of habitat. Largemouth bass appeared to continue to use the same areas before and after SAV elimination, although movement increased significantly. In contrast, largemouth bass in the Spring Creek arm of Lake Seminole were primarily found in shallow hydrilla before herbicide treatment, then shifted to offshore large woody debris following elimination of hydrilla (Sammons et al. 2003). Savino and Stein (1982) predicted that as SAV density declined below a certain threshold, largemouth bass would switch from a sedentary ambush strategy to actively searching for prey. Our results support this prediction, and suggested that switching habitats may not be necessary for continued predation success. Bain and Boltz (1992) found that following herbicide treatment, largemouth bass remained in or near the site they had been previously captured.

Similarly, fish in Desser Cove showed little inclination to seek out new areas to live after herbicide treatment. Despite the common assumption that largemouth bass seek edge habitat (Engel 1986, 1995), we observed little attraction to edge or open habitats following herbicide treatment. Largemouth bass were generally found in the same general areas before and after Aquathol K treatment. Hydrilla continued to be the primary habitat used by largemouth bass after herbicide treatment, although we observed an increase in the use of water hyacinth and giant cutgrass following treatment. Similarly, Boyer and Cichra (1994) observed no changes in movement or activity areas of largemouth bass in two Florida lakes following herbicide treatment.

This study demonstrated that herbicide treatments and associated reduction or elimination of SAV were related to changes in largemouth bass behavior or activity patterns, although these changes were not very dramatic. Most of the changes in largemouth bass behavior were subtle, and fish did not exhibit a repulsion from treatment areas, or an attraction to the resulting edge habitat created. The gradual disappearance then elimination of all SAV in Peacock Lake was associated with greater movement and activity centers compared to Desser Cove where hydrilla occupied about half the area of this cove after treatment. Largemouth bass are commonly found to be a sedentary predator, with little long-range movements reported (Warden and Lorio 1975, Bain and Boltz 1992, Furse et al. 1998, Woodward and Noble 1999). The species is highly adaptable and commonly found in a wide variety of habitats (Heidinger 1975), thus, it is not surprising that changes in SAV density did not cause large shifts in largemouth bass behavior and movement.

While largemouth bass apparently did not leave these two areas when vegetation was reduced or eliminated by herbicides, they did respond by changing movement patterns, depth distribution, and habitat use, similar to the results of Sammons et al. (2003). The exact nature of the behavior change is likely mediated by a suite of variables, including lake or embayment morphology, hydrology, and the amount of SAV remaining after treatment. For instance, in this study, largemouth bass increased daytime movement after herbicide treatment in Peacock Lake, where all SAV was eliminated. A similar response was found for largemouth bass in the Spring Creek arm of Lake Seminole after 1,800 ha of hydrilla was eliminated, which the authors attributed to the decline in water clarity following treatment (Sammons et al. 2003). In contrast, daytime movement of largemouth bass declined after treatment in Desser Cove; however, approximately half the hydrilla remained after treatment and water clarity never changed. Thus managers may not be able to predict exact changes in largemouth bass behavior in response to herbicide treatment; however, our studies on Lake Seminole demonstrated that application of Aquathol K and subsequent decline in SAV did not cause fish to leave the treatment area or cause extremely large shifts in behavior or activity patterns.

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