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Effect of eastern red cedar brush on nest abundance and survival of age-0 black bass in Bull Shoals Lake, Missouri

M. Siepker, A. Pratt and X. Gao

THE AUTHORS:

Michael J. Siepker is a Resource Scientist with the Missouri Department of Conservation, Ozark Regional Office (551 Joe Jones Blvd., West Plains, MO 65775). A.J. Pratt is a Fisheries Management Biologist with the Missouri Department of Conservation, Ozark Regional Office (551 Joe Jones Blvd., West Plains, MO 65775). Xiaoming (Sherry) Gao is a Biometrician with the Missouri Department of Conservation, Central Regional Office and Conservation Research Center (3500 East Gans Road, Columbia, MO 65201).

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EXECUTIVE SUMMARY
Recruitment of black bass *Micropterus* spp. in large reservoirs is often related to fluctuations in water levels, although the specific mechanism driving recruitment is not known. Eastern red cedar *Juniperus virginiana* brush was added to coves within Bull Shoals Lake to replicate habitat conditions present during high water events in an effort to increase numbers of nesting adult black bass and abundance of age-0 black bass. Number of nests within each study site was documented via snorkel surveys whereas abundance of age-0 black bass and potential predators of these bass was determined via electrofishing surveys. Number of black bass nests was greater in sites with brush compared to control sites. However, abundance of age-0 black bass was not greater in these same sites. Black bass congeners and sunfish *Lepomis* spp. were the most prevalent predators sampled, and their abundance was always greater in brush sites relative to controls; however, the magnitude of difference varied by year. It appears that the simple addition of brush did not fully replicate habitat present during high water events and as a result did not increase the abundance of age-0 black bass.

Keywords: black bass, Bull Shoals Lake, reservoir, abundance, spawning, habitat, predation.

INTRODUCTION

Black bass *Micropterus* spp. are one of the most sought freshwater sportfish in the United States (U.S. Department of the Interior 2003). In Missouri, no other sportfish receive as much attention as black bass. In 2001, almost half of Missouri's 1.2 million anglers collectively spent over 5.5 million days fishing for black bass. A substantial portion of this angling specifically targets largemouth bass *M. salmoides* and occurs on Missouri's large reservoirs. For example, Aggus and Elliott (1975) found that largemouth bass made up one-third of the recreational harvest on Bull Shoals Lake. Schramm et al. (1991) estimated that 75% of 1,650 competitive angling events in Missouri targeted black bass. A later survey by Kerr and Kamke (2003) found the number of competitive angling events targeting largemouth bass in Missouri had increased to over 2,000 events annually. Subsequently, fisheries management personnel devote substantial effort towards management of these popular fisheries.

A better understanding of how abiotic and biotic factors (e.g., increased cover, nutrient load, turbidity, decreased predation) affect recruitment in large reservoirs would aid fisheries management staff in developing best management practices for largemouth bass. Reproductive success of largemouth bass has been correlated to water levels and changes in habitat availability (Aggus and Elliott 1975; Allan and Romero 1975; Summerfelt and Shirley 1978; Miranda et al. 1984; Kohler et al. 1993; Raibley et al. 1997; Parkos and Wahl 2002). Increased numbers of age-0 largemouth bass have also been positively related to high water levels in Bull Shoals Lake (Aggus and Elliott 1975; Novinger 1988). Often, first summer survival of age-0 fish is positively correlated to water levels that increase and remain high for extended periods of time (Summerfelt and Shirley 1978; Miranda et al. 1984; Kohler et al. 1993). The timing of water fluctuations can greatly influence recruitment, especially when these fluctuations occur during the nesting period. Receding water during nesting can reduce nesting success (Allan and Romero 1975) and ultimately, year class strength (Summerfelt and Shirley 1978). However, increasing water levels can also negatively affect nesting success, with stable water levels considered optimal for successful largemouth bass spawning (Kohler et al. 1993).

It is not clear what specific factors associated with high water levels drive increased recruitment, but past research has suggested that both predation and starvation may interact to influence survival of juvenile fish (Rice et al. 1987; Miranda and Hubbard 1994; Garvey et al. 1998) and ultimately, recruitment dynamics (Dong and DeAngelis 1998). Specifically, Aggus and Elliott (1975) suggested predation was a primary cause of mortality for young black bass in Bull Shoals Lake whereas Novinger (1988) suggested that survival of young fish in Table Rock Lake was inversely related to the abundance of potential predators. Susceptibility to predation is often related to size of age-0 fish (Miller et al. 1988), with smaller fish succumbing to predation more often than larger conspecifics (Miranda and Hubbard 1994; Garvey et al. 1998). Age-0 largemouth bass that quickly switch to piscivory often have increased growth and lower vulnerability to predation, improving the likelihood of overwinter survival (Olson 1996; Ludsin and DeVries 1997). Habitat complexity can also decrease predation success rates, especially when habitats are very complex (Savino and Stein 1982; Olson et al. 2003; Ostrand et al. 2004). As water levels increase and submerge terrestrial vegetation, greater habitat complexity could reduce predation rates on age-0 black bass, thereby increasing recruitment. The negative effects of predation and starvation on recruitment appear to be reduced when high water conditions are present.

Unfortunately, high water does not occur often enough on Bull Shoals Lake to maintain a high quality largemouth bass fishery; therefore, alternative means to improve recruitment in the reservoir during low water years might be warranted. One possible approach may be to mimic high water conditions with the addition of fertilizer or brush cover. To date, limited work has actually attempted to manipulate specific abiotic factors with hope of re-creating conditions found during high water events. Vogele and Rainwater (1975) added brush to Bull Shoals Lake and noted increase use by spawning black bass of areas with brush. Novinger (1988) later attempted to increase nutrient inputs in neighboring Table Rock Lake by placing alfalfa bales in shallow littoral areas in the lake. Eastern red cedar *Juniperus virginiana* trees were also placed in shallow littoral areas to determine the effect of increased cover on age-0 largemouth bass abundance. Unfortunately, rising water prevented the practices from being thoroughly evaluated (Novinger 1988). Miranda and Hubbard (1994) suggested the effect of predators on the survival of age-0 black bass could be tempered by shelter. Increasing habitat complexity within research ponds by adding brush increased overwinter survival of age-0 largemouth bass. Red cedar trees are readily available around Bull Shoals Lake; therefore, we attempted to increase habitat complexity in select study coves by cutting and sinking cedar trees in an effort to increase survival of age-0 black bass throughout the summer months. Objectives of our study were to 1)observe number of nesting adult largemouth bass in experimental coves with artificially placed brush compared to control coves without brush, 2) monitor abundance of age-0 black bass in these study sites throughout the summer, and 3) concurrently monitor predator abundance at these sites. Although addition of brush could provide increased cover and protection from potential predators, presence of brush could also attract more predators, thereby negating any potential positive side effects.

STUDY SITES

Bull Shoals Lake (18,400 ha) is a popular largemouth bass fishery in southern Missouri and northern Arkansas (Figure 1). Located below Lake Taneycomo on the White River system of reservoirs, the lake can experience annual water level fluctuations of over 12 m. The reservoir is steep sided and controls flooding for the lower White River basin while also providing hydroelectric power and recreational activities. The reservoir supports no aquatic vegetation and has some residual woody cover remaining from pre-impoundment logging. The reservoir also has woody and herbaceous vegetation present along the shorelines; submerged cover is limited when water levels are at or below conservation pool elevation of 199 m above sea level. Bull Shoals Lake has highly variable black bass recruitment rates (Novinger 2004). Relative abundance of age-1 largemouth bass within the reservoir ranged from less than 10 to over 250 bass/h of electrofishing from 1984 to 2002.

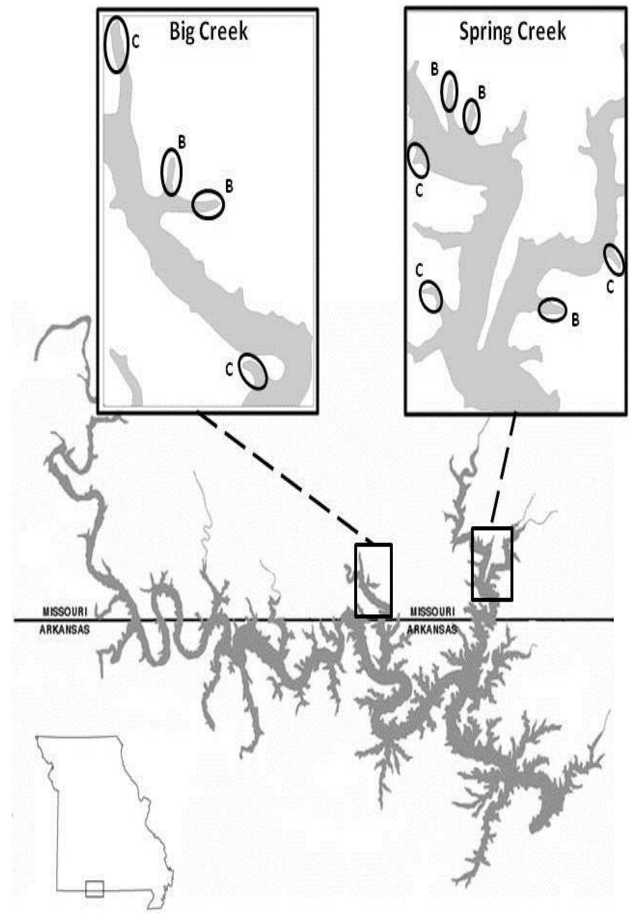

Figure 1. Location of Bull Shoals Lake in Missouri, and control (C) and brush (B) study sites within Big Creek and Spring Creek where nest surveys and electrofishing surveys for age-0 black bass and potential predators were conducted.

METHODS

Work was initiated in January 2005 with selection of appropriate sites ($N = 6$) within the Spring Creek arm of Bull Shoals Lake (Figure 1). Study coves were selected based on local availability of medium to large sized red cedar trees (trunk diameter of 0.2 to 0.4 m) on adjacent shorelines and coves that also had low to moderately-sloped inshore zones. Study sites were stratified by reservoir location and then randomly designated as a control or experimental cove. Experimental coves ($N = 3$) received 100 red cedar trees each. Trees were cut, pulled to the water's edge, and 4 or 5 concrete blocks were attached to ensure trees would remain in place underwater. Trees were then pulled by boat from the bank and positioned perpendicular to the shoreline with the trunk end adjacent to the shoreline. Trees were placed in ten groups of ten trees each in water depths ranging from 0 to 4.6 m at conservation pool elevation within each experimental cove (Figure 2). This ensured that some portion of the red cedar brush would be submerged even if the lake level decreased throughout the summer. We attempted to provide over 20% brush coverage within the inshore zone following results of Miranda and Hubbard (1994). We termed the wetted shoreline zone from 199 m to 197 m above sea level that was routinely sampled during this study the "inshore zone". Sites and brush locations were mapped using a geographical information system (GIS) to determine total brush coverage of the inshore zone. Shoreline lengths of all study transects were mapped at lake levels of 199 m and 197 m using a handheld GPS data recorder. Control coves (*N* = 3) did not receive any red cedar brush and, therefore, were void of any woody cover. In April 2006, additional sites (*N* = 4) within the Big Creek arm of Bull Shoals Lake were selected as described above. Sites were randomly assigned as either experimental *N* = 2) or control (*N* = 2), and treatments were applied as described above.

Largemouth Bass Nesting

Beginning in April 2006, sample sites within Spring Creek were snorkel surveyed and all largemouth bass nests documented. Snorkel surveys were planned weekly, but weather and logistics occasionally limited field opportunities. Adult males guarding their nests were identified to species, developmental stage of offspring noted, and location of the nests mapped on a plastic slate. Total number of nests within each site was determined at the conclusion of each spawning season and divided by the length of that transect. All snorkel surveys were discontinued in 2008 due to high water levels and reduced underwater visibility.

Age-0 Black Bass Abundance

Age-0 black bass were sampled monthly (June through October) beginning in June 2005. Spring Creek sites were sampled during 2005, 2006, and 2007 whereas Big Creek sites were only sampled in 2007. Fish were collected at night with a boat-mounted electrofishing unit (rectified AC, 180-200 V, 8-10 A). All collected fish were counted, identified to species, and measured for total length (TL). Fish were then released at their respective collection site. A subsample of age-0 black bass was collected during the last sample in October to verify fish ages.

Due to the complexity of the brush sites, and the increased effort required to effectively sample those sites, we chose to use distance of shoreline sampled as our effort instead of time electrofishing. Times to sample were markedly different between control and brushed sites because brush sites required much more boat maneuvering than did control sites. Age-0 black bass catch rates, therefore, were calculated as the total number of individuals collected within a site divided by the total distance of shoreline sampled.

Predator Abundance

Abundance of predators that could potentially prey upon age-0 black bass was also monitored monthly following the schedule outlined above. All piscivorous species (TL ≥ 127 mm) were considered potential predators. Fish were collected at night with a boat-mounted electrofishing unit (rectified AC, 180-200 V, 8-10 A) and at the end of each study transect, collected fish were counted, identified to species, and measured (TL) before their release. Predator catch rates were then calculated as total number of predators collected divided by total distance sampled as described above.

Statistical Analyses

Analyses were conducted with SAS/STAT software, Version 9.1 of the SAS System for Windows (SAS 2002), and significance was assessed at an α level of 0.05. Means are presented ± 1 SE. The effect of brush on number of black bass nests was evaluated using a one-way analysis of variance (ANOVA) whereas the effect of treatment and year on total number of young-of-year (YOY) black bass, number of YOY largemouth bass, number of YOY smallmouth bass *M. punctulatus* in Spring Creek was tested with a

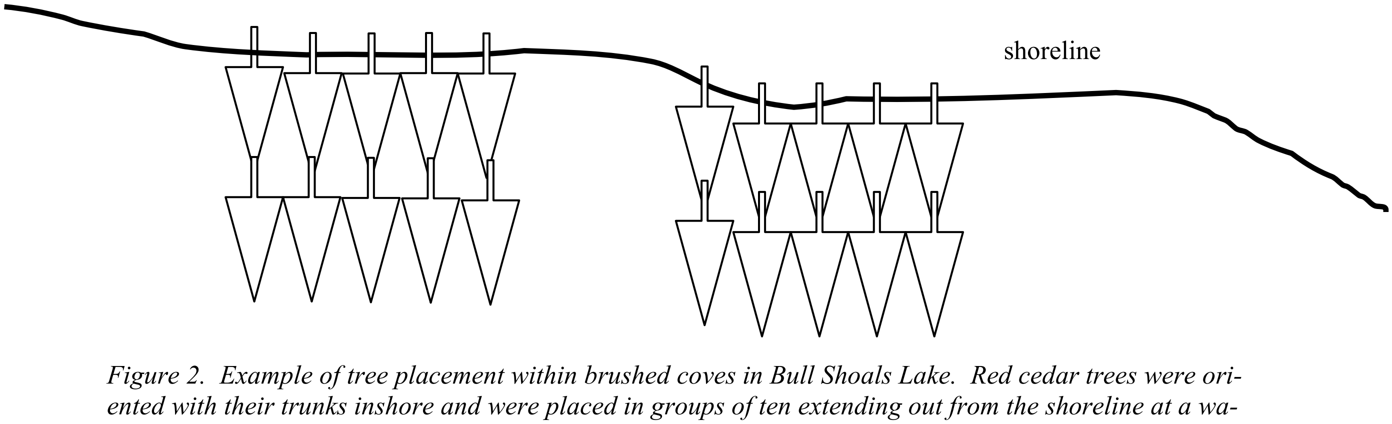

Figure 2. Example of tree placement within brushed coves in Bull Shoals Lake. Red cedar trees were oriented with their trunks inshore and were placed in groups of ten extending out from the shoreline at a water level elevation of 199 m above sea level.

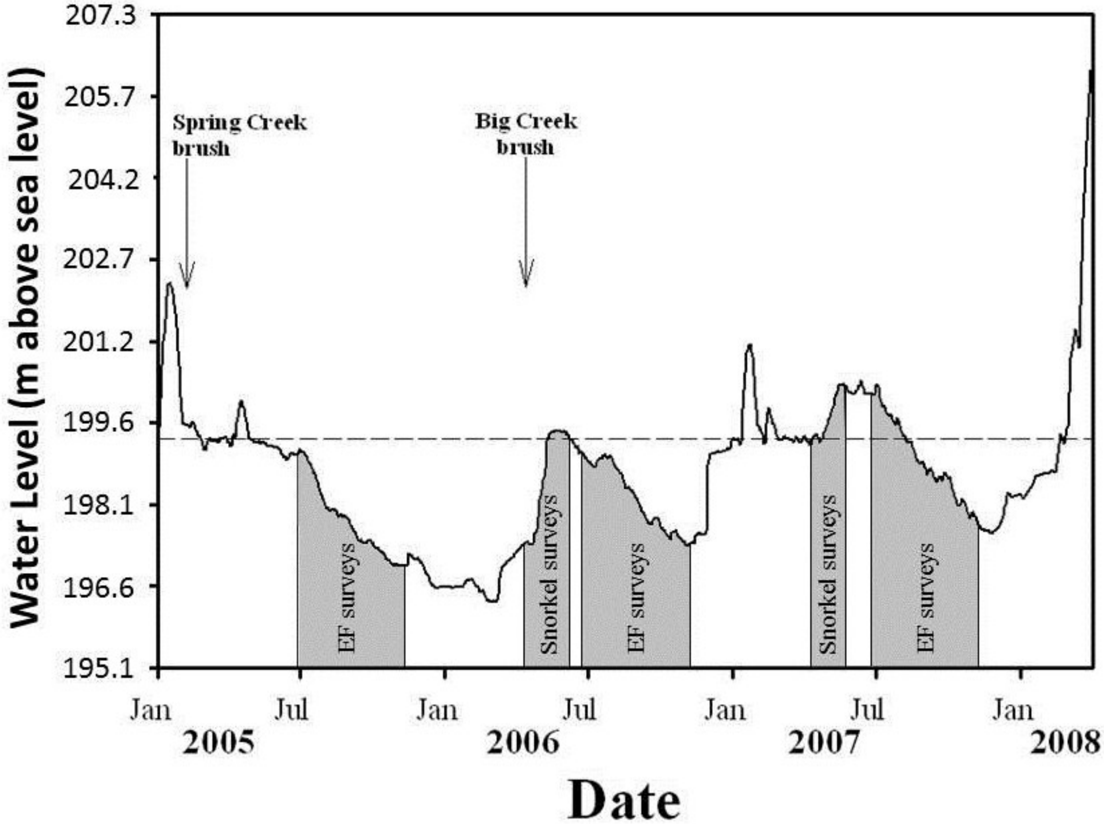

Figure 3. Bull Shoals Lake water levels during the study period and important red cedar brush installation dates. Daily water levels are shown by the solid black line whereas the conservation pool elevation of 199 m above sea level is shown by the dashed line. The shaded areas below the water level line denotes sampling periods when snorkel surveys or electrofishing surveys were completed.

split-plot analysis with year as the split-plot factor. Differences in number of YOY between treatments were tested using a least significant differences (LSD) post hoc test. Differences in total number of YOY black bass as well as differences by species in Big Creek were tested using a randomized block ANOVA with paired sites treated as blocks in the analysis. The effect of treatment and year on the number of predators present within each Spring Creek site was also evaluated using a split-plot ANOVA and differences between treatments were tested using a LSD test. Differences in predator abundance between treatments within Big Creek were tested using a randomized block ANOVA.

RESULTS

Water levels in Bull Shoals Lake remained similar during the initial years of the study, but rapidly increased in March 2008 following a heavy precipitation event (Figure 3). Water levels remained high throughout 2008 and increased again in April 2009, resulting in the discontinuation of the study. Snorkel surveys were effective at surveying for largemouth bass nests in Spring Creek during 2006 and 2007; however, reduced underwater visibility in the Big Creek arm of Bull Shoals Lake throughout the spring resulted in cancellation of surveys in that area during 2007. All snorkel survey data presented, therefore, are taken from Spring Creek sites only.

Shoreline length of study transects ranged from 350 m to 958 m (629 ± 67 m [mean total length ± SE]) at a lake level of 199 m above sea level (Table 1). When the lake level decreased to 197 m, mean transect length (545 ± 54 m) also decreased. Shoreline lengths measured at a water level of 199 m were used in all calculations of catch rates (number of individuals per km shoreline) unless the lake level dropped below 198 m when lengths of shoreline within transects at water levels of 197 m were used (Table 1).

Largemouth bass Nesting

Largemouth bass nest surveys were conducted within Spring Creek sites from 13 April to 25 May 2006 and from 26 April to 17 May 2007. Number of nests observed across sites did not vary between years

(ANOVA, $F_{1,8} = 0.00$, $P = 0.96$), and year and treatment did not interact (ANOVA, $F_{1,8} = 0.83$, $P = 0.39$) to influence the number of largemouth bass nests per km of shoreline (Figure 4). Significantly more largemouth bass (ANOVA, $F_{1,8} = 12.7$, $P = 0.007$) spawned in experimental sites (45.2 ± 7.1 number of nests/km shoreline) compared to controls (16.5 ± 2.7) throughout both spawning seasons (Figure 4).

Age-0 Black Bass Abundance

Total number of age-0 black bass observed in study sites within Spring Creek varied across the three years of study (ANOVA, $F_{2,4} = 15.26$, $P = 0.02$; Table 2). Numbers of largemouth bass (ANOVA, $F_{2,4} = 14.16$, $P = 0.01$) and spotted bass (ANOVA, $F_{2,4} = 16.22$, $P = 0.01$) varied across years, whereas number of smallmouth bass observed did not vary by year (ANOVA, $F_{2,4} = 3.78$, $P = 0.12$). Overall, year did not interact (range $P = 0.36$ to 0.96) with treatment in Spring Creek sites to affect numbers of black bass or species individually.

Numbers of individuals collected from Big Creek in 2007 and those from Spring Creek were subsequently examined by year using a randomized block ANOVA. Within Big Creek, addition of brush in coves (62.3 ± 5.6 number of individuals/km shoreline) did not increase the number of age-0 black bass collected (ANOVA, $F_{1,1} = 0.83$, $P = 0.53$) compared to controls (94.9 ± 16.8; Table 2). Specifically, addition of brush did not affect the number of age-0 largemouth bass (ANOVA, $F_{1,1} = 2.48$, $P = 0.34$), spotted bass (ANOVA, $F_{1,1} = 0.04$, $P = 0.87$), nor smallmouth bass (ANOVA, $F_{1,1} = 0.51$, $P = 0.60$) collected. Numbers of age-0 black bass in Spring Creek were also not affected by addition of brush in 2005 (ANOVA, $F_{1,2} = 0.21$, $P = 0.69$), 2006 (ANOVA, $F_{1,2} = 0.10$, $P = 0.78$), nor 2007 (ANOVA, $F_{1,2} = 0.36$, $P = 0.60$). Again, age-0 largemouth bass numbers were not affected by addition of brush in any year of the study (range $P = 0.13$ to 0.18), nor were spotted bass (range $P = 0.31$ to 0.62) or smallmouth bass (range $P = 0.08$ to 0.92) when examined individually.

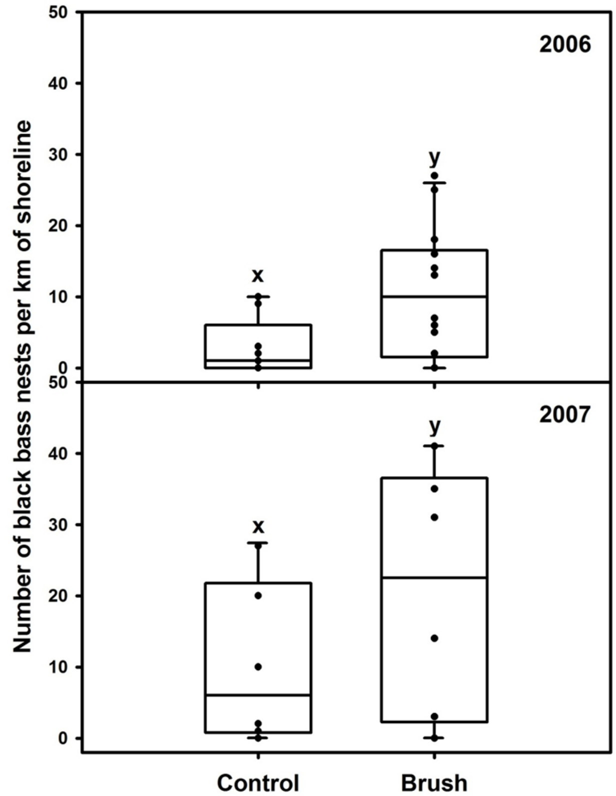

Figure 4. Number of largemouth bass nests per km found during Bull Shoals Lake snorkel surveys in 2006 and 2997 are shown as black circles. Boxplots representing the median, 25th and 75th percentile, and 10th and 90th percentiles (error bars) are also shown. Different letters denote significant differences in numbers of nests.

	Lake level (m above sea level)		
Spring Creek	199 m	197 m	% Coverage
Control 1	869	772	0
Control 2	958	807	0
Control 3	812	724	0
Brush 1	675	488	32
Brush 2	657	509	29
Brush 3	624	568	26
Big Creek			
Control 1	592	503	0
Control 2	350	338	0
Brush 1	410	407	50
Brush 2	352	336	53

Table 1. Shoreline lengths within each study site on Bull Shoals Lake. Lengths (m) were measured at water levels of 199 m and 197 m above sea level using a handheld GPS data logging unit. Percent coverage represents the percent of the inshore zone that was covered with red cedar brush at a lake level of 199 m.

Predator Abundance

A total of 2,596 potential predators of age-0 black bass was collected throughout the study. Species collected included bluegill *Lepomis macrochirus*, green sunfish *Lepomis cyanellus*, longear sunfish *Lepomis megalotis*, black crappie *Pomoxis nigromaculatus*, channel catfish *Ictalurus punctatus*, flathead catfish *Pylodictis olivaris*, longnose gar *Lepisosteus osseus*, largemouth bass, spotted bass, smallmouth bass, walleye *Sander vitreus*, white bass *Morone chrysops*, freshwater drum *Aplodinotus grunniens*, and yellow perch *Perca flavescens*; however, age-0 black bass congeners were the most abundant (68% of total) potential predators across all sites. *Lepomis* spp. accounted for an additional 23% of total predators sampled.

Treatment and year sampled interacted to influence the total number of predators sampled within each Spring Creek site (ANOVA, $F_{2,4} = 9.02$, $P = 0.03$). Number of predators sampled per km of shoreline was always greater in experimental sites than in control sites; however, magnitude of difference varied by year (Figure 5). When examining the two most commonly sampled predators, number of *Micropterus* spp. was also influenced by the interaction between treatment and year sampled (ANOVA, $F_{2,4} = 25.08$, $P = 0.005$); however, number of *Lepomis* spp. sampled as potential predators did not vary across years (ANOVA, $F_{2,4} = 6.49$, $P = 0.06$) or between treatments (ANOVA, $F_{1,4} = 0.22$. $P = 0.66$; Figure 5).

Predators were also sampled from four study sites within Big Creek during the summer of 2007. Total number of predators sampled within Big Creek was greater in experimental sites (112.3 ± 1.6 predators/km shoreline) than in control sites (32.2 ± 11.8); however, these differences were not significant (ANOVA, $F_{1,1} = 35.42$, $P = 0.10$) likely due to low sample sizes. This trend was also evident for *Micropterus* spp. predators with no difference in abundance detected (ANOVA, $F_{1,1} = 111.7$, $P = 0.06$) although number of *Micropterus* spp. sampled varied between control (18.9 ± 7.3 predators/km shoreline) and brushed sites (90.6 ± 0.6). There was also no difference (ANOVA, $F_{1,1} = 0.35$, $P = 0.66$) in the number of *Lepomis* spp. predators sampled from control (8.7 ± 1.4 predators/km shoreline) and brushed sites (11.9 ± 4.0).

DISCUSSION

We attempted to replicate conditions present during a high water event within Bull Shoals Lake by sinking red cedar brush to increase habitat complexity within study coves. Typically, increases in reservoir water levels are thought to increase nutrient levels due to increased inflows and increase habitat complexity by inundating terrestrial vegetation, and as a result, increase recruitment of black bass often occurs (e.g., Summerfelt and Shirley 1978; Miranda et al. 1984). We did not observe increased numbers of age-0 fish within our study sites; however, brush did increase the number of nests within study coves suggesting that added cover attracted nest-building male largemouth bass.

It is not surprising that we observed more largemouth bass nests in sites where brush was added compared to controls. Hoff (1991) found increased numbers of smallmouth bass nests and fingerlings when habitat structures were installed. Hunt and Annett (2002) also noted that nearly all largemouth bass nests within surveyed sections of shoreline were associated with some type of cover whereas Hunt et al. (2002) also found that most largemouth bass nested adjacent to some type of physical structure. Vogele and Rainwater (1975) added brush to coves in Bull

Year	**Site**	**Treat-ment**	**Total black bass /km**	**LMB/km**	**SPB/km**	**SMB/km**
2005	Spring Creek	Control	17.7 (4.7)	0.9 (0.4)	12.2 (3.7)	4.6 (1.4)
		Brush	15.3 (3.8)	6.3 (3.6)	7.5 (1.9)	1.5 (0.8)
2006	Spring Creek	Control	17.5 (2.9)	3.4 (0.7)	12.5 (2.4)	1.6 (0.6)
		Brush	15.8 (3.0)	5.7 (1.2)	10.0 (2.3)	0.1 (0.1)
2007	Spring Creek	Control	31.4 (3.4)	8.5 (1.9)	20.3 (3.2)	2.6 (0.5)
		Brush	30.5 (2.9)	11.4 (2.2)	16.7 (2.4)	2.4 (1.0)
	Big Creek	Control	94.9 (16.8)	51.1 (15.8)	37.4 (11.0)	6.4 (3.0)
		Brush	62.3 (5.6)	26.0 (4.6)	32.4 (5.3)	3.8 (1.3)

Table 2. Mean (± 1 S.E.) number of total black bass, largemouth bass, spotted bass, or smallmouth bass found in control coves and coves receiving red cedar brush within Bull Shoals Lake. Sites within Spring Creek were monitored during 2005, 2006, and 2007 whereas sites within Big Creek were only monitored in 2007.

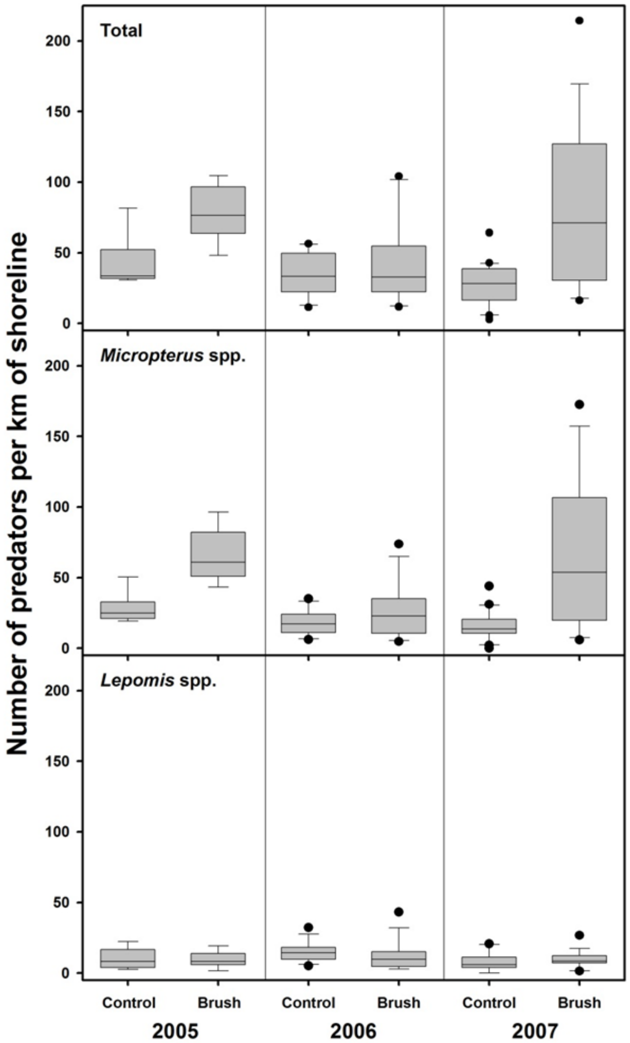

Figure 5. Boxplots showing the number of potential predators of age-0 black bass collected per km of shoreline in control sites and sites receiving red cedar brush in the Spring Creek arm of Bull Shoals Lake during 2005, 2006, and 2007. The median, 25th and 75th percentile, and 10th and 90th percentiles (error bars) are shown for the total number of predators and the number of the two most commonly sampled predators (Micropterus spp. and Lepomis spp.). Outliers within the data are shown as black circles.

Shoals Lake and observed increased numbers of spotted and largemouth bass nests. Although smallmouth bass nests were the most common within their study sites, Vogele and Rainwater (1975) noted that smallmouth bass were not relating to added cover. Our evaluation was done in a section of Bull Shoals Lake that also contained smallmouth and spotted bass; however, we only observed nesting largemouth bass in our snorkel surveys. The emphasis of our study was largemouth bass, and our study sites were located in the far backs of coves on low to moderately sloped banks, areas more likely to be used by largemouth bass for spawning than by spotted bass or smallmouth bass. Combined, these results suggest that management personnel can increase the number of black bass nests within specific sections of reservoirs by increasing the amount of physical cover present.

What is surprising is the fact that increasing red cedar brush cover and numbers of black bass nests did not result in an increase in numbers of age-0 black bass within study sites. Perhaps some other biotic or abiotic factor limited production of offspring at some point between nesting and our age-0 sampling efforts. A multitude of variables other than cover have been linked to recruitment in black bass (see Garvey et al. 2002; Parkos and Wahl 2002; DeVries et al. 2009), nearly all of which were not monitored in this study. An alternative explanation could be that more age-0 fish were indeed produced in experimental coves, but were not collected for a variety of reasons. Habitat complexity in coves where brush was added could have reduced our sampling efficiency, resulting in fewer age-0 fish collected. This is probably not the case given we expended more effort (time) in coves with added brush to ensure that the habitat was thoroughly sampled. However, we adjusted for the increased effort required by calculating our catch per unit effort using the distance of shoreline sampled rather than time spent sampling the site. Another explanation may be that age-0 bass were produced within the experimental coves, but then migrated out of the coves or to deeper water. Copeland and Noble (1994) observed little movement of age-0 largemouth bass out of coves during the first summer of life; however, both Allen and Romero (1975) and Hightower et al. (1982) noted age-0 largemouth bass moving offshore as the summer progressed. Movement of age-0 black bass could have occurred in Bull Shoals Lake if certain conditions existed, such as a shortage of prey. Larval sunfish *Lepomis* spp. and shad *Dorosoma* spp. are important prey for age-0 largemouth bass (Olson 1996; Allen et al. 1999; Parkos 2008), but little information exists on their spawning patterns and offspring movement patterns in Bull Shoals Lake. Finally, more age-0 black bass could have been produced within the experimental sites where brush was added; however, it appears that added brush may have also attracted potential predators. Increased predator densities within the study sites could have resulted in higher predation pressures on age-0 black bass that were present.

Although we attempted to mimic high water conditions by adding brush to the inshore zone, it is difficult to accurately reproduce conditions that exist during high water events. Various changes occur to the reservoir landscape during high water events. Increase inflows to the reservoir often carry increased levels of sediment and nutrients (Horne and Goldman 1994). It was not possible to recreate this increase in nutrients within our study coves; artificial fertilization attempts are often unsuccessful and cost-prohibitive (e.g., Buynak et al. 2001). Large amounts of terrestrial vegetation are also inundated during high water events relative to the small proportion of the lake that experienced increased cover during our study. While adding cover did increase number of black bass nests, this may have also focused predation pressures on our sites and ultimately reduced the number of age-0 black bass collected. This effect would not be as severe in actual high water conditions where the shoreline of the entire reservoir has increased cover available for both age-0 fish and predators. Types of cover inundated around Bull Shoals Lake during high water could include leaf litter, grasses, shrubs, and hardwoods in addition to red cedars; our coves only received red cedar brush during the evaluation. Multiple mechanisms are likely at work during actual high water events that allow for increased levels of recruitment.

Recruitment of black bass is a complex process driven by numerous abiotic and biotic influences (Garvey et al. 2002; Parkos and Wahl 2002; DeVries et al. 2009). Of these, water level fluctuations are most often linked to changes in black bass recruitment (e.g., Summerfelt and Shirley 1978; Miranda et al. 1984); however, it is still unclear as to what specific aspects of high water events result in increased recruitment of black bass. Based on the results of this study and others, we know that fisheries management personnel can add brush or other physical structure to coves if they wish to increase the number of nesting black bass. Increased numbers of nests will likely translate into increased numbers of YOY black bass hatched (Post et al. 1998). Considering the results of this study and others (Post et al. 1998), increased numbers of nesting largemouth bass likely do not translate to increased numbers of age-0 individuals present later in the season. Abiotic (e.g., nutrient inflow) and biotic influences (e.g., predation, starvation, emigration) other than adult densities (i.e., stock-recruitment relationship) are acting on age-0 black bass and influencing recruitment in Bull Shoals Lake. Future work on recruitment dynamics should consider our findings and focus on the apparent bottleneck in recruitment that occurs at some point after nesting but before the offspring's first winter.

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LITERATURE CITATIONS

Allan, R. C., and J. Romero. 1975. Underwater observations of largemouth bass spawning and survival in Lake Mead. Pages 104-112 *in* R. H. Stroud and H. Clepper, editors. Black bass biology and management. Sport Fishing Institute, Washington D.C.

Allen, M. S., J. C. Greene, F. J. Snow, M. J. Maceina, and D. R. DeVries. 1999. Recruitment of largemouth bass in Alabama reserovirs: relations to trophic state and larval shad occurrence. North American Journal of Fisheries Management 1999:67-77.

Aggus, L. R., and G. V. Elliott. 1975. Effects of cover and food on year-class strength of largemouth bass. Pages 317-322 *in* R. H. Stroud and H. Clepper, editors. Black bass biology and management. Sport Fishing Institute, Washington, D. C.

Buynak, G. L., B. Mitchell, L. Kornman, A. F. Surmont, B. Reeder, and S. Malvestuto. 2001. Responses to artificial fertilization at Grayson Lake, Kentucky. North American Journal of Fisheries Management 21:393-403.

Copeland, J. R., and R. L. Noble. 1994. Movements by young-of-year and yearling largemouth bass and their implications for supplemental stocking. North American Journal of Fisheries Management 14:119-124.

DeVries, D. R., J. E. Garvey, and R. A. Wright. 2009. Early life history and recruitment. Pages 105-133 *in* S. J. Cooke and D. P. Philipp, editors. Centrarchid fishes: diversity, biology, and conservation. Blackwell Scientific Publications, Oxford, UK.

Dong, Q., and D. L. DeAngelis. 1998. Consequences of cannibalism and competition or food in a smallmouth bass population: and individual-based modeling study. Transactions of the American Fisheries Society 127:174-191.

Garvey, J. E., R. A. Stein, R. A. Wright, and M. T. Bremigan. 2002. Exploring ecological mechanisms underlying largemouth bass recruitment along environmental gradients. Pages 7-23 *in* D. P. Philipp and M. S. Ridgway, editors. Black bass: ecology, conservation, and management. American Fisheries Society, Symposium 31, Bethesda, Maryland.

Garvey, J. E., R. A. Wright, and R. A. Stein. 1998. Overwinter growth and survival of age-0 largemouth bass (*Micropterus salmoides*): revisiting the role of body size. Canadian Journal of Fisheries and Aquatic Sciences 55:2414-2424.

Hightower, J. E., R. J. Gilbert, and T. B. Hess. 1982. Shoreline and cove sampling to estimate survival of young largemouth bass in Lake Oconee, Georgia. North American Journal of Fisheries Management 2:257-261.

Hoff, M. H. 1991. Effects of increased nesting cover on nesting and reproduction of smallmouth bass in northern Wisconsin lakes. Pages 39-43 *in* D. C. Jackson, editor. Proceedings of the first international smallmouth bass symposium. Mississippi Agricultural and Forestry Experiment Station, Mississippi State University.

Horne, A. J., and C. R. Goldman. 1994. Limnology. 2nd edition. McGraw-Hill, Inc. New York, New York.

Hunt, J., and C. A. Annett. 2002. Effects of habitat manipulation on reproductive success of individual largemouth bass in an Ozark reservoir. North American Journal of Fisheries Management 22:1201-1208.

Hunt, J., N. Bacheler, D. Wilson, E. Videan, and C. A. Annett. 2002. Enhancing largemouth bass spawning: behavioral and habitat considerations. Pages 277-290 *in* D. P. Philipp and M. S. Ridgway, editors. Black bass: ecology, conservation, and management. American Fisheries Society, Symposium 31, Bethesda, Maryland.

Irwin, E. R., R. L. Noble, and J. R. Jackson. 1997. Distribution of age-0 largemouth bass in relation to shoreline landscape features. North American Journal of Fisheries Management 17:882-893. Kerr, S. J., and K. K. Kamke. 2003. Competitive fishing in freshwaters of North America. Fisheries 28(3):26-31.

Kohler, C. C., R. J. Sheehan, and J. J. Sweatman. 1993. Largemouth bass hatching success and first-winter survival in two Illinois reservoirs. North American Journal of Fisheries Management 13:125-133.

Ludsin, S. A., and D. R. DeVries. 1997. First-year recruitment of largemouth bass: the interdependency of early life stages. Ecological Applications 7:1024-1038.
Matthews, W. J., F. P. Gelwick, and J. J. Hoover. 1992. Food and habitat use by juveniles of species of *Micropterus* and *Morone* in a Southwestern reservoir. Transactions of the American Fisheries Society 121:54-66.
Meals, K. O., and L. E. Miranda. 1991. Variability in abundance of age-0 centrarchids among littoral habitats of flood control reservoirs in Mississippi. North American Journal of Fisheries Management 11:298-304.
Miller, T. J., L. B. Crowder, J. A. Rice, and E. A. Marschall. 1988. Larval size and recruitment mechanisms in fish: toward a conceptual framework. Canadian Journal of Fisheries and Aquatic Sciences 45:1657-1670.
Miranda, L. E., W. L. Shelton, and T. D. Bryce. 1984. Effects of water level manipulation on abundance, mortality, and growth of young-of-the-year largemouth bass in West Point Reservoir, Alabama-Georgia. North American Journal of Fisheries Management 4:314-320.
Miranda, L. E., and W. D. Hubbard. 1994. Winter survival of age-0 largemouth bass relative to size, predators, and shelter. North American Journal of Fisheries Management 14:790-796.
Novinger, G. D. 1988. Recruitment of largemouth bass and spotted bass at Table Rock Lake. Missouri Department of Conservation, Federal-Aid Project F-1-R-37 Final Report, Study I-24. Jefferson City, Missouri.
Novinger, G. D. 2004. Black bass recruitment in large lakes: a literature review and recommendations for future studies. Missouri Department of Conservation Report. Jefferson City, Missouri.
Olson, M. H. 1996. Ontogenetic niche shifts in largemouth bass: variability and consequences for first-year growth. Ecology 77:179-190.
Olson, M. H., B. P. Young, and K. D. Blinkoff. 2003. Mechanisms underlying habitat use of juvenile largemouth bass and smallmouth bass. Transactions of the American Fisheries Society 132:398-405.
Ostrand, K. G., B. J. Braeutigam, and D. H. Wahl. 2004. Consequences of vegetation density and prey species on spotted gar foraging. Transactions of the American Fisheries Society 133:794-800.
Parkos, J. J. III. 2008. Role of parental care and ontogenetic diet shifts in the recruitment variation of an aquatic predator. Doctoral dissertation. University of Illinois at Urbana-Champaign, Urbana-Champaign.
Parkos, J. J., III, and D. H. Wahl. 2002. Towards an understanding of recruitment mechanisms in largemouth bass. Pages 25-45 *in* D. P. Philipp and M. S. Ridgway, editors. Black bass: ecology, conservation, and management. American Fisheries Society, Symposium 31, Bethesda, Maryland.
Phillips, J. M., J. R. Jackson, and R. L. Noble. 1997. Spatial heterogeneity in abundance of age-0 largemouth bass among reservoir embayments. North American Journal of Fisheries Management 17:894-901.
Post, D. M., J. F. Kitchell, and J. R. Hodgson. 1998. Interactions among adult demography, spawning date, growth rate, predation, overwinter mortality, and the recruitment of largemouth bass in a northern lake. Canadian Journal of Fisheries and Aquatic Sciences 55:2588-2600.
Raibley, P. T., K. S. Irons, T. M. O'Hara, K. D. Blodgett, and R. E. Sparks. 1997. Largemouth bass size distributions under varying annual hydrologic regimes in the Illinois River. Transactions of the American Fisheries Society 126:850-856.
Rice, J. A., L. B. Crowder, and M. E. Holey. 1987. Exploration of mechanisms regulating larval survival in Lake Michigan bloater: a recruitment analysis based on characteristics of individual larvae. Transactions of the American Fisheries Society 116:703-718.
SAS Institute Inc., SAS OnlineDoc 9.1.3, Cary, NC: SAS Institute Inc., 2002-2005.
Savino, J. F., and R. A. Stein. 1982. Predator-prey interactions between largemouth bass and bluegills as influenced by simulated, submersed vegetation. Transactions of the American Fisheries Society 111:255-266.
Schramm, H. L., Jr., M. L. Armstrong, N. A. Funicelli, D. M. Green, D. P. Lee, R. E. Manns, Jr., B. D. Taubert, and S. J. Waters. 1991. The status of competitive sport fishing in North America. Fisheries 16(3):4-12.

Summerfelt, R. C., and K. E. Shirley. 1978. Environmental correlates to year-class strength of largemouth bass in Lake Carl Blackwell. Proceedings of the Oklahoma Academy of Science 58:54-63.
United States Department of the Interior and United States Department of Commerce. 2003. 2001 national survey of fishing, hunting, and wildlife-associated recreation. Washington D.C.
Vogele, L. E., and W. C. Rainwater. 1975. Use of brush shelters as cover by spawning black basses (*Micropterus*) in Bull Shoals Reservoir. Transactions of the American Fisheries Society 104: 264-269.

PAST MISSOURI DEPARTMENT OF CONSERVATION TECHNICAL REPORTS

Aquatic

Weyer, A.E. 1942. Report on classification of lakes in Missouri. Missouri Conservation Special Report, 1942 (1).

McVey, R.W. 1956. Special report on the fish populations in drainage ditches of Southeast Missouri. Missouri Conservation Special Report. 1956(1).

Funk, J.L. 1957. Species of fish present in selected areas of four Missouri streams with criteria for the determination of important species. Special Report. 1957(1).

Funk, J.L. 1957. Relative efficiency and selectivity of gear used in the study of fish populations in Missouri streams. Special Report . 1957(2).

McVey, R.W. 1957. Special report on the fish populations in drainage ditches of Southeast Missouri. Missouri Conservation Special Report. 1957(1).

Purkett, C.A. 1957. A study of the growth rates of six species of fish from Spring River, Missouri. Special Report Series. 1957(6).

Purkett, C.A. 1957. A continuing study of the growth rate and year class abundance of the freshwater drum of the lower Salt River. Special Report. 1957.

Funk, J.L. 1958. Is Missouri ready for a year-round open fishing season on streams? Missouri Conservation Special Report. 1958(1).

Purkett, C.A. 1958. Growth rates of Missouri stream Fishes. Missouri Conservation Dingell-Johnson Project Report Series. 1958.

Purkett, C.A. 1960. The invasion of Current River by carp. Missouri Conservation Special Report. 1960(1).

Funk, J.L., Fleener, G.G. 1966. Evaluation of a year-round open fishing season upon an Ozark smallmouth bass stream, Niangua River, Missouri. Missouri Conservation Dingell-Johnson Project Report Series. 1966(2).

Pflieger, W.L. 1966. A check-list of the fishes of Missouri with keys for identification. Missouri Conservation Dingell-Johnson Project Report Series. 1966(3).

Clifford, H.F. 1966. Some limnological characteristics of six Ozark streams. Missouri Conservation Dingell-Johnson Project Report Series. 1966(4).

Pflieger, W.L. 1968. A check-list of the fishes of Missouri with keys for identification (revised edition). Missouri Conservation Dingell-Johnson Project Report Series. 1968(3).

Funk, J.L. 1968. Missouri's fishing streams. Missouri Conservation Dingell-Johnson Project Report Series. 1968(5).

Funk, J.L. 1969. Missouri's state-wide general creel census. Missouri Conservation Dingell-Johnson Project Report Series. 1969(6).

Dillard, J.G., Hamilton, M. 1969. Evaluation of two stocking methods for Missouri farm ponds. Missouri Conservation Dingell-Johnson Project Report Series. 1969(7).

Funk, J.L. 1972. Current River: its aquatic biota and fishery. Missouri Conservation Special Report. 1972(1).

Ryck, F.M. 1974. Missouri stream pollution survey. Missouri Conservation Aquatic Report Series. 1974(8).

Fleener, G.G., Funk, J.L., Robinson, P.E. 1974. The fishery of Big Piney River and the effects of stocking fingerling smallmouth bass. Missouri Conservation Aquatic Report Series. 1974(9).

Ryck, F.M. 1974. Water quality survey of the southeast Ozark mining area, 1965-1971. Missouri Conservation Aquatic Report Series. 1974(10).

Funk, J.L., Robinson, J.W. 1974. Changes in the channel of the lower Missouri River and effects on fish and wildlife. Missouri Conservation Aquatic Report Series. 1974(11).

Funk, J.L. 1975. The fishery of Black River, Missouri, 1947-1957. Missouri Conservation Aquatic Report Series. 1975(12).

Funk, J.L. 1975. The fishery of Gasconade River, Missouri, 1947-1957. Missouri Conservation Aquatic Re port Series. 1975(13).

Hickman, G.D. 1975. Value of instream cover to the fish populations of Middle Fabius River, Missouri. Missouri Conservation Aquatic Report Series. 1975(14).

Dieffenbach, W.H., Ryck, F.M. 1976. Water quality survey of the Elk, James and Spring River basins of Mis souri, 1964-1965. Missouri Conservation Aquatic Report Series. 1976(15).
Fleener, G.G. 1976. Recreational use of Pool 21, Mississippi River. Missouri Conservation Special Report. 1976(1).
Pflieger, W.L. 1978. Distribution, status, and life history of the Niangua darter, Etheostoma nianguae. Mis souri Conservation Aquatic Report Series. 1978(16).
Buchanan, A.C. 1980. Mussels (naiads) of the Meramec River Basin. Missouri Conservation Aquatic Report Series. 1980(17).
Weithman, A.S. 1981. Invertebrate and trout production at Lake Taneycomo, Missouri. Missouri Conserva tion Special Report. 1981(1).
Pflieger, W.L. 1984. Distribution, status, and life history of the bluestripe darter, Percina cymatotaenia. Mis souri Conservation Aquatic Report Series. 1984(18).
Pflieger, W.L. 1989. Aquatic community classification system for Missouri. Missouri Conservation Aquatic Report Series. 1989(19).
Knuth, D.S., Siepker, M.J. 2011. Movement and survival of Black River strain walleye *Sander vitreus* in southern Missouri rivers. Science and Management Technical Series: Number 3. Missouri Department of Conservation, Jefferson City, MO.

Terrestrial

Dalke, P.D., Leopold, A.S., Spencer, D.L. 1946. The ecology and management of the wild turkey in Missouri. Special Report. 1946.
Bennitt, R. 1951. Some aspects of Missouri quail and quail hunting, 1938-1948. Special Report. 1951(2).
Biffle, E.B. 1951. Development and applications of a wildlife cover restoration project in Missouri. Missouri Conservation Pittman-Robertson Report Series. 1951.
Crail, L.R. 1951. Viability of smartweed and millet in relation to marsh management in Missouri. Missouri Conservation Pittman-Robertson Report Series. 1951.
Brohn, A., Korschegen, L.J. 1951. The precipitin test – a useful tool in game law enforcement. Missouri Conservation Pittman-Robertson Report Series. 1951.
Christisen, D.M. 1951. History and status of the ring-necked pheasant in Missouri. Missouri Conservation Pittman-Robertson Report Series. 1951(1).
Shanks, C.E., Arthur, G.C. 1951. Movements and population dynamics of farm pond and stream muskrats in Missouri. Missouri Conservation Pittman-Robertson Report Series. 1951(5).
Greenwell, G.A. 1952. Farm ponds – their utilization by wildlife. Missouri Conservation Pittman-Robertson Report Series. 1952(6).
Korschgen, L.J. 1952. Analysis of the food habits of the bobwhite quail in Missouri. Missouri Conservation Pittman-Robertson Report Series. 1952(7).
Korschgen, L.J. 1952. A general summary of the food of Missouri predatory and game animals. Missouri Conservation Pittman-Robertson Report Series. 1952(8).
Stanford, J.A. 1952. An evaluation of the adoption method of bobwhite quail propagation in Missouri. Missouri Conservation Pittman-Robertson Report Series. 1952(9).
Nagel, W.O. 1953. The harvests, economic values, and soil-fertility relationships of Missouri furbearers. Missouri Conservation Pittman-Robertson Report Series. 1953(10).
Korschgen, L.J. 1954. A study of the food habits of Missouri deer. Missouri Conservation Pittman-Robertson Report Series. 1954(11).
Korschgen, L.J. 1955. A study of the food habits of Missouri doves. Missouri Conservation Pittman-Robertson Report Series. 1955(12).
Brohn, A., Dunbar, R. 1955. Age composition, weights, and physical characteristics of Missouri's deer. Missouri Conservation Pittman-Robertson Report Series. 1955(13).
Korschgen, L.J. 1955. Fall foods of waterfowl in Missouri. Missouri Conservation Pittman-Robertson Report Series. 1955(14).

Korschgen, L.J. 1957. Food habits of coyotes, foxes, house cats, bobcats in Missouri. Missouri Conservation Pittman-Robertson Report Series. 1957(15).
Korschgen, L.J. 1958. Availability of fall game bird food in Missouri topsoil. Missouri Conservation Pittman -Robertson Report Series. 1958(16).
Vaught, R.W., Kirsch, L.M. 1966. Canada geese of the eastern prairie population, with special reference to the Swan Lake flock. Missouri Conservation Technical Report. 1966(3).
Murphy, D.A., Crawford, H.S. 1970. Wildlife foods and understory vegetation in Missouri's national forests. Missouri Conservation Technical Report. 1970(4).
Schwartz, C.W., Schwartz, E.R. 1974. The three-toed box turtle in central Missouri: Its population, home range, and movements. Missouri Conservation Terrestrial Report Series. 1974(5).
Korschgen, L.J. 1980. Food and nutrition of cottontail rabbits in Missouri. Missouri Conservation Terrestrial Report Series. 1980(6).
Sampson, F.W. 1980. Missouri fur harvests. Missouri Conservation Terrestrial Report Series. 1980(7).
LaVal, R.K., LaVal, M.L. 1980. Ecological studies and management of Missouri bats, with emphasis on cave -dwelling species. Missouri Conservation Terrestrial Report Series. 1980(8).
Sayre, M.W., Baskett, T.S., Sadler, K.C. 1980. Radiotelemetry studies of the mourning dove in Missouri. Missouri Conservation Terrestrial Report Series. 1980(9).
Humburg, D.D., Babcock, K.M. 1982. Lead poisoning and lead/steel shot: Missouri studies and a historical perspective. Missouri Conservation Terrestrial Report Series. 1982(10).
Clawson, R.L. 1982. The status, distribution, and habitat preferences of the birds of Missouri. Missouri Conservation Terrestrial Report Series. 1982(11).
Schwartz, E.R., Schwartz, C.W., Kiester, A.R. 1984. The three-toed box turtle in central Missouri, part II: A nineteen-year study of home range, movements and population. Missouri Conservation Terrestrial Report Series. 1984(12).
Christisen, D.M., Kearby, W.H. 1984. Mast measurement and production in Missouri (with special reference to acorns). Missouri Conservation Terrestrial Report Series. 1984(13).
Skinner, R.M., Baskett, T.S., Blenden, M.D. 1984. Bird habitat on Missouri prairies. Missouri Conservation Terrestrial Report Series. 1984(14).
Christisen, D.M. 1985. The greater prairie chicken and Missouri's land-use patterns. Missouri Conservation Terrestrial Report Series. 1985(15).
Kearby, W.H., Christisen, D.M., Myers, S.A. 1986. Insects: Their biology and impact on acorn crops in Missouri's upland forests. Missouri Conservation Terrestrial Report Series. 1986(16).
Kurzejeski, E.W., Hunyadi, B.W., Hamilton, D.A. 1987. The ruffed grouse in Missouri: Restoration and habitat management. Missouri Conservation Terrestrial Report Series. 1987(17).
Christisen, D.M., Kurzejeski, E.W. 1988. The Missouri squirrel harvest: 1947-1983. Missouri Conservation Terrestrial Report Series. 1988(18).
Henderson, D.E., P. Botch, J. Cussimanio, D. Ryan, J. Kabrick, and D. Dey. 2009. Growth and Mortality of Pin Oak and Pecan Reforestation in a Constructed Wetland: Analysis with Management Implications. Science and Management Technical Series: Number 1. Missouri Department of Conservation, Jefferson City, MO.
Reitz, R., and D. Gwaze. 2010. Landowner Attitudes Toward Shortleaf Pine Restoration. Science and Management Technical Series: Number 2. Missouri Department of Conservation, Jefferson City, MO.

Natural History Series

Gardner, J. E. Undated. Invertebrate Fauna from Missouri Caves and Springs. Natural History Series. Undated(3).
Schroeder, W. 1981. Presettlement Prairie of Missouri. Natural History Series. 1981(2).
Summers, B. 1981. Missouri Orchids. Natural History Series. 1981(1).
Ladd, D. 1996. Checklist and Bibliography of Missouri Lichens. Natural History Series. 1996(4).
Wu, S.K., Oesch, R., Gordon, M. 1997. Missouri Aquatic Snails. Natural History Series. 1997(5).
Jacobs, B., Wilson, J.D. 1997. Missouri Breeding Bird Atlas: 1986-1992. Natural History Series. 1997(6).