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RESEARCH ARTICLE

Nest Success, Abundance, and Length Distribution of Age-0 Largemouth Bass in Sanctuaries and Areas Open to Fishing

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Abstract: Protecting an area from fishing by establishing a sanctuary is one possible management strategy that could protect adults during spawning, potentially enhancing recruitment in freshwater systems. From 2001-2006, Briery Creek Lake (342 ha), Virginia was characterized by high fishing pressure in spring when adults were spawning and low abundance of age-0 Largemouth Bass *Micropterus salmoides*. Therefore, we created two sanctuaries in 2006 in Briery Creek Lake that were closed to angling and boats; these areas provided protection for nest-guarding male Largemouth Bass. However, the nest-success rate did not differ significantly between open areas and sanctuaries (30-40% nest success). Catch per unit effort of age-0 Largemouth Bass did not differ between areas open to angling (28.8/h and 39.0/h in 2006 and 2007, respectively) and sanctuaries (14.6/h and 22.2/h in 2006 and 2007, respectively). Similarly, mean length-at-capture was not different for age-0 Largemouth Bass between sanctuaries and open areas. Closing spawning areas to fishing may not be an effective management option to increase Largemouth Bass recruitment success in Briery Creek Lake.

Keywords: Fishing, Largemouth bass, Micropterus salmoides, Recruitment, Sanctuaries, Spawning.

INTRODUCTION

In the United States, Largemouth Bass *Micropterus salmoides* are a popular target of recreational anglers and thus have considerable economic importance. However, angling-related stress may influence the *via*bility of Largemouth Bass populations [1 - 4]. Angling during spawning may reduce spawning success, resulting in lower recruitment compared to unfished or lightly fished populations [5]. Given the potentially detrimental effects of angling on sportfish populations, many states historically prohibited spring fishing for Black Bass *Micropterus* spp. to attempt to protect spawning adults and sustain recruitment [6]. However, such seasonal closures were often unpopular, difficult to enforce, and resulted in conflicting outcomes [2, 7, 8]. Currently, few states manage using closed seasons, although several states enforce catch-and-release fishing during the spring.

Instead of seasonal closures, Kubacki *et al*. [7] recommended the use of sanctuaries or year-round closed areas, claiming that such sanctuaries are more effective at reducing the negative impacts on Largemouth Bass from angling than are closed seasons. Some successes in the protection and rehabilitation of overfished populations have been attributed to the use of sanctuaries or freshwater protected areas [9], including conservation of several rare fish species in the western United States [10, 11]. Sanctuaries on the spawning grounds of Lake Trout *Salvelinus namaycush* aided in the rehabilitation of this species in Lake Superior; spawning sanctuaries are being used as a management strategy in other Great Lakes for Lake Trout restoration [12]. In marine systems, sanctuaries increased population resilience to

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overfishing [13, 14] by increasing fish abundance, size distribution, and yield-per-recruit [15]. Sanctuaries may also provide the additional benefit of improving catch rates in areas adjacent to sanctuaries [16].

However, using sanctuaries to improve recruitment of Largemouth Bass has seldom been applied [17]. To evaluate the effects of Largemouth Bass sanctuaries, we studied Briery Creek Lake (BCL), an impoundment managed by the Virginia Department of Game and Inland Fisheries (VDGIF). Briery Creek Lake consistently produces trophy-sized (> 3.6 kg) Largemouth Bass. This trophy fishery attracts anglers from across the United States and has received a high amount of fishing pressure since opening to fishing in 1989 [18, 19]. Managers employ a protective-slot length limit (355-610 mm) to promote trophy Largemouth Bass abundance. However, population estimates conducted by VDGIF since 2001 have demonstrated lower recruitment to age-1 Largemouth Bass abundances in BCL than in other nearby impoundments. The objectives of this study were to compare Largemouth Bass nest success, relative abundance of age-0 fish, and size structure of age-0 fish in two sanctuaries (where anglers were prohibited) with the remainder of the lake where angling was allowed.

METHODS

Study Site

Briery Creek Lake, a 342-ha impoundment, was created in 1986-87 for flood control and recreation and opened to fishing in 1989. The majority of the watershed around Briery Creek is forested. Much of the existing forested land remained uncut during reservoir construction; therefore, the majority of the lake has abundant woody structure, with standing timber throughout. Aquatic vegetation covers nearly 100% of the shoreline, which has subsequently led to greater water clarity (Secchi depth transparency about 2 m) than during pre-vegetation levels that lasted about 10 years after impoundment (Secchi depth transparency about 1 m). The aquatic vegetation consists of watershield *Brasenia schreberi*, eelgrass *Vallisneria americana*, Brazilian elodea *Elodea densa*, common elodea *E. canadensis*, and Illinois pondweed *Potamogeton illinoensis* [20].

The fish species present in BCL include: Largemouth Bass, Bluegill *Lepomis macrochirus*, Redear Sunfish *Lepomis microlophus*, Warmouth *L. gulosus*, Green Sunfish *L. cyanellus*, Black Crappie *Pomoxis nigromaculatus*, Blueback Herring *Alosa aestivalis*, Channel Catfish *Ictalurus punctatus*, and Chain Pickerel *Esox niger* [20]. In 2003, BCL fishing effort during the spring (March–May) totaled 58,559 hours, with 88% of the effort (51,256 hours) directed at Largemouth Bass. Anglers released 99% of the Largemouth Bass that were caught [20].

Field Sampling

We established sanctuaries in two coves in BCL in April 2006. The cove at the north end of the lake was 1.0 ha and the southern cove was 2.2 ha; these coves were chosen for topography that facilitated easy exclusion of anglers. These two coves also had similar habitat to other areas of the lake and represented areas that Largemouth Bass had previously been observed spawning. Entry to the two coves was blocked with prominent fencing strung between trees on each side of the coves, while not impeding fish movement. Signs prohibiting fishing in the sanctuaries were placed on the fence, the surrounding trees, and at each boat ramp to alert anglers of the closures. The closures were enforced by the law enforcement division of VDGIF. Other potential closures were not used due to our inability to prominently fence the areas. The rest of the lake remained open to angling and regulated by the protective slot limit. Outside the sanctuaries, we classified lake areas as either coves or non-cove areas, defining coves as inlets with an opening < 300 m between shorelines.

We conducted visual nest surveys by boat every three days between 21 April and 26 May 2007 [20]. We surveyed approximately 70% of the potential littoral spawning habitat of the lake by selecting twelve 1-km shoreline transects to visually observe nests. Each transect encompassed the littoral habitat from the shoreline to a depth of two meters. Three or four transects were surveyed each sampling day, which allowed each transect to be surveyed for new nests on three separate occasions. Additionally, all previously observed nests were monitored every three days by snorkeling, until either hatching was observed and swim-up fry were present (success) or the male had abandoned the nest and no eggs remained (failure). Two of the 1-km transects included the entirety of the sanctuaries plus the adjacent area that was classified as non-cove habitat. We geo-referenced nests and classified them as being in a cove or non-cove area based on the location within the lake in order to make comparisons between the similar habitats of sanctuaries and coves that were open to angling.

We also sampled age-0 Largemouth Bass using pulsed DC electrofishing on nine separate occasions during August-

October 2006 and June-September 2007 [20]. Eight 15-minute transects were selected based on the nest survey transects that produced the most nests. Each transect covered approximately the same area that was visually surveyed for nests (1 km), which allowed for 50% of the shoreline to be sampled each night. We recorded the abundance of age-0 Largemouth Bass to determine catch-per-unit-effort (CPUE) and measured age-0 Largemouth Bass for total length (TL, mm).

Data Analyses

We used a two-sample *t*-test to test for a difference in mean depth of nests in open areas and sanctuaries. We used a chi-square test to determine if open cove areas and open non-cove areas differed in nest success. Open areas did differ; therefore, we used a chi-square test to test for a difference in the mean number of successful nests between open coves and closed coves and open non-cove areas and sanctuaries. Electrofishing catch data (number of fish/h) were log10(X +1) transformed. We compared CPUE and TL in open areas and sanctuaries by using repeated measures analysis of variance (ANOVA) procedures [21].

RESULTS

We observed 63 nests in Briery Creek Lake. We found 10 nests in sanctuaries, 28 nests in open coves, and 25 in open non-cove areas (Table **1**). The success rate in sanctuaries (30%; 3 successful nests) and open (39.3%; 11 successful nests) coves of the lake did not differ significantly ($P = 0.83$). We found the highest success rate of nests in open non-cove areas (80%; 20 successful nests), which was significantly higher than sanctuary coves ($P < 0.01$) and open coves ($P < 0.01$).

Table 1. Number of Largemouth Bass nests and success rate, of the nests found in open coves, open non-coves, and sanctuaries in Briery Creek Lake, Virginia. Columns with different letters indicate significant differences among areas.

Area	Number	Success Rate
Open Coves	28	0.40[a]
Open Non-coves	25	0.82[b]
Sanctuaries	10	0.30[a]

During 2006, CPUE of age-0 Largemouth Bass in sanctuaries ranged from 11.2 - 20.5 fish/h whereas in open areas, CPUE ranged from 16.7 - 45.2 fish/h (Table **2**). In 2007, CPUE in sanctuaries and open areas ranged from 13.7 - 42.4 and 17.3 - 56.5 fish/h, respectively. However, for both years combined, catch rates for age-0 Largemouth Bass did not differ between sanctuaries and areas open to angling ($F = 3.87$; $df = 1,69$; $P = 0.30$).

Table 2. Electrofishing catch-per-unit-effort (CPUE) (fish/hour) of age-0 Largemouth Bass collected from sanctuaries and areas open to angling in Briery Creek Lake, Virginia. N is the number of electrofishing transects.

		Sanctuaries			Open to Angling		
Year	Week	N	CPUE	SE	N	CPUE	SE
2006	5-Aug	2	20.5	9.6	6	25.3	12.6
2006	19-Aug	2	11.4	11.4	6	22.0	8.9
2006	2-Sep	2	11.2	11.2	6	16.7	5.1
2006	16-Sep	2	11.7	11.7	6	45.2	14.1
2006	28-Oct	2	18.0	18.0	6	34.7	10.9
2007	24-Jun	2	13.7	4.6	6	56.5	20.1
2007	22-Jul	2	14.2	6.4	6	46.0	15.3
2007	5-Aug	2	18.3	18.3	6	17.3	9.2
2007	16-Sep	2	42.4	20.3	6	36.3	11.1

Age-0 Largemouth Bass length did not differ in sanctuaries compared to open areas in 2006 and 2007 ($F = 7.91$; $df = 1,422$; $P = 0.22$). In 2006, age-0 Largemouth Bass mean lengths-at-capture in sanctuaries ranged from 61-100 mm whereas in open areas mean length ranged from 68 - 99 mm (Table **3**). We obtained similar results in 2007 where mean lengths ranged from 31 - 80 mm in sanctuaries and 34 - 89 mm in open areas.

Table 3. Mean total length (mm) of age-0 Largemouth Bass collected by electrofishing from sanctuaries and areas open to angling in Briery Creek Lake, Virginia.

		Sanctuaries			Open to Angling		
Year	Week	N	TL	SE	N	TL	SE
2006	5-Aug	9	61	6.5	28	68	4.4
2006	19-Aug	7	62	3.6	30	75	3.7
2006	2-Sep	4	66	21.2	32	81	4.0
2006	16-Sep	0	na	na	67	88	2.0
2006	28-Oct	9	100	7.6	51	99	3.3
2007	24-Jun	2	31	2.0	49	34	0.6
2007	22-Jul	6	51	4.8	31	49	3.0
2007	5-Aug	23	67	4.6	21	59	4.7
2007	16-Sep	12	80	6.3	42	84	3.4

DISCUSSION

Angling did not appear to limit Largemouth Bass nest success or recruitment in Briery Creek Lake; we found no differences in age-0 Largemouth Bass relative abundance (CPUE) between sanctuaries and open areas of BCL and greater nest success in non-cove areas open to fishing. In a study of five Michigan lakes, Wagner *et al*. [22] found that the chance of producing swim-up fry did not decrease with increasing fishing pressure. Catch-and-release angling did not change movement or behavior of Pike *Esox lucius* in a slightly eutrophic lake in Germany [23]. The catch-and release angling that occurs on BCL does not appear to negatively impact nest success rates and therefore would not be expected to influence recruitment.

The observed nest success rates of 30-82% (54% lake-wide) at BCL closely resembled other published nest success rates (38-63% in [24]; 44-84% in [2]). However, those studies reported higher nest success rates in sanctuaries compared to angler-accessible areas within lakes, which is contrary to our findings. We found only 10 nests within the sanctuaries of BCL and only three of those were successful. This small number of nests may have been insufficient to identify any differences in hatching success between open areas and sanctuaries of the lake.

We did not observe any differences in the length of age-0 Largemouth Bass between sanctuaries and areas open to fishing. However, only two small coves were closed to angling; at only 1% of the total lake area, this may not be a large enough area to identify significant differences in nest success, CPUE of age-0 Largemouth Bass, or length. Larger sanctuaries may provide better insight by providing a greater area for Largemouth Bass to spawn, without effects from catch-and-release angling. However, the popularity of fishing on BCL precluded the experimental closure of more coves.

Previous studies on the beneficial effects of sanctuaries on reproductive success have been conducted on northern lakes that typically have higher water clarity than in southern systems [7, 24]. In those systems, anglers are able to "sight fish," visibly targeting a specific nesting fish. That fishing approach may have compounded negative effects of catch-and-release angling on Largemouth Bass reproductive success. The relatively low water clarity of BCL (average spring secchi = 2 m) may limit the amount of sight fishing that can occur, thereby providing a natural sanctuary from angling for deeper nesting Largemouth Bass. Sanctuaries would provide greater protection to fish in systems with longer nest seasons and clearer water than in BCL.

Illegal angling in the sanctuaries could have masked the effects of the experiment. If sanctuaries lack adequate enforcement, the "sanctuary" designation may negatively impact Largemouth Bass reproductive success [24]. Anglers view sanctuaries as areas where quality Largemouth Bass may be found, and, without enforcement, these areas may put Largemouth Bass at a higher risk of being captured [24]. In this study, VDGIF Conservation Police Officers adequately enforced the closure and witnessed no one fishing in the sanctuaries. Additionally, the areas were marked as closed, and the fencing strung across the coves made it more difficult for anglers to access the areas. Therefore, the lack of significant differences between areas open to angling and sanctuaries did not likely result from illegal angling or insufficient enforcement.

Sanctuaries did not improve Largemouth Bass recruitment in protected areas in BCL. Other limiting factors to recruitment of Largemouth Bass may be overriding any positive impacts on recruitment the sanctuaries may have provided. The early-life prey resources for age-0 Largemouth Bass, predation on age-0 Largemouth Bass, juvenile

habitat quality, and potential competition between age-0 Largemouth Bass and Bluegill could also affect Largemouth Bass recruitment and require further investigation.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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