Response of Juvenile Largemouth Bass to Habitat Enhancement Through Addition of Artificial Substrates

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Abstract: The availability of quality nursery habitats can be an important factor in the recuitment dynamics of littoral fish species. Eight artificial habitats composed of crushed rock substrate were established in littoral areas of an embayment of B. E. Jordan Lake, North Carolina, that historically exhibited low abundances of juvenile largemouth bass *(Micropterus salmoides).* Response of juvenile largemouth bass to habitats was assessed by night shoreline electrofishing at treatment sites and associated controls on 4 occasions during the growing season in each of 3 years. Significantly more age-0 largemouth bass were collected on the artificial substrates than at control sites during 3 of 4 sampling periods. Densities of age-0 largemouth bass in shoreline areas where habitat was added increased over the course of the study relative to those recorded at long-term monitoring sites. These results demonstrate that juvenile largemouth bass will utilize artificial substrates, and that habitat enhancements of this type may be useful in systems where treatment of adequate amounts of shoreline is feasible.

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The role of habitat in structuring fish communities and governing population dynamics has become a central issue in fisheries management in recent years (e. g., Benaka 1999). Spatial patterns in fish community structure have been correlated with variations in habitat types in large, heterogeneous systems such as reservoirs (Chipps et al. 1997) as well as in natural lakes (Keast et al. 1978, Jennings et al. 1999). Similarly,

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vital population processes such as recruitment dynamics and predator-prey interactions are frequently influenced by the availability and arrangement of required or suitable habitats (Werner et al. 1977, Minns et al. 1999, Williams 1999). As fisheries management continues to evolve from species-specific to system-wide approaches, identification of critical habitats, and development of methods to manage and enhance these habitats, will play an increasingly important role in maintaining sustainable fisheries.

The largemouth bass is among the most important recreational fish species in the southeast and is commonly the keystone predator in both large and small lentic systems (Heidinger 1975). Historically, research concerning population and recruitment dynamics of largemouth bass has focused on community structure and predator-prey dynamics (e.g., Davies et al. 1982). However, more recent research has recognized that life-stage specific habitat requirements can play an equally important role in controlling largemouth bass population dynamics, particularly through their influence on recruitment success (Annett et al. 1996). Nesting largemouth bass tend to prefer complex substrates such as gravel for nest construction, typically in association with cover (Stuber et al. 1982, Annett et al. 1996). Age-0 largemouth bass also prefer habitats that provide complex physical structure, such as vegetation, and several studies have reported positive correlations between the availability of aquatic vegetation and juvenile largemouth bass abundance, growth, and survival (Durocher et al. 1984, Miranda and Pugh 1997). However, relatively few studies have addressed habitat preferences of juvenile largemouth bass in systems that lack vegetation and the potential influence that habitat availability has on juvenile dynamics in such systems (but see Irwin 1994).

B. Everett Jordan Lake, a flood control reservoir in the central Piedmont of North Carolina that does not support aquatic vegetation, has been the site of long-term research on recruitment dynamics of largemouth bass since 1987 (see Jackson and Noble 2000*a*, 2000*b*). Assessments of spatial patterns in age-0 largemouth bass distributions in Jordan Lake have demonstrated that the embayments of the reservoir serve as the primary nursery areas for largemouth bass, presumably due to the absence of well-developed littoral habitats in main-channel areas (Jackson et al. 1991). Additionally, comparisons of catch-per-effort data identified consistent differences in juvenile largemouth bass production among four major embayments of Jordan Lake that persisted over 7 years despite annual variations in year class strength (Phillips et al. 1997). Irwin et al. (1997) found that juvenile largemouth bass in Jordan Lake exhibited strong preferences for complex substrates such as gravel, particularly when associated with shorelines of intermediate slope. Furthermore, persistent patterns in the spatial distribution of age-0 largemouth bass within one embayment of Jordan Lake were found to be significantly correlated with the availability of these preferred substrates (Irwin et al. 1997). Habitat inventories of the embayment nursery areas in Jordan Lake suggested that the among-bay differences in age-0 largemouth bass production identified by Phillips et al. (1997) could be related to differences in the relative availability of littoral areas characterized by complex substrates (Irwin 1994). These results suggest that the availability of suitable nursery habitat may set an upper limit for juvenile largemouth bass production in Jordan Lake and that the carrying capacity of traditionally low-productivity areas might be enhanced through habitat manipulations.

In 1995, we established artificial habitats consisting of crushed rock in shoreline areas of Jordan Lake that previous assessments indicated were characterized by low age-0 largemouth bass catches and a lack of suitable habitat. Our primary objective was to determine if juvenile largemouth bass demonstrated a preference for these habitats relative to untreated control areas. We also present long-term, large-scale catch comparisons to assess whether treated areas were characterized by higher age-0 largemouth bass catches following addition of the artificial habitats than in 2 pre-treatment years. Additionally, we compare estimated growth rates of age-0 largemouth bass from treatment areas, controls, and long-term sampling sites.

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Methods

Establishment of Artificial Habitats

Eight artificial habitats were established in Little Beaver Creek, a 64-ha embayment at the southeastern end of the New Hope arm of Jordan Lake, in early July 1995 in areas that previous assessments indicated lacked suitable juvenile largemouth bass habitat (Fig. 1). Habitats consisted of ≈20 mm diameter crushed rock (hereafter referred to as gravel) substrate spread from the shoreline (at conservation pool, 65.5 m above mean sea level) out to a depth of approximately 1 m. Habitats were established by loading gravel onto a barge, transporting it to the treatment areas, and distributing it into littoral areas with shovels and a high-pressure water hose. Two different gravel bed designs were used in establishing habitats. Four habitats consisted of a continuous patch of gravel 20 m in length, while the remaining 4 patches consisted of 3 intermittent 6.6 m patches of gravel with 2 equivalent open intervals between patches. Habitats were further partitioned among shallow (water depth of 1 m reached ≥9 m from the shoreline) and relatively steep (water depth of 1 m reached ≤4.5 m from shoreline) sloping shorelines, with 2 habitats of each gravel design applied in each slope type. Within treatment areas, we attempted to achieve complete coverage with gravel, but actual depth of added substrate within and among sites was variable and averaged approximately 7–8 cm. Control areas, representative of pre-treatment habitat and equal in shoreline length to treatment habitats (20 m for continuous; 33 for intermittent), were established adjacent to each habitat ($N = 8$), but separated from treatment areas by at least 6.6 m.

Sampling of Fish

Artificial habitats and adjacent unaltered control areas were sampled by night shoreline electrofishing with 260-V DC delivered via a hand-held anode (Jackson and Noble 1995). Four samples were collected each year between July and November during 1995,1997, and 1998. High water levels associated with hurricanes precluded sampling in 1996. All age-0 largemouth bass collected were measured (total length, mm (TL)), capture location relative to treatment and control areas recorded, and the released at a point midway between the treatment and control site where they were captured.

To examine the response of age-0 largemouth bass to the artificial habitats in relation to bay-wide densities, and assess annual variability in year class strength, night electrofishing samples were also collected in July and October at 5 sites in Little Beaver Creek for which a long-term data set was available (Jackson and Noble *2000a,* 2000*b;* hereafter referred to as long-term sampling sites). Average sampling effort at each site was 15–20 minutes. All largemouth bass captured were measured (TL) and released at the site of capture. Measures of age-0 largemouth bass abundance (catch/m) for the sites where habitat treatments were established were available for two dates from each of two pre-treatment years (1991–1992) from Irwin (1994). Densities of age-0 bass from treatment areas, both pre- and post-treatment, were then compared to those from the 5 long-term sampling sites during the same years.

Analyses of Data

Initial statistical analyses tested whether age-0 largemouth bass catch rates (catch/m) were higher on treatment areas than at their associated control sites. Differences in catch rates (D_i) between individual treatments and their controls were calculated for each site for each of the 4 annual sampling periods, regardless of gravel arrangement or slope, and comparisons for each sampling period conducted using a one-tailed *t*-test, treating samples from the 3 years as replicates (Snedecor and Cochran 1980). Comparisons were made by sampling period to control for potential effects of ontogenetic changes in habitat use related to fish growth, declining catch rates through the growing season due to natural mortality, and the possible influence of declines in water levels through the summer. Catches from one of the continuous gravel/shallow slope areas during 1995 were excluded from analyses because the control site had to be shifted slightly between sample periods 2 and 3 to account for the effects of water level declines. Catches from all sites during sample period 4 of 1998 were excluded from analyses because water levels had declined to a point where all treatments were out of the water.

For those sampling periods with significant differences in age-0 largemouth bass catch rates, additional tests were conducted to determine if the magnitude of response differed according to gravel arrangement or slope type. The proportion of all largemouth bass collected at each treatment-control pair that was captured on the treatment was calculated and arc-sine transformed as recommended by Snedecor and Cochran (1980). The proportions were then tested for homogeneity of variance using

Bartlett's test and an Analysis of Variance (ANOVA) conducted to test for differences in response based on gravel arrangement or slope type (Snedecor and Cochran 1980).

Summer growth rates (mm/day) of age-0 largemouth bass captured in treatment, control, and long-term sampling areas were calculated based on changes in sample mean lengths through time. Linear growth models were developed each year for each treatment area by regressing mean length as a function of day of year, and statistically compared by testing for homogeneity of regression slopes (Snedecor and Cochran 1980).

Results

Largemouth Bass Catches in Artificial Habitats

A total of 212 age-0 largemouth bass were collected from habitat enhancement areas and their controls during the 4 sampling periods in 1995, and 187 in 1997. Because of an unusually small year class, only 42 age-0 largemouth bass were collected in 1998 samples.

Differences in catches of age-0 largemouth bass between treatment and control sites varied widely among seasons and years, but catch rates from treatment sites were equal to or higher than those from their paired control sites in 81% of the comparisons used in analyses (Figs. 2–4). Statistical evaluations of catch differences between treatment and control areas revealed that catches from treatment sites were

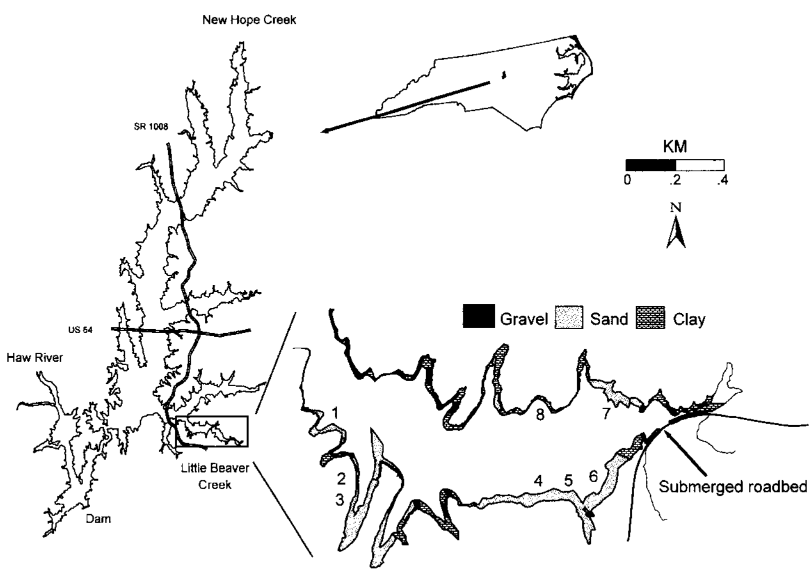

Figure 1. Distribution of shoreline habitats in Little Beaver Creek, B. E. Jordan Lake. Numbers indicate locations of 8 artificial habitats

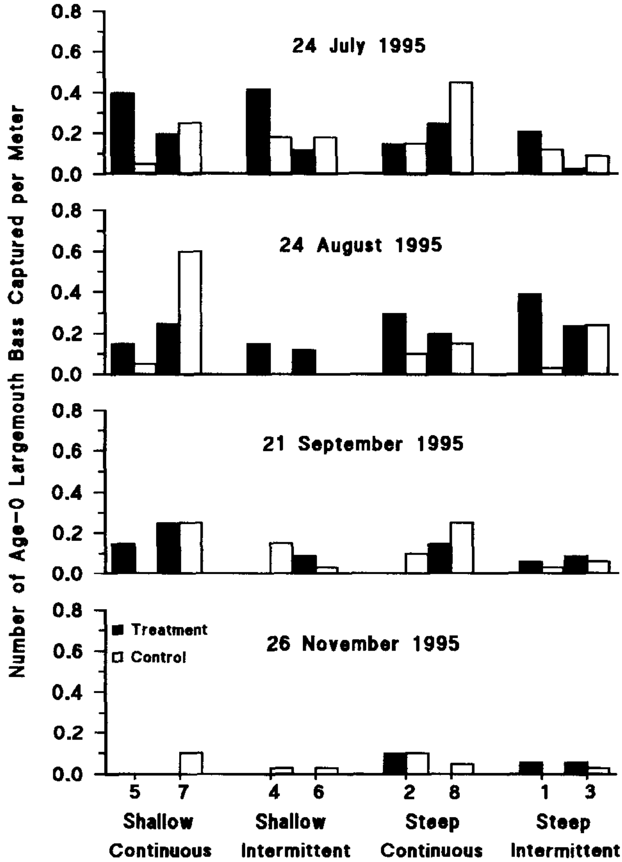

Figure 2. Catches (bass/m) of age-0 largemouth bass at treatment sites and associated controls in Little Beaver Creek, B. E. Jordan Lake, 1995.

significantly higher than those in associated control sites during 3 of the 4 sampling periods (Period 1–July/August: $P < 0.03$; Period 2–August/September: $P < 0.02$; Period 4–October/November: $P < 0.03$). No statistical difference in catch rates between treatment and control sites was detected in the mid- to late-summer sampling period (Period 3- $P > 0.10$).

Further analysis of the data from the three sample periods with significant catch differences revealed that arc-sine transformed proportions of site-specific age-0 largemouth bass catches demonstrated homogeneity of variance (For treatment type—all $P \geq 0.18$, for slope type–all $P \geq 0.70$). Therefore an ANOVA was used to test for differences in magnitude of response. No significant differences in response were detected in comparisons of continuous and intermittent treatment designs (all $P \geq 0.23$). Likewise, no differences were detected in responses of age-0 largemouth bass to artificial habitats as a function of slope (all $P \geq 0.10$).

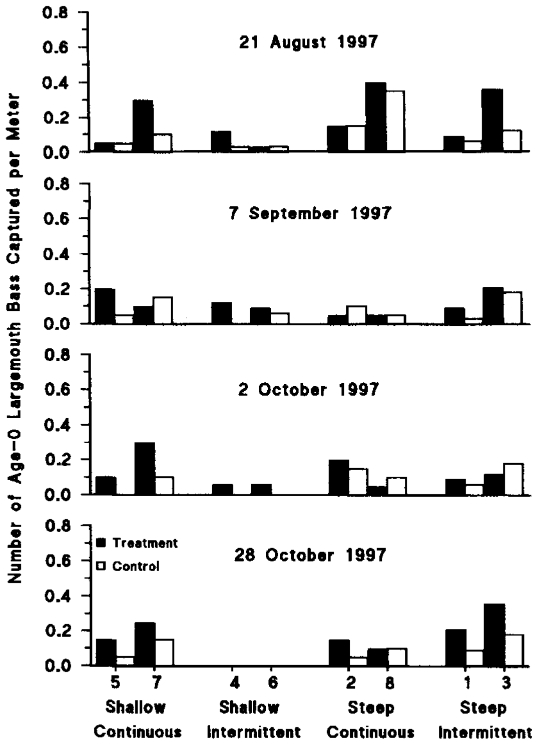

Figure 3. Catches (bass/m) of age-0 largemouth bass at treatment sites and associated controls in Little Beaver Creek, B. E. Jordan Lake, 1997.

Prior to establishment of the artificial habitat sites, catch rates (catch/m) in the 8 treatment/control areas of shoreline where gravel was added were low relative to those recorded from 5 sites sampled as part of a long term study in the same embayment. Mean catch rates from long-term sampling sites were up to 8× higher in July samples than pre-treatment catches from the shoreline areas where treatments were applied, and October catches 12× higher (Fig. 5). However, relative to the long-term sampling sites, catches in treatment areas increased in the years following gravel additions, and by 1998 catch rates at treatment sites had increased to 1/3 of those from the long-term sites (Fig. 5). Plots of the ratio of catches from the long-term sites and treatment areas during the pre- and post-treatment periods suggested a trend towards increasing numbers of age-0 largemouth bass in treatment areas relative to long-term sites through the post-treatment years (Fig. 5).

Age-0 Largemouth Bass Growth

First-year growth rates of age-0 largemouth bass in the habitat enhancement areas were similar to those observed during the long-term studies of largemouth bass dynamics in Little Beaver Creek over the previous 8 years (Jackson and Noble

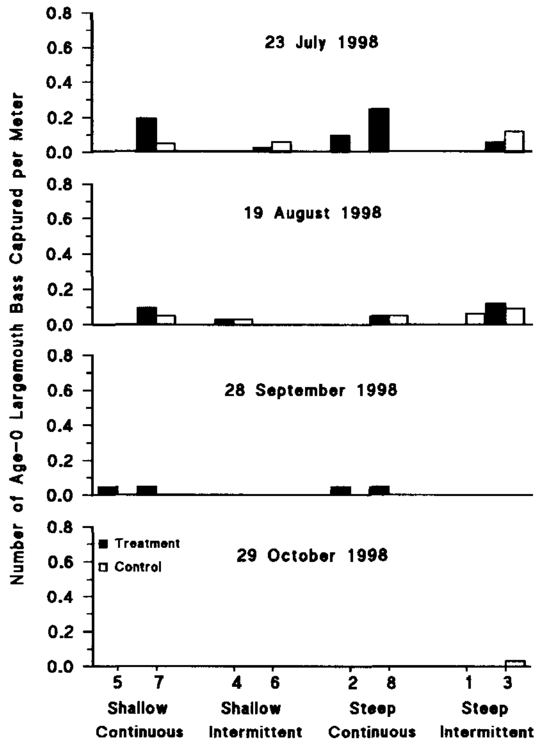

Figure 4. Catches (bass/m) of age-0 largemouth bass at treatment sites and associated controls in Little Beaver Creek, B. E. Jordan Lake, 1998.

2000*b*). Increases in sample mean lengths tended to be faster early in the growing season than later in the summer, and age-0 largemouth bass mean lengths rarely exceeded 90 mm at the end of the growing season. Slope comparisons of linear growth models indicated that growth rates did not differ among treatment, control and long-term sites during the course of the study (all $P \geq 0.41$).

Discussion

Our results establish that age-0 largemouth bass will use shoreline areas enhanced with artificial substrates. Furthermore, our study provides evidence that habitat-enhanced areas held higher relative densities of juvenile bass following treatment. These responses provide strong support for the idea that unproductive habitats can be enhanced through the addition of artificial structure, and that in systems where nursery habitats limit recruitment, management directed at increasing habitat availability can generate positive responses.

A common difficulty in the assessment of habitat manipulations is determining if colonization of treatment areas represents an actual increase in densities or simply a redistribution of fish that would have otherwise occupied pre-existing habitats. Our

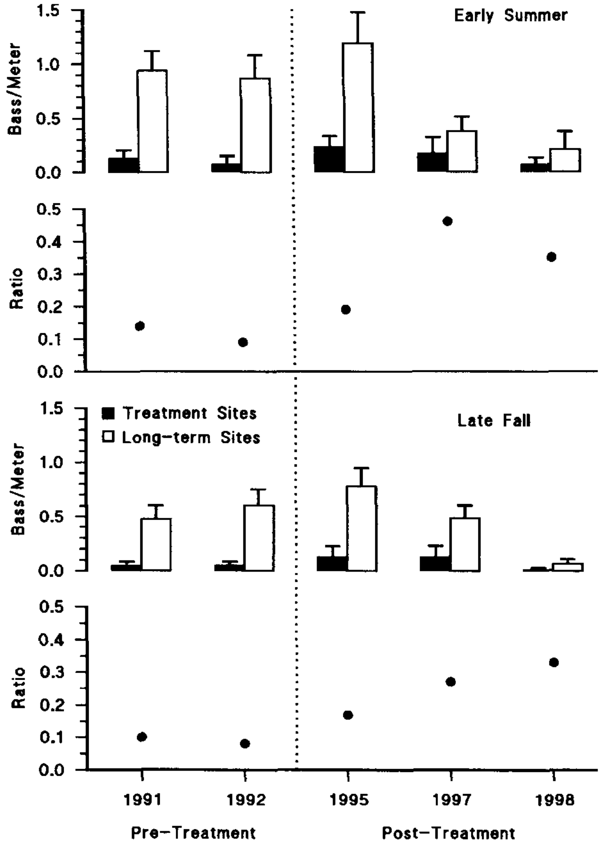

Figure 5. Seasonal catches (bass/m) of age-0 largemouth bass in treatment areas and long-term sampling sites, before and after habitat enhancement (bar graphs), and ratios of catches (treatment site catch/long-term site catch) for the same period (scatter plots), Little Beaver Creek, B. E. Jordan Lake, 1991–1998.

data do not allow us to refine either hypothesis. Similarly, we cannot establish whether trends towards increasing use of the artificial habitats by age-0 largemouth bass may have resulted from their use by adult bass as spawning substrate. However, treatments were applied late in spring 1995 to preclude their use as spawning habitat by adults. In subsequent years, adult bass may have used the gravel beds as spawning habitat, thereby contributing to higher numbers of young in the treatment areas and explaining the trend towards higher relative catches during the course of the study. Previous studies of walleye *(Stizostedion vitreum vitreum)* and lake trout *(Salvelinus namaycush)* have reported positive responses to the addition of artificial spawning substrates (Fitzsimons 1996, Gelling et al. 1996, Hartig and Kelso 1999). These studies documented increases in both egg counts and juvenile catch rates on their artificial substrates. It is likely that for species like largemouth bass that utilize similar habitats for spawning and nursery areas, additions or enhancements of such habitats will benefit recruitment through effects on both spawning adults and juveniles.

While the use of complex natural habitats such as vegetation by young largemouth bass is well-documented (Anett et al. 1996), such habitats are frequently unavailable in reservoirs which exhibit water level fluctuations. Previous studies have documented that adult largemouth bass will concentrate near larger artificial structures such as brush shelters and tire reefs (Prince et al. 1975, Vogele and Rainwater 1975), but published reports of manipulations designed to provide artificial habitats for juvenile largemouth bass are rare. Brouha and von Geldern (1979), in a review of efforts to revegetate littoral zones of California reservoirs to provide nursery habitat for small centrarchids, demonstrated the difficulty of using natural plants to enhance littoral areas of reservoirs with fluctuating water levels. However, Strange et al. (1982) reported successful establishment of rye in littoral areas of a fluctuating reservoir as well as increased use of planted areas by age-0 largemouth bass. Artificial habitats, such as gravel, are not subject to physical impacts due to desiccation and inundation, and may therefore provide more lasting benefits for habitat enhancement than plantings in flood control reservoirs characterized by unstable water levels. Added substrates, like gravel, may be subject to siltation, but our experience indicates that as water levels fluctuate, wave action tends to wash accumulated silt from artificial substrates and extend their usefulness. Most of the gravel we distributed in Jordan Lake was still exposed after nearly 4 years, and plot designs and borders were still recognizable, suggesting that the habitats may have long-term benefits.

Strange et al. (1982) reported that use of rye plantings by juvenile largemouth bass was sensitive to water levels, with differences in use of planted and unplanted areas becoming less pronounced as the percentage of the rye beds which were under water declined. In Jordan Lake, water levels at or above conservation pool result in wide availability of structures such as tree roots, but as water levels decline the availability of complex habitat declines precipitously (Irwin and Noble 1996). We do not have adequate data for quantifying the interactions between water levels and catch rates in our habitat enhancement areas. However, catch differences between treatment and control areas tended to be more pronounced when water levels were below conservation pool. Design of habitat enhancement areas in fluctuating reservoirs should take into account the availability of natural habitats through the range of typical water levels so that habitats can be established at depths that will produce the greatest benefit.

Growth rates of age-0 largemouth bass captured on artificial substrates did not differ from those estimated for fish collected from natural substrates and were well within the range previously reported from Jordan Lake (Jackson and Noble 2000*b*). These results suggest that prey taxa important to juvenile largemouth bass growth were available in the treatment areas in adequate numbers to support growth rates comparable to those exhibited in natural environments. These findings indicate that in addition to providing valuable physical habitat for juvenile largemouth bass, artificial substrates can also provide good foraging habitats as well.

The lack of significant differences in response of age-0 largemouth bass to continuous and intermittent gravel bed designs suggests that it is not necessary to establish large, continuous habitats to elicit positive responses. If closely spaced patches of habitat can produce similar responses to continuous treatments, then greater distances of shoreline could be treated with the same amount of gravel, reducing initial costs of establishing habitats. Additionally, the response of age-0 largemouth bass to crushed rock habitats may also allow savings in habitat establishment. Our original intention was to use more expensive pea gravel for creating habitat enhancement areas, since it more closely matched natural habitats in the lake, but we chose to use less costly crushed rock to expand the area we were able to treat. Our results suggest that artificially created substrates do no have to mimic those naturally available to produce positive responses, and might allow for significant savings.

While our results indicate that age-0 largemouth bass will use artificial habitats as nursery areas, responses were relatively subtle compared to the effort and expense of establishing the habitats. In large systems such as reservoirs, it may prove impracticable to employ such habitat enhancement techniques on a large enough scale to realize a measurable increase in largemouth bass production. However, smaller systems such as city lakes, particularly where shoreline areas are accessible with vehicles for transporting and distributing gravel, might lend themselves to such habitat manipulations on a scale that would produce stronger lake-wide results than we were able to obtain.

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