ABSTRACT

BARWICK, ROBERT DEMPSEY. Fish Populations Associated with Habitat-Modified Piers and Natural Woody Debris in Piedmont Carolina Reservoirs. (Under the direction of Thomas Kwak and Richard Noble.)

A primary concern associated with reservoir residential development is the loss of littoral habitat complexity. One potential approach to compensate for this loss is to deploy artificial habitat modules under existing piers, but the benefit of this practice on developed reservoirs has not been demonstrated. To determine the effect of pier habitat modifications, 77 piers located on 47, 100-m transects on two Piedmont Carolina reservoirs were selected for modification using plastic "fish hab" modules augmented with brush (brushed habs), hab modules alone (habs), or as reference piers without modification. Fish were sampled from all piers and transects in April, July, and October 2001 using a boat-mounted electrofisher. Generally, catch rates were higher at brushed hab piers and piers with habs than at reference piers during all seasons. Similarly, fish abundance was generally higher on transects containing natural woody debris, brushed habs, or habs than that on reference developed transects during spring and summer with exceptions during fall. On these reservoirs, fish abundance associated with developed shorelines appears to be related to the structural complexity of available habitat, regardless of structure composition. Supplementing piers with habitat structures appears to serve as an effective management technique to enhance littoral habitat complexity in residentially developed reservoirs.

Fish Populations Associated with Habitat-Modified Piers and Natural Woody Debris in Piedmont Carolina Reservoirs

by

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BIOGRAPHY

The author was born March 4, 1978, in Anderson, South Carolina. He graduated from North Mecklenburg High School in Huntersville, North Carolina, and enrolled at North Carolina State University in 1996. He received his Bachelor of Science in Zoology from North Carolina State University in 2000. At that time, he joined the Department of Zoology of North Carolina State University to begin graduate studies in Fisheries and Wildlife leading to a Master of Science degree in that field.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Introduction

The importance of structural cover as fish habitat has been well documented. To avoid predation, fish often move to structurally complex areas where predators cannot forage efficiently (Glass 1971, Savino and Stein 1982); thus, complex habitats that provide an abundance of cover are important for survival, growth, and as nursery areas for young and small fish of many species (Hall and Werner 1977, Orth et al. 1984, Lowe-McConnell 1987). Areas that provide this type of refuge include littoral areas with an abundance of inundated vegetation (Aggus and Elliot 1975), macrophyte beds (Hall and Werner 1977), large boulders (Trendall 1988), shaded areas (Helfman 1981), woody debris (Angermeier and Karr 1984, Flebbe and Dolloff 1995), standing timber (Burress 1961, Davis and Hughes 1971, Willis and Jones 1986), and in some cases pier, and riprapped areas constructed by lakeshore landowners (Colle et al 1989, Beauchamp et al. 1994, Jennings et al. 1999).

Attempts have been made to construct reservoirs that preserve structure for fish habitat. Standing timber left during basin clearing and later flooded can increase fish reproductive success, prey organism abundance, and standing stock and harvest of fishes (Ploskey 1981). Generally, standing timber tends to concentrate littoral fish species, such as largemouth bass *Micropterus salmoides* and bluegill *Lepomis macrochirus,* more so than pelagic species (Willis and Jones 1986), and angler catch rates have been reported to be higher in areas with an abundance of standing timber (Burress 1961).

As with standing timber, fish densities have been reported to be higher in vegetated areas (Borawa et al. 1979, Killgore et al. 1989), and sunfish (Centrarchidae) were positively related to aquatic plant abundance (Forester and

Lawrence 1978, Durocher et al. 1984). Stands of aquatic vegetation provide habitat for macroinvertebrates, which may attract insectivorous fishes and piscivores. This attraction is based on the diversity of microhabitats created by the increased surface area of leaves and stems that provide substrate for attachment of epiphytic organisms and protection of macroinvertebrates from predation (Gilinsky 1984, Keast 1984, Beckett et al. 1992). Young and small fishes may utilize these vegetated areas to escape predation by larger piscivores, as complex habitat mediates the extent of predator-prey interactions (Glass 1971, Saiki and Tash 1979, Savino and Stein 1982). In the absence of vegetative areas, such as instances where grass carp *Ctenopharyngodon idella* have been introduced, certain fishes appear to prefer other types of structures such as piers over water containing little structure (Colle et al. 1989).

Although most of the available literature on woody debris targets its importance in streams and rivers, the ecological function may be similar to that of woody debris in lentic systems. Inundated woody debris provides habitat for fish in the same manner that vegetation and standing timber does—it provides structure as cover for fish (Dolloff 1986, Bisson et al. 1987) and stable attachment sites for bacteria (Triska et al. 1984), fungi (Shearer 1972), and invertebrates (Anderson et al. 1978, Benke et al. 1984), all of which serve as food and habitat resources for fish. Angermeier and Karr (1984) reported that fish and benthic invertebrates were more attracted to areas with an abundance of woody debris than they were to cleared areas and that most large fish avoided reaches without debris. Similarly, streams with an abundance of woody debris support higher fish densities and biomass than streams with little or no debris (Flebbe and Dolloff 1995). However, fish used deep water more frequently than woody debris as cover in California streams (Berg et al. 1998), and the presence of woody debris in stream pools did not influence immigration or growth of fish in western U.S. streams (Harvey 1998).

Natural cover, such as woody debris and vegetation, is usually not as abundant in reservoirs, relative to densities in streams, due to the disruptive nature of water level fluctuations and the impact of human removal of woody debris (Christensen et al. 1996) and macrophytes (Bryan and Scarnecchia 1992). However, in a lake that has both vegetation and residential development, Bryan and Scarnecchia (1992) found that fish species richness and total abundance were consistently greater in areas with vegetation than in developed areas. Additionally, annual growth rates and bluegill production have been found to be lower in intensively developed lakes than in undeveloped ones (Schindler et al. 2000), thus emphasizing the importance of vegetation as fish habitat.

In reservoirs that lack extensive stands of vegetation, fish in littoral areas affected by residential development may utilize cover that provides similar benefits as vegetation and woody debris. In Wisconsin lakes, Jennings et al. (1999) found that species richness was greater in riprapped areas than in less complex areas, and Beauchamp et al. (1994) found that highest densities of littoral zone fishes were found at sites with an abundance of cobble substrates in Lake Tahoe. Their results are consistent with studies in streams that report positive correlations between biota and habitat complexity (Gorman and Karr 1978, Schlosser 1982, Angermeier and Karr 1984, Minshall 1984, Marcus et al. 1990, Hawkins et al. 1993). Thus, it appears that fish may not respond to littoral structure alone, but to the cumulative effect of all spaces, complexities, and shoreline characteristics created by structure (Jennings et al. 1999).

Since fish respond favorably to complex habitats, it is conceivable that upon introducing complexities, such as artificial fish attractors, fish would associate in a fashion similar to their associations with natural structure. Artificial structures have often been used to provide additional habitat and increase harvest in waters where natural cover is limited (Stone et al. 1974, Darovec et al. 1975, Prince et al. 1975). Such attractors also provide fish locations conducive to resting, refuge, concealment, feeding, and ambushing prey (Thomas et al. 1968). Most studies evaluating fish attractors constructed from stake beds (Petit 1973, Herrig and Miller 1985, Johnson and Lynch 1992), plastic structures (Herrig and Miller 1985, Rold et al. 1996), vitrified clay pipes (Wilbur 1978), brushed structures (Wilbur 1978, Pierce and Hooper 1979, Johnson and Lynch 1992), tire reefs (Paxton and Stevenson 1979, Pierce and Hooper 1979, Prince et al. 1979), evergreen trees (Johnson and Lynch 1992, Rold et al. 1996), plywood (Lawson 1981), and fiberglass panels with automobile tires (Smith et al. 1980) have concluded that fish abundance was higher in structured areas than non-structured areas.

Many reservoirs in the southeastern U.S. are structure-poor, and shorelines are being residentially developed by landowners at a rapid rate. Often, removal of woody debris and vegetation is associated with residential development (Bryan and Scarnecchia 1992, Christensen et al. 1996) and may be necessary to provide lake access for recreation, building of piers, and installation of erosion control devices such as riprap (Kahler et al. 2000). Development of this type often results in a loss of lake-wide habitat diversity and sometimes habitat complexity if retaining walls are constructed as erosion control devices (Jennings et al. 1999). Given the tendency of shoreline residential and commercial landowners and developers to remove woody debris, habitat management has potential for fish enhancement. One management technique, the addition of complex structure under piers on residentially developed shorelines, may be an approach to improve habitat that once contained natural woody debris and meet the requirements of reservoir managers, anglers, and shoreline landowners.

The objectives of this study were (1) to evaluate fish responses to artificial habitat modifications under piers and (2) to evaluate this technique as a habitat management response to the loss of natural woody debris in reservoirs that have some degree of residential shoreline development. Secondary objectives were (3) to evaluate gear catchability among pier habitats and (4) to quantify natural woody debris characteristics and compare those to brush incorporated into one type of pier-habitat modification.

My approach was to apply one of two pier modifications to piers on two reservoirs and make comparisons with untreated, reference piers as well as with shorelines containing natural woody debris. Fish responses were observed over three seasons. The specific null hypotheses that I tested were (1) no significant difference will be detected in fish occurrence among piers with or without artificial habitat modifications and (2) no significant difference will be detected in fish occurrence among shorelines containing natural woody debris and residentially developed shorelines with habitat-modified piers.

Methods

Study Areas

This research was conducted on Fishing Creek Reservoir and Lake Hickory, two Catawba River reservoirs in the Piedmont region of North Carolina and South Carolina, respectively (Figure 1). The Catawba River flows more than 321 km from the mountains of North Carolina to east of Columbia, South Carolina. Lake Hickory and Fishing Creek Reservoir are two of 11 reservoirs formed by dams on the Catawba River.

Fishing Creek Reservoir is the eighth reservoir from the headwaters of the Catawba River. The reservoir was formed in 1916 with the completion of the Fishing Creek Hydroelectric Station Dam and is currently classified primarily as a eutrophic reservoir. Fishing Creek Reservoir is a dual-purpose reservoir with the capacity to support hydroelectric generation and water supply for Chester County, South Carolina (Duke Power 1999). Shoreline use on Fishing Creek Reservoir is comprised of 7% residential and commercial, 18% undeveloped with natural woody debris, and 75% undeveloped (Duke Power unpublished data). Fishing Creek Reservoir has a drainage area of 9,870 km^2, which is comprised of 17% allocation to urban uses, 18% allocation to agricultural purposes, while 65% remains forested (Duke Power 2000). Full pool elevation is 127 m above sea level. The reservoir contains a volume of 74 million m^3, a surface area of 13.7 km^2, and a mean depth of 5.4 m. Maximum depth of the reservoir is 27.3 m, and mean retention time is 6 days (Duke Power unpublished data).

Lake Hickory is the third reservoir from the headwaters of the Catawba River and is near Hickory, North Carolina. This reservoir was created in 1927 with the completion of the Oxford Dam and is currently classified primarily as mesotrophic. Lake Hickory is also a dual-purpose reservoir, with the capacity for hydroelectric generation and water supply for the nearby cities of Hickory and Longview, North Carolina (Duke Power 1999). Shoreline use on Lake Hickory includes 52% residential and commercial, 2% undeveloped with natural woody debris, and 46% undeveloped (Duke Power unpublished data). Lake Hickory has a drainage area of 3,390 km^2, which is comprised of 6%

allocation to urban uses, 33% allocation to agricultural purposes, and 61% remains forested (Duke Power 2000). Full pool elevation is 285 m above sea level. The reservoir has a surface area of 16.6 km^2, a total volume of 157.3 million m^3, and a mean depth of 9.5 m. Maximum depth of the reservoir exceeds 25 m, and mean retention time is 33 days (Duke Power unpublished data).

Pier Modifications

In an effort to enhance piers on Fishing Creek Reservoir and Lake Hickory, the Berkley Fish Hab, a plastic, pallet-type structure was used as a basic assembly (Figure 2a). This basic assembly alone was deployed under the stationary components of seven piers on Fishing Creek Reservoir and 14 piers on Lake Hickory. To increase structural complexity of the plastic module, small saplings were incorporated into the basic assembly that were similar in composition to natural woody debris found on other shorelines of the same reservoir (Figure 2b). This combination of plastic modules and brush was deployed under stationary pier components of eight piers on Fishing Creek Reservoir and 15 piers on Lake Hickory. Fifteen piers on Fishing Creek Reservoir and 18 piers on Lake Hickory remained unaltered and served as reference locations. The number of habs installed under study piers varied according to pier length, and in most cases, structures were modified to enhance shallow water while remaining submersed during normal water level. All piers were modified during the winter of 2000-2001, prior to the start of sampling in April 2001.

Field and Analytical Procedures

Fish communities associated with 77 piers located on 47, 100-m undeveloped transects containing natural woody debris and residentially developed transects containing either brushed hab piers, piers with habs, and reference piers on Fishing Creek Reservoir and Lake Hickory were sampled during April, July, and October 2001. Transects were stratified into three components, a stationary pier component where the treatment was applied, a floating pier component (if present), and a shoreline component between adjacent piers. Fish collected were quantified according to component to evaluate the effect of pier modifications at the stationary pier scale and transect scale.

Fish sampling was conducted using a boat-mounted, Smith-Root model 5.0 GPP electrofisher powered by pulsed DC at a frequency of 120 pulses per second and a voltage sufficient to draw 4-6 amperes. All fish collected were identified to species and enumerated. Fish collected from each isolated component were measured (± 1 mm TL) and weighed (± 1 g) individually by species. In cases where many fish of a species were collected, total numbers and biomass were recorded for that species, a random subsample of at least 30 fish was selected from the component catch, and each fish of the subsample was measured and weighed individually.

Surface area of stationary components and floating components of all piers on Fishing Creek Reservoir and Lake Hickory were measured using a distance measuring wheel, and catch rates from stationary components were calculated as number of fish collected per 100 m^2 of pier area (no./100 m^2), and biomass of fish was calculated as kilograms of fish collected per 100 m^2 of pier area (kg/100 m^2). Catch rates from transects were calculated as number of fish collected per 100 m of shoreline (no./100 m) and biomass of fish collected per 100 m of shoreline (kg/100 m).

Catch rates for stationary components of piers were calculated and compared among treatments. Catch rates for all species (total catch), largemouth bass, bluegill, and redbreast sunfish *Lepomis auritus* were calculated for each stationary pier component, and each stationary pier component of the same treatment served as a replicate for statistical analysis. Similarly, fish abundance from transects included fish collected from all components of piers and shoreline between piers and was calculated for all species (total catch), and individually for largemouth bass, bluegill, and redbreast sunfish for each transect and compiled as replicates.

Mean relative weights were calculated for largemouth bass and bluegill collected from stationary components of modified piers, reference piers, and entire modified transects, natural woody debris transects, and reference transects. All largemouth bass or bluegill were pooled separately from individual stationary pier components or entire transects depending on the scale of the analysis, and mean relative weight was calculated for largemouth bass > 150 mm TL and bluegill > 80 mm TL using equations suggested by Murphy et al. (1991) and compiled as replicates.

Mean length was also calculated for largemouth bass and bluegill collected from stationary components of modified piers, reference piers, and entire modified transects, reference transects, and natural woody debris transects. All largemouth bass and bluegill were pooled separately from individual stationary pier components or entire transects, depending on the scale of the analysis, and mean total length was calculated from all fish of each species and compiled as replicates.

Evidence of nonnormality was detected in catch, biomass, relative weight, and mean length data, which subsequent transformations did not improve. Thus, a Kruskal-Wallis one-way analysis of variance on ranks was used to detect if differences existed in those data among treatments at the pier scale and transect scale within each reservoir. A pairwise comparison of mean ranks controlling the experimentwise error rate at $\alpha = 0.05$ was used to determine differences between treatments using Statistix 7 software (Analytical Software 2000).

Catchability

To determine if fish catchability differed among pier treatments using the boat-mounted electrofisher described above, five piers of each treatment were randomly selected on Lake Hickory during summer of 2001. To estimate catchability, we employed two methods. Initially, each pier was snorkeled, and all fish observed were counted and recorded. Subsequent to snorkeling, a three-pass depletion procedure was performed to estimate fish population sizes using the same electrofisher as described above. Electrofishing passes were conducted in quick succession, and numbers of fish were recorded according to species and pass. First-pass catchability was determined using the equation,

$$\hat{\beta}_1 = C_1 / \hat{N}_d$$

where β_1 is first-pass catchability, C_1 is first-pass electrofishing catch, and N_d is the population estimate based on a maximum-likelihood estimator incorporating the three depletion passes under model M_{bh} which allows for both heterogeneity of capture probabilities among fish, and varying capture probabilities due to previous electrofishing experience (trap response) (Pollock et al. 1990). Additionally, overall catchability over the course of three removals was calculated according to Seber (1982) and Bohlin et al. (1989). First-pass electrofishing catch was expressed as a proportion of the associated snorkeling counts to determine a calibration ratio (total catch from first pass electrofishing/total count from snorkeling) that was used as a comparison of sampling methods and to make inferences concerning catchability among pier treatments.

Natural Woody Debris Survey

Criteria for selecting natural woody debris transects included that windfelled trees constituted at least 80% coverage by shoreline distance, made up of trees at least 25 cm at breast height. Diameter of natural woody debris located on 100-m transects in Lake Hickory and Fishing Creek Reservoir was measured (± 1 cm) to determine the diameter size distribution of this type of structure. Three natural woody debris transects included in the study were randomly selected from each reservoir. Selected transects were partitioned into 10 quadrats that were each 10 m in length (parallel to shoreline) and extended perpendicularly from the bank at normal water level to the 1.2 m depth contour. At each selected transect, three quadrats were randomly selected, and the diameter of all woody debris submersed during normal water level in each quadrat was measured and recorded.

Size distribution of brush incorporated into hab modules under study piers was also estimated. Brush, small saplings, and tree limbs were incorporated into one hab module to a density similar to that of brushed hab modules installed under study piers. Diameter of all incorporated brush was measured (± 1 cm) and recorded.

Pier Owner Survey

Permission to modify pier habitat was sought by project personnel and granted voluntarily by pier owners. All pier owners who agreed to participate and whose piers received either the brushed hab treatment or the hab module treatment were mailed surveys during November 2001, shortly after completion of fish sampling and approximately one year after installation of treatments. Forty-three copies of the survey (Appendix 1) were sent to pier owners and returned by mail. The survey asked pier owners questions regarding overall satisfaction with the modification structures, pier usage by owners, regularity of fishing from the pier, fishing success, observations of fish and wildlife around the pier, effect of the modification on property aesthetics, and general opinions of the modification structures. Pier owners were presented a combination of yes/no questions, categorical questions, and open-ended questions to allow pier owners to offer as much information as they would like.

Results

Fish Utilization of Piers

For comparison of fish assemblages associated with treatments at the pier scale, 30 piers on Fishing Creek Reservoir and 47 piers on Lake Hickory were sampled. Catch from piers for all seasons combined on Fishing Creek Reservoir and Lake Hickory totaled 1,430 fish representing 20 species, and 6,396 fish representing 14 species, respectively (Table 1).

Fishing Creek Reservoir -- Electrofishing catch results by number from Fishing Creek Reservoir (Figure 3) indicate that total catch rates (no./100 m^2) were higher at brushed hab piers than at piers modified with habs or reference piers during all seasons, but only significantly higher than piers with habs and reference piers during fall. Total catch at brushed hab piers was significantly higher than that at reference piers during all seasons. During spring, largemouth bass catch rates were not significantly different among pier treatments, however during summer and fall, differences were detected. During summer, largemouth bass catch rates were higher at brushed hab piers than at piers modified with hab modules alone. However during fall, catch rates of largemouth bass were higher at brushed hab piers than at reference piers. Bluegill catch rates were higher at brushed hab piers than at reference piers during spring and fall; however, no differences in bluegill catch rates were detected among pier treatments during summer. Catch rates of redbreast sunfish were not significantly different among pier treatments during spring, summer, or fall in Fishing Creek Reservoir. No species were consistently more common at reference piers than at modified piers.

Biomass (kg/100 m^2) followed similar trends as those of numerical catch rates (Figure 4). Total fish biomass was higher at brushed hab piers than at piers modified with hab modules or reference piers during all seasons, but was only significantly higher than piers with habs and reference piers during fall. During spring, total fish biomass was significantly higher at brushed hab piers than at reference pier locations, and during summer, it was significantly higher at both types of modified piers. Biomass of largemouth bass and bluegill followed similar trends as those of total fish biomass. During spring and fall, biomass of largemouth bass and bluegill was higher at brushed hab piers than at reference piers. During summer, largemouth bass biomass was highest at brushed hab piers, while no differences were detected in bluegill biomass among pier treatments during this season. No differences in redbreast sunfish biomass were detected among pier treatments during any season in Fishing Creek Reservoir.

Relative weight of largemouth bass and bluegill was not significantly different among piers modified with brushed habs, hab modules, or reference piers during any season (Figure 5). No significant trends in mean length were observed for largemouth bass or bluegill among pier treatments within any season (Figure 6).

Lake Hickory-- Catch rates by number (no./100 m^2) from stationary components of piers on Lake Hickory show trends similar to those on Fishing Creek Reservoir (Figure 7). Total numerical catch from brushed hab piers was higher than at piers modified with hab modules and reference pier locations during all seasons, but was only significantly higher than that at piers with habs and at reference piers during spring. During summer and fall, total catch of all species was significantly higher at brushed hab piers and piers modified with habs. Largemouth bass catch rates were higher at brushed hab piers than at reference piers during spring. During summer, largemouth bass catch rates were higher at piers modified with brushed habs and piers modified with hab modules than at reference pier locations. However, largemouth bass catch rates during fall were not significantly different among pier treatments. During spring and summer, bluegill catch rates were significantly higher at brushed hab piers than at piers modified with hab modules or reference piers, however during fall, catch rates were significantly higher at both types of modified piers. During spring and fall, catch rates of redbreast sunfish were not significantly different among pier treatments, but during summer, they were significantly higher at brushed hab piers and piers with habs than at reference piers.

Biomass (kg/100 m^2) of fish collected from Lake Hickory followed the same general trend as that of catch by number (Figure 8). Within each season, total fish biomass was significantly higher at brushed hab piers and piers with habs than at reference piers. Largemouth bass biomass followed this trend during all seasons as well. Biomass of bluegill during summer and fall was significantly higher at brushed hab piers and hab module piers than at reference piers, but during spring, biomass was highest at brushed hab piers. Redbreast sunfish biomass was not significantly different among pier treatments during spring and fall, but during summer, it was higher at brushed hab piers and piers with habs than at reference piers.

Relative weight of largemouth bass and bluegill on Lake Hickory was not significantly different among pier treatments, with the exception of bluegill during summer (Figure 9). Relative weight values for bluegills during summer were significantly higher at reference piers than at brushed hab piers.

Mean length of largemouth bass and bluegill was not significantly different among pier treatments with the exception of largemouth bass during fall and bluegill during summer (Figure 10). During fall, largemouth bass mean length was greater at brushed hab piers and piers with habs, while during summer, bluegill were significantly larger at piers with habs.

Catchability

Both first-pass catchability and catchability over three passes were generally similar among pier treatments (Table 1). Mean first-pass catchability ranged from 0.588 at reference piers, 0.682 at brushed hab piers, to 0.765 at piers with habs. Overall catchability estimates over the course of three removals were similar to first pass catchability estimates. Mean calibration ratios (first pass removal catch / snorkeling counts) at brushed hab piers, piers modified with hab modules and reference piers were 1.148, 2.672, and 4.500 respectively. Counts of fish while snorkeling under reference piers were low, and at three of the five selected reference piers, no fish were observed.

Fish Utilization of Transects

For comparison of fishes associated with residentially developed transects and natural woody debris at the transect scale, 20 transects on Fishing Creek Reservoir and 27 transects on Lake Hickory were sampled. Total catch of all seasons combined from transects on Fishing Creek Reservoir and Lake Hickory was 6,375 fish representing 25 species and 12,767 fish representing 22 species, respectively (Table 2).

Fishing Creek Reservoir -- Total fish catch rates (no./100 m) of all species were significantly different among transect treatments within each season on Fishing Creek Reservoir, but multiple comparison tests failed to detect where differences occurred (Figure 11). Although largemouth bass catch rates did not differ significantly among transect treatments during any season, numerical catch rates of bluegills differed among transect treatments in Fishing Creek Reservoir. During spring, catch rates for bluegill were significantly higher at natural woody debris transects than at transects with habs and reference developed transects. No significant differences in bluegill catch rates among transect treatments were detected during summer; however, during fall, differences were detected. During fall, bluegill catch rates were significantly higher at brushed hab transects than at transects with habs or reference developed transects. No significant trends were detected for redbreast sunfish catch rates during summer, but during spring and fall, significant differences among transect treatments were detected. During spring, catch rates were significantly higher at brushed hab transects and reference developed transects than at natural woody debris transects. During fall, the same general trend was observed, however the only significant difference in redbreast sunfish catch rate was between brushed hab transects and natural woody debris transects. In this case, redbreast sunfish catch rates were higher at brushed hab transects.

Biomass (kg/100 m) of fish collected from transects on Fishing Creek Reservoir followed similar trends (Figure 12) as those for catch rate by number. Total fish biomass was significantly different among transect treatments during summer and fall; however, during summer, multiple comparison tests failed to detect where differences occurred. During fall, total biomass was higher at brushed hab transects than at reference developed transects. As with numerical catch rates, biomass of largemouth bass did not differ significantly among transect treatments within any season, but differences in bluegill biomass and redbreast sunfish biomass were apparent. During spring, bluegill biomass was significantly higher at natural woody debris transects than at reference developed transects. During summer, bluegill biomass was higher at transects with habs than at reference developed transects. During fall, bluegill biomass was significantly higher at brushed hab transects than at reference developed transects. Significant differences in redbreast sunfish biomass were detected during spring, but multiple comparison tests failed to detect a significant trend among treatments. Differences in redbreast sunfish abundance were also detected during fall. During fall, redbreast sunfish biomass was significantly higher at brushed hab transects than at woody debris transects.

During spring, largemouth bass relative weight was not significantly different among transect treatments, but differences in bluegill relative weight were detected during this season (Figure 13). During spring, bluegill relative weight values were significantly higher at brushed hab transects than those of bluegill collected from natural woody debris transects. During summer, differences in largemouth bass relative weights were detected among transect treatments. Values for this species were significantly higher at natural woody debris transects than at reference developed transects. During summer, no differences in bluegill relative weights were detected among transect treatments. During fall, no differences in largemouth bass or bluegill relative weight were detected among transect treatments.

Similarly, few differences in largemouth bass and bluegill mean length were detected among transect treatments during each season (Figure 14). During spring, no differences were detected in mean length of largemouth bass among transects, but trends in bluegill mean length were apparent. During spring in Fishing Creek Reservoir, bluegill mean length was significantly larger at developed transects with habs, than at reference developed transects. During summer and fall, no significant differences in mean length for either species were detected among transect treatments.

Lake Hickory -- Transect catch rates by number (no./100 m) for all species combined were not significantly different among transect treatments during spring and fall on Lake Hickory as determined using multiple comparison tests, although differences were suggested by Kruskal-Wallis *p*-values during spring (Figure 15). However, clear differences during summer existed. During summer, total species catch rates were higher at brushed hab transects than those at reference developed transects. Largemouth bass catch rates followed trends similar to those observed for total combined species, as no significant differences in largemouth bass catch rates were detected during spring or fall using multiple comparison tests. During summer, largemouth bass catch rates were higher at natural woody debris transects than at reference developed transects. Significant trends in bluegill catch rates were detected during spring and fall, but not during summer. During spring, bluegill catch rates were significantly higher at brushed hab transects than at transects with habs. During fall, brushed hab transects exhibited significantly higher bluegill catch rates than reference developed transects. No significant trends were observed for transect catch rates of redbreast sunfish during any season.

Trends in catch biomass (kg/100 m) among transect treatments generally resembled those observed for catch rate by number (Figure 16). Total fish biomass was not significantly different among transect treatments during spring and fall, but significant trends were detected during summer. During summer, total fish biomass was significantly higher at transects with habs than that at reference developed transects. Largemouth bass biomass was not significantly different among transect treatments within any season; however, differences in bluegill biomass were detected. During spring, bluegill biomass was significantly higher at brushed hab transects than at transects with habs or reference developed transects. During summer and fall, bluegill biomass remained significantly higher at brushed hab transects than that collected from reference developed transects. No significant trends were detected for redbreast sunfish biomass among transect treatments during any season.

No apparent trends were observed for relative weight values calculated for largemouth bass or bluegill collected from transects (Figure 17) and few significant trends in mean length of largemouth bass and bluegill were observed from transects in Lake Hickory (Figure 18). Within each season, mean length of largemouth bass was not significantly different among transect treatments. Bluegill mean length was not significantly different among transect treatments during spring and fall, but during summer, was significantly higher at transects with habs than at either transects with brushed habs or reference developed transects.

Natural Woody Debris Survey

Mean diameter of natural woody debris found on study transects of Fishing Creek Reservoir and Lake Hickory differed from that incorporated into hab modules used to modify piers with the brushed hab treatment (Figure 19). In Fishing Creek Reservoir, diameter of natural woody debris ranged from 1 cm to 52 cm with an average diameter of 4.3 cm. In this reservoir, approximately 82% of natural woody debris located on study transects was less than 5 cm in diameter.

On Lake Hickory, diameter of natural woody debris on study transects was slightly different from that on Fishing Creek Reservoir. On Lake Hickory, natural woody debris diameter ranged from 1 cm to 26 cm with an average diameter of 3.2 cm. More than 88% of natural woody debris sampled from transects in Lake Hickory was less than 5 cm in diameter.

Diameter of brush incorporated into hab modules was considerably smaller than that of natural woody debris found on transects of Lake Hickory and Fishing Creek Reservoir (Figure 19). Diameter of brush in hab modules ranged from 1 cm to 3 cm with an average of 1.3 cm.

Pier Owner Survey

Of 43 surveys mailed to pier owners receiving brushed habs or hab modules, 31 completed surveys were received for a response rate of 72%. Generally, pier owners whose piers received either the brushed hab treatment (Table 4) or hab module treatment (Table 5) were satisfied with the modifications. However, pier owners receiving the brushed hab treatment had concerns with brush extending beyond the borders of the pier and noted the potential for injury to children jumping off of the pier and interference with swimming in the vicinity of the modified pier. Concerns about brushed habs moving from under the piers during storms were also noted. Pier owners receiving the hab module treatment had concerns with fishing from the pier. They noted that lure snags were more common because the hab modules were installed and that hab modules had also been blown from under the pier during storm events (a problem that was addressed during the middle of the study by securing structures to pier pilings). None of the respondents indicated that either type of structure caused damage to their pier, and most perceived fishing success to be better after modification with either type of structure.

Although pier owners perceived increased fishing success, the majority of respondents did not notice increased fishing pressure by other anglers. Pier owners receiving either modification not only perceived more fish around their pier but also additional wildlife, such as ducks, geese, turtles, and snakes. Neither pier owners receiving brushed habs nor those receiving hab modules felt that the structures diminished aesthetics of their properties, and some felt that by modifying their pier, they increased the aesthetic value of their property. All pier owners receiving the brushed habs and 93% of pier owners receiving hab modules indicated that they would suggest this type of modification to friends or neighbors. The majority of pier owners agreed to keep the structures under their piers.

Discussion

Fish Utilization of Piers

In most cases, total catch rates by number and biomass were three to four times higher at brushed hab piers or piers with habs than catch rates from reference piers during spring, summer, and fall. Apparently, fish receive some type of ecological or energetic benefit by occupying these areas; however, these benefits may be species specific.

It has been suggested that increased structural complexity allows coexistence of predators and prey by creating more microhabitat types (Crowder and Cooper 1982). Inherently, increasing habitat complexity may influence predator efficiency by providing partial or complete refuges from predation for small fishes at high structure densities (Hall and Werner 1977, Werner et al. 1983, Orth et al. 1984, Lowe-McConnell 1987). Piers enhanced with brushed habs may provide this type of refuge, thus attracting prey fish species, resulting in high electrofishing catch rates of bluegills that are utilizing this type of structure in an attempt to avoid predation. While small bluegills (<100 mm) may utilize these complex habitats in an attempt to avoid predation, larger bluegills that are less vulnerable to predation may use these habitats to a greater extent for foraging for invertebrates.

Artificial pier modifications may provide other benefits to fishes that are similar to benefits provided by vegetation and woody debris. Artificial structures not only provide refugia for fish, but may also provide important habitat for invertebrates (Nilsen and Larimore 1973, Benke et al. 1984), thus further increasing the suitability of complex pier habitats to bluegills relying on invertebrates as a food resource during a portion of their life history (Schneider 1999). Because bluegills rely on invertebrates as a portion of their diet, they would conceivably be attracted to structured locations, such as modified piers that simulate woody structure and possibly support higher densities of this resource (Anderson et al. 1978, Benke et al. 1984). Thus, complex pier habitats may provide locations that benefit bluegills in this fashion; however, it has been suggested that complex habitat utilization may be more closely related to the advantages of camouflage than to increased invertebrate resources (Angermeier and Karr 1984).

Largemouth bass may be more abundant at modified piers due to several of the same factors affecting bluegill abundance. Juvenile largemouth bass (< 150 mm) have been observed near complex structure and possibly use this structure to escape predation from predators (Annett et al. 1996). As with bluegill, structure may act as substrate for invertebrate food resources for juvenile largemouth bass, thus increasing foraging efficiency up to some threshold of structure density. Nonnesting largemouth bass (>150 mm) have been observed in habitats with and without structure (Annett et al. 1996). This may be related to high densities of sunfish in habitats with structure, indicating that this type of habitat may be used by nonnesting largemouth bass while searching for prey, and unstructured habitats may simply be corridors through which largemouth bass move between food patches (Killgore et al. 1989). Nesting largemouth bass have been reported in high abundance near simple woody structure, as opposed to complex structure (Annett et al. 1996). These factors may influence largemouth bass abundance to some extent in my study reservoirs. However, pooled catch rates of all size groups of this species were higher at modified piers in only 50% of the cases, which is not consistent with observations that largemouth bass catch rates by electrofishing are higher in small ponds with complex structure (Wege and Anderson 1979) and that largemouth bass are more selective for brushed shelters during spawning (Vogele and Rainwater 1975). This contradiction may be due to influences by structures adjacent to piers that affect fish abundance at piers on my study reservoirs. Qualitative field observations during this study suggest that individual piers, whether modified or not, appeared to hold fewer fish when littoral habitat adjacent to the pier was complex.

Redbreast sunfish abundance was lower than that observed for largemouth bass and bluegill and was generally not different among pier treatments. It appears that redbreast sunfish are attracted to modified piers to a lesser extent than bluegill and largemouth bass. My field observations suggest that redbreast sunfish may be attracted to a greater extent by riprapped shorelines adjacent to piers and may be responding to a habitat that has been observed by others to harbor high species richness relative to other lake habitats (Jennings et al. 1999).

Calibration ratios were used to examine differences in sampling efficiencies for piers based on fish observed by snorkeling. Large ratios (>1.0) indicate that more fish were collected during the first-pass of electrofishing than observed while snorkeling, and small ratios (<1.0) indicate the opposite relation. A trend exists between pier structural complexity and the mean calibration ratio calculated for each pier treatment. As pier habitat complexity decreases, the mean calibration ratio tends to increase. This suggests that as pier habitat complexity increases, fish are more easily observed and snorkeling counts approach the number of fish collected while electrofishing. At reference piers containing little structure, proportionally fewer fish were counted by snorkeling, which was likely related to a fright response that would cause fish to leave the area if sufficient cover was not available for refuge. This phenomenon would explain the resulting large ratios for this treatment group.

Although a trend in calibration ratios with pier habitat complexity exists, in instances where many fish were observed by snorkeling, electrofishing catch rates were higher indicating that relative abundance determined by electrofishing among pier treatments is valid. This result parallels observations by Thurow and Schill (1996) who reported correlations between snorkeling observations and electrofishing catch rates of bull trout *Salvelinus confluentus* in Idaho streams. Nevertheless, electrofishing catchability estimated from depletion sampling was similar among pier treatments, and no trends were evident among pier treatments. This suggests that a constant proportion of fish were collected among pier treatments during normal sampling periods.

Relative weight values calculated for largemouth bass and bluegill rarely differed significantly among pier treatments. One factor that may influence relative weight results is fish movement and home range. Largemouth bass relative weight was never observed to differ among pier treatments. This may be related to the finding that largemouth bass is a mobile species that moves long distances even in a lake with standing timber and artificial reefs (Prince and Maughan 1979), spanning home ranges that would encompass several piers in my study (Colle et al. 1989). Thus, observed condition may be influenced by other factors inherent in the larger home range and not directly attributed to the local effect of modified piers.

Significant differences in mean length for bluegill or largemouth bass were not detected among pier treatments in Fishing Creek Reservoir and detected during summer for bluegill and fall for largemouth bass in Lake Hickory. Where differences existed, bluegill mean length was smaller at piers modified with brushed habs (small interstice) than at piers modified with habs (larger interstice) or reference piers. In the presence of predators such as largemouth bass, juvenile bluegills have been reported to utilize complex habitat with small interstitial spaces (Johnson et al. 1988, Lynch and Johnson

1989). In my study lakes, largemouth bass and bluegill coexist, and small bluegills appear to occupy habitats with small interstitial spaces such as brushed hab piers, while larger bluegills that are not as susceptible to predation by largemouth bass inhabit larger interstitial spaces such as piers modified with habs. The lack of significant differences in mean length among pier treatments in Fishing Creek Reservoir may be related to water clarity. Predation by visual methods has been implied by Helfman (1981) and may partially explain this lack of observed differences. Although water clarity was not measured, Fishing Creek Reservoir is more eutrophic than Lake Hickory, and lower water clarity in Fishing Creek Reservoir may provide small bluegill with reduced predation risk by visual predators (Lynch and Johnson 1989), thus contributing to the lack of significant differences in bluegill mean length among pier treatments in this reservoir.

During fall on Lake Hickory, largemouth bass mean length was significantly higher at both types of modified piers than at reference piers. This result supports observations from telemetry studies performed by Wanjala et al. (1986) in that large bass inhabit complex habitats due to reduced swimming efficiency in open waters relative to smaller bass. Occupying complex littoral habitats may largely be a response to decreased limnetic foraging efficiency and a lesser extent to food availability since pelagic species remained the primary source of prey even while foraging in littoral habitats (Wanjala et al. 1986). Thus, largemouth bass in the reservoirs that I studied may be affected in the same fashion, resulting in greater fish mean length in complex littoral habitats.

Largemouth bass mean length was not significantly different among pier treatments during spring, summer, and fall on Fishing Creek Reservoir. Lack of differences in largemouth bass mean length may be due to low statistical power since residential development is relatively rare on Fishing Creek Reservoir, and fewer pier replicates were obtained. On both study reservoirs, larger largemouth bass were sampled during the spring, compared to those sampled during summer, at all types of pier and transect treatments, indicating that adult largemouth bass migrate to shallow-water habitat during the spawning season.

Overall, it appears that fish respond to complexities created by artificial structures to a greater extent than to the type of structure. There are in many cases observable trends, where catch by number and biomass generally decrease as pier complexity decreases. Although this appears to hold for numerical catch rates and biomass, relative weight and mean length do not seem to be affected to the same extent.

Fish Utilization of Transects

At the transect scale, the effect of shoreline habitat adjacent to and between piers may contribute to catch rates, biomass, relative weight, and mean length, in addition to pier treatment effects. This adjacent shoreline habitat component is usually riprap that provides additional structural complexity or to a lesser extent, bulkheads and sometimes unstructured clay banks. Nevertheless, there appears to be an effect of the adjacent shoreline habitat, which may influence fish abundance, relative weight, and mean length. The effect that this complex shoreline component has on fish abundance may be considerable, and could contribute to fish abundance at reference developed transects that is not significantly different from fish abundance at natural woody debris shorelines.

On Lake Hickory, significant differences in fish abundance were only apparent during summer. During summer, numbers of total catch were higher at transects enhanced with brushed habs than at reference transects, but no type of developed habitat held significantly fewer fish than natural woody debris habitat. As with numerical catch rates, residentially developed habitats, whether modified or not, exhibited total biomass catch that was not significantly different than that of natural woody debris habitats during all seasons. Complex habitat created by riprap on residentially developed transects may provide suitable habitat and support fish abundances on residentially developed transects that is similar to that on natural woody debris transects.

Numbers of largemouth bass rarely differed among transect treatments during any season in Fishing Creek Reservoir and Lake Hickory. However, when differences were detected, all transects held fewer fish than natural woody debris but the difference was only significant for reference developed transects. Apparently, the effect of modifying piers with either brushed habs or habs alone may have increased largemouth bass numbers to values more similar to those observed in natural woody debris habitats.

Numbers of bluegill were not significantly different among transect treatments in both reservoirs during summer, but differed among treatments during spring and fall in Fishing Creek Reservoir and Lake Hickory. Where differences were detected, bluegills were generally more abundant in habitats with woody structure. Bluegill catch from brushed hab transects was not significantly different than that from natural woody debris transects. This observed trend might be explained by the presence of woody structure. Habitat of this type in aquatic systems provides structure for production of invertebrates (Angermeier and Karr 1984), which in turn provides a food resource for bluegill (Schneider1999). Bluegill may be more abundant at these woody areas owing to increased invertebrate production.

In most cases, bluegill biomass at residentially developed shorelines, regardless whether piers were modified or not, was generally comparable to biomass of this species at natural woody debris shorelines in both reservoirs. During spring on both reservoirs, bluegill biomass was significantly higher at natural woody debris or brushed hab transects, suggesting that woody structure is important to bluegill during the spawning season. This lack of significant difference among woody debris transects and brushed hab transects may also be related to the presence of riprap on residentially developed shorelines. However, during spring on Fishing Creek Reservoir, shorelines with an abundance of natural woody debris supported significantly more fish than residentially developed shorelines that received no pier modification.

In most cases, mean length of largemouth bass and bluegill were not significantly different among transect treatments. This could be due to variable interstitial spaces on all transects. Interstitial spaces vary in woody debris habitat due to limb characteristics of trees that create woody debris. Interstitial spaces also vary in residentially developed habitat. Brushed habs or hab modules under piers create small and large interstices, respectively, but riprap interstice varies depending on configuration and grain size. Variability of transect interstitial spaces may be make it difficult to determine trends in interstice selection by juvenile and adult fish as Lynch and Johnson (1989) illustrated.

Conclusions and Management Implications

By modifying pier habitat in this fashion, it is apparent that habitat is enhanced to the benefit to fishes in these reservoirs. This benefit is manifested in attraction to these areas, as reflected in increased electrofishing catch rates and biomass of total catch, largemouth bass, and bluegill abundance at both the scales of the pier and transect.

Habitat enhancement techniques have several management possibilities. They can be implemented to increase angler catch rates in locations that ordinarily would provide little success. However, by implementing these techniques at a localized region, fish abundance for certain species may be increased at a larger scale. Although total fish, largemouth bass, and bluegill abundance was significantly higher at modified piers and consistently higher at modified and natural woody debris transects, fewer significant differences were observed at the scale of the transect, compared the pier scale.

During each season in both reservoirs, total catch rates and total biomass did not differ significantly between natural woody debris shorelines and residentially developed shorelines that did not receive modification; however, natural woody debris transects consistently yielded greater catch by number and biomass compared to unmodified developed transects. Although the difference was not significant, this consistent trend highlights the importance of natural woody debris habitat to fish in these reservoirs.

It appears that in reservoirs that differ in location and trophic status, fish may respond to the complexity of the habitat rather than to the type of structure creating those complexities (Jennings et al. 1999). Thus, complex structures such as riprap found on residentially developed shorelines may provide useable habitat for fishes, thus resulting in fewer differences than expected between reference developed transects and natural woody debris transects. Artificial habitat enhancement, however, provides additional structure that is suitable for fish and appears to be a feasible habitat management response to the lack of structure in reservoirs and is likely to provide overall benefits for fish. It was apparent that modifying piers by these techniques was well received by lakeshore homeowners; furthermore, if a habitat management plan is implemented using this method of modifying littoral habitat in residentially developed reservoirs, cooperative pier owners will not be difficult to locate.

Limitations exist in this management approach. Maintenance of modification structures under piers may be necessary. Although plastic hab modules are non-biodegradable, brush incorporated into these structures may need to be replaced periodically due to the decomposition of wood, especially if water levels fluctuate. Other maintenance may include resetting of modification structures blown from under piers by wave and wind action during storms, if not anchored securely.

It remains unknown if the concentrations of fish resulting from pier modifications increase angler harvest, thus significantly reducing gamefish populations. Currently, this possibility is unlikely for largemouth bass due to the increased popularity of catch-and-release fishing practices, but the result is less clear for other species of sunfish, such as black crappie, which also provide a popular recreational fishery in these reservoirs.

It is also unclear whether modified piers simply attract fish or actually increase local fish production. It is likely that introducing complex surface areas into systems that are structure poor will facilitate establishment of a periphytic community (Prince at al. 1979) that contributes to increased fish production in the vicinity of the structures (Pardue 1973).

Fishing Creek Reservoir and Lake Hickory are managed primarily for hydroelectric generation and water supply, and much of the structure has been removed or decayed in these reservoirs, and it is probable that habitat for structure-oriented fish may be limiting. If habitat is limiting, pier habitat modifications can potentially increase fish production by increasing the foraging habitat of fish, increasing nesting habitat of adult fishes, and providing refuges from predation. As a result of these three mechanisms, fish production may increase.

Fish abundance in Fishing Creek Reservoir and Lake Hickory was observed to be consistently higher at modified piers, thus if modified piers create habitat that is conducive to foraging, spawning, and as refugia, a production response may be observed. However, few studies have been conducted that unambiguously demonstrate increased structure results in increased production rather than simply attracting fishes (Grossman et al. 1997). Likewise, few studies have examined the ecological functions of physical structure, in addition to support of fishes. More detailed investigations with an emphasis on processes and mechanisms may yield important results that are useful in fully understanding the effect of modifying pier habitat in this fashion.

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Table 1: Total numbers of fish collected by electrofishing eight brushed hab piers (BHP), seven piers with habs (HP), and 15 reference piers (RP) on Fishing Creek Reservoir and 15 brushed hab piers, 14 piers with habs, and 18 reference piers on Lake Hickory during spring, summer, and fall 2001.

	Fishing Creek Reservoir			Lake Hickory		
Species	BHP	HP	RP	BHP	HP	RP
Gizzard shad	76	47	223	20	47	10
Threadfin shad	20	0	18	0	0	0
Greenfin shiner	0	0	0	7	20	3
Whitefin shiner	1	1	0	0	0	0
Common carp	9	10	3	0	1	0
Golden shiner	25	0	11	0	0	0
Spottail shiner	1	0	3	0	0	0
Quillback	2	0	0	0	0	0
Snail bullhead	0	0	0	4	5	0
White catfish	18	12	11	10	34	0
Flat bullhead	0	0	0	2	0	0
Channel catfish	4	0	2	0	0	0
White bass	0	4	0	0	0	0
Redbreast sunfish	25	17	11	142	135	67
Green sunfish	11	2	6	0	0	0
Pumpkinseed	25	5	10	7	0	0
Warmouth	19	1	7	22	5	0
Bluegill	371	124	70	2,777	1,041	231
Redear sunfish	20	1	0	41	37	9
Hybrid sunfish	1	0	0	2	0	1
Largemouth bass	72	31	40	736	636	152
White crappie	0	0	0	0	0	0
Black crappie	42	8	6	80	26	1
Tessellated darter	0	1	0	0	0	0
Yellow perch	0	2	1	34	15	36
Total	742	266	422	3,884	2,002	510
Total number of species	17	15	15	13	12	8

Table 2: Total numbers of fish collected by electrofishing four brushed hab transects (BHT), three transects with habs (HT), five reference transects (RT), and eight natural woody debris transects (WDT) on Fishing Creek Reservoir and five brushed hab piers, seven piers with habs, seven reference piers, and eight natural woody debris transects on Lake Hickory during spring, summer, and fall 2001.

	Fishing Creek Reservoir				Lake Hickory			
Species	BHT	HT	RT	WDT	BHT	HT	RT	WDT
Gizzard shad	203	205	320	363	217	411	57	96
Threadfin shad	46	34	14	577	0	0	1	0
Goldfish	0	0	0	0	0	12	0	0
Greenfin shiner	0	0	2	0	9	21	0	4
Whitefin shiner	3	4	2	8	0	0	0	0
Common carp	11	21	7	27	0	1	0	8
Eastern silvery minnow	1	0	0	0	0	0	0	0
Golden shiner	38	13	22	43	0	0	0	3
Spottail shiner	3	10	4	0	0	0	5	1
Quillback	2	1	2	3	0	0	0	0
Smallmouth buffalo	0	0	0	4	0	0	0	0
Shorthead redhorse	3	0	3	0	0	0	0	0
Snail bullhead	0	0	0	0	20	11	8	12
White catfish	25	10	30	81	17	63	40	195
Brown bullhead	0	0	0	1	0	0	0	0
Flat bullhead	0	0	0	0	3	1	3	10
Channel catfish	5	1	9	14	0	1	0	0
White bass	0	4	0	0	0	1	0	1
Redbreast sunfish	147	35	109	38	337	342	386	170
Green sunfish	91	13	24	84	0	0	0	0
Pumpkinseed	77	23	42	107	7	4	0	18
Warmouth	45	1	31	2	25	7	10	25
Bluegill	759	210	331	1,320	2,149	1,259	894	1,193
Redear sunfish	28	6	7	23	53	52	37	65
Hybrid sunfish	4	3	3	0	4	4	2	1
Largemouth bass	141	63	77	234	651	815	616	1,602
White crappie	0	0	0	0	0	0	0	1
Black crappie	40	8	10	49	30	26	12	43
Tessellated darter	0	0	1	4	0	0	1	2
Yellow perch	2	2	2	0	20	56	146	470
Total	1,674	667	1,052	2,982	3,542	3,087	2,218	3,920
Total number of species	20	19	21	18	13	17	14	19

Table 3: Electrofishing removal catch, population estimates based on removals, first-pass catchability, overall catchability over the duration of three removals, snorkeling counts and calibration ratios from five brushed hab piers (BHP), five piers with habs (HP), and five reference piers (RP) on Lake Hickory during summer, 2001. Population estimates are based on maximum-likelihood approximation. Calibration ratios calculated as catch

complete census.

	Electrofishing Depletion				Depletion Estimates				
Location	Pass 1	Pass 2	Pass 3	Total Catch	Pop. Estimate	1st Pass Catchability	Overall Catchability	Snorkeling Count	Calibration Ratio
BHP1	110	33	20	163	172	0.640	0.612	127	0.866
BHP2	131	23	12	166	168	0.780	0.752	66	1.985
BHP3	53	3	3	59	59	0.898	0.862	48	1.104
BHP4	81	33	21	135	151	0.536	0.515	76	1.066
BHP5	81	34	18	133	146	0.555	0.542	113	0.717
Mean	91	25	15	131	139	0.682	0.657	86	1.148
HP1	60	13	7	80	81	0.741	0.707	21	2.857
HP2	49	8	1	58	58	0.845	0.845	39	1.256
HP3	31	6	3	40	40	0.775	0.738	43	0.721
HP4	21	7	0	28	28	0.750	0.780	109	0.193
HP5	25	2	7	34	35	0.714	0.592	3	8.333
Mean	37	7	4	48	48	0.765	0.732	43	2.672
RP1	6	1	2	9	9	0.667	0.515	2	3.000
RP2	6	4	4	14	20	0.300	0.194	1	6.000
RP3	3	1	0	4	4	0.750	0.780	0	
RP4	4	3	1	8	8	0.500	0.449	0	
RP5	13	2	3	18	18	0.722	0.615	0	
Mean	6	2	2	11	12	0.588	0.510	1	4.500

Table 4: Survey results from pier owners on Fishing Creek Reservoir and Lake Hickory whose pier(s) received the brushed hab treatment.

Survey Question	Yes	No	Don't Know	Comments
Are you satisfied with the enhancement structures?	94%	6%		Problems with brush extending beyond pier
Have you experienced problems with the structures?	18%	82%		Structures blown from under pier during storms
Have the structures caused damage to your pier?	0%	100%		
Does your household fish from the pier?	100%	0%		
Have you noticed better fishing success since enhancement?	76%	24%		
Have you noticed an increase in other anglers fishing your pier?	41%	59%		
Have you observed more fish around your pier since enhancement?	59%	6%	35%	
Have you observed more or different types of wildlife since enhancement?	59%	41%		Respondents answering "yes" noted ducks, geese, herons, snakes, and turtles
Have the pier enhancements altered the aesthetics of your property?	18%	82%		
Would you suggest this type of enhancement to friends?	100%	0%		
Would you like the structures removed?	6%	94%		
What uses does your pier serve?				
Boat Access	100%	0%		
Swimming	59%	41%		
Fishing	100%	0%		
Other	6%	94%		Sunbathing
How often did your household fish from your pier last year?				
Less than 5 times	46%	54%		
5-10 times	24%	76%		
10-20 times	18%	82%		
More than 20 times	12%	88%		
What can be done to improve the design to meet needs of pier owners?				Trim limbs so that they do not extend beyond the pier
Other opinions				

Table 5: Survey results from pier owners on Fishing Creek Reservoir and Lake Hickory whose pier(s) received the hab module treatment.

Survey Question	Yes	No	Don't Know	Comments
Are you satisfied with the enhancement structures?	93%	7%		Difficult to fish pier, lure hangs on structures
Have you experienced problems with the structures?	14%	86%		
Have the structures caused damage to your pier?	100%	0%		
Does your household fish from the pier?	100%	0%		
Have you noticed better fishing success since enhancement?	57%	43%		
Have you noticed an increase in other anglers fishing your pier?	21%	79%		
Have you observed more fish around your pier since enhancement?	57%	14%	29%	
Have you observed more or different types of wildlife since enhancement?	21%	79%		Respondents answering "yes" noted ducks, geese, turtles, and snakes
Have the pier enhancements altered the aesthetics of your property?	36%	64%		Respondents answering "yes" indicated an improvement in aesthetics
Would you suggest this type of enhancement to friends?	93%	7%		
Would you like the structures removed?	21%	79%		Respondents answering "yes" noted that sharp edges may cut swimmers
What uses does your pier serve?				
Boat Access	93%	7%		
Swimming	71%	29%		
Fishing	100%	0%		
Other	14%	86%		Sunbathing, sitting, nature watching
How often did your household fish from your pier last year?				
Less than 5 times	14%	86%		
5-10 times	21%	79%		
10-20 times	36%	64%		
More than 20 times	29%	71%		
What can be done to improve the design to meet needs of pier owners?				Darker color habs that blend in more with the water and bottom
Other opinions				None given

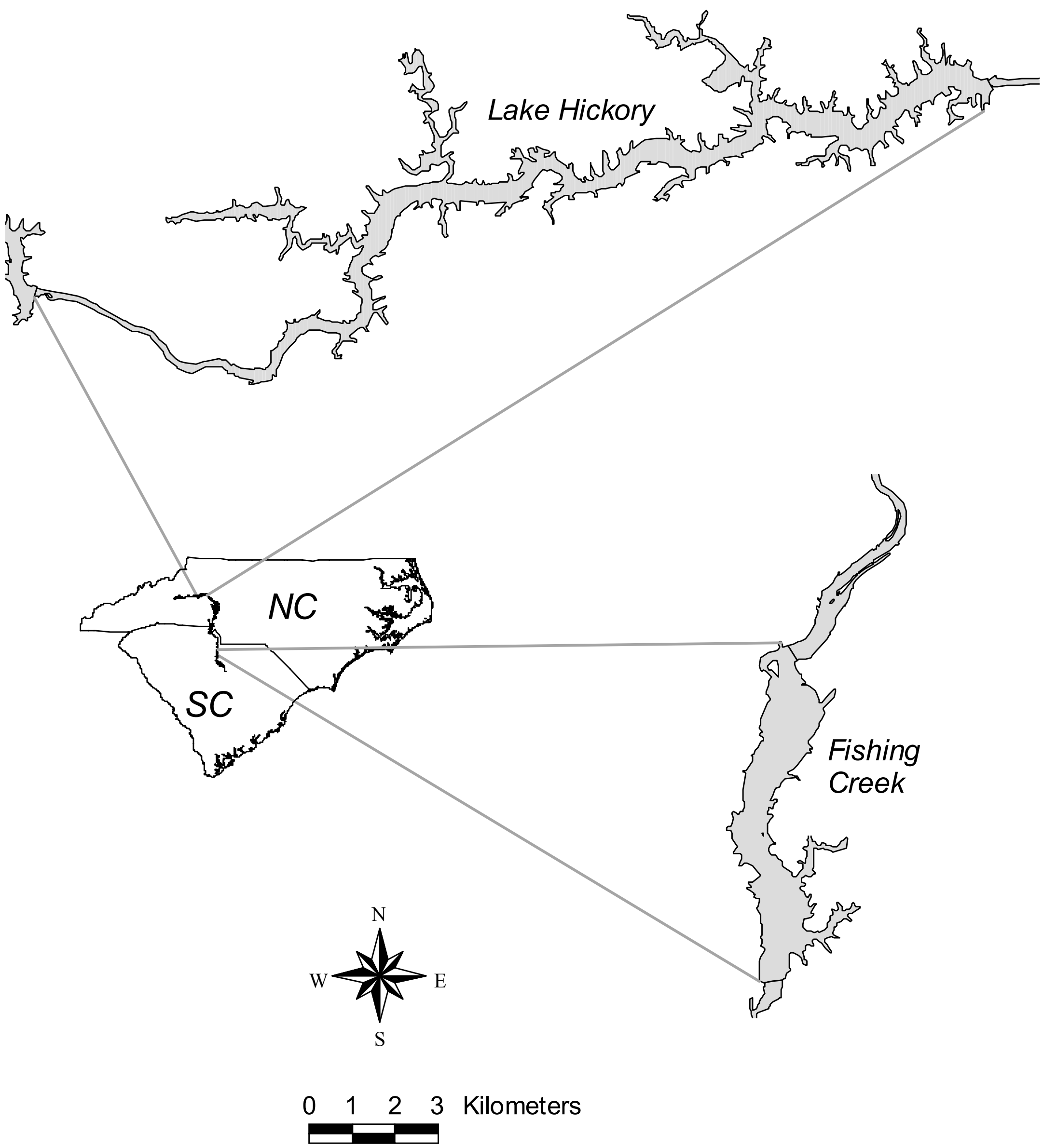

Figure 1: Locations of study reservoirs, Fishing Creek Reservoir, South Carolina and Lake Hickory, North Carolina, two of 11 reservoirs on the Catawba River.

Figure 2a: Hab module used as a pier modification structure in an effort to enhance a subset of piers on Fishing Creek Reservoir and Lake Hickory.

Figure 2b: Brushed hab module used as a pier modification structure in an effort to enhance a subset of piers on Fishing Creek Reservoir and Lake Hickory.

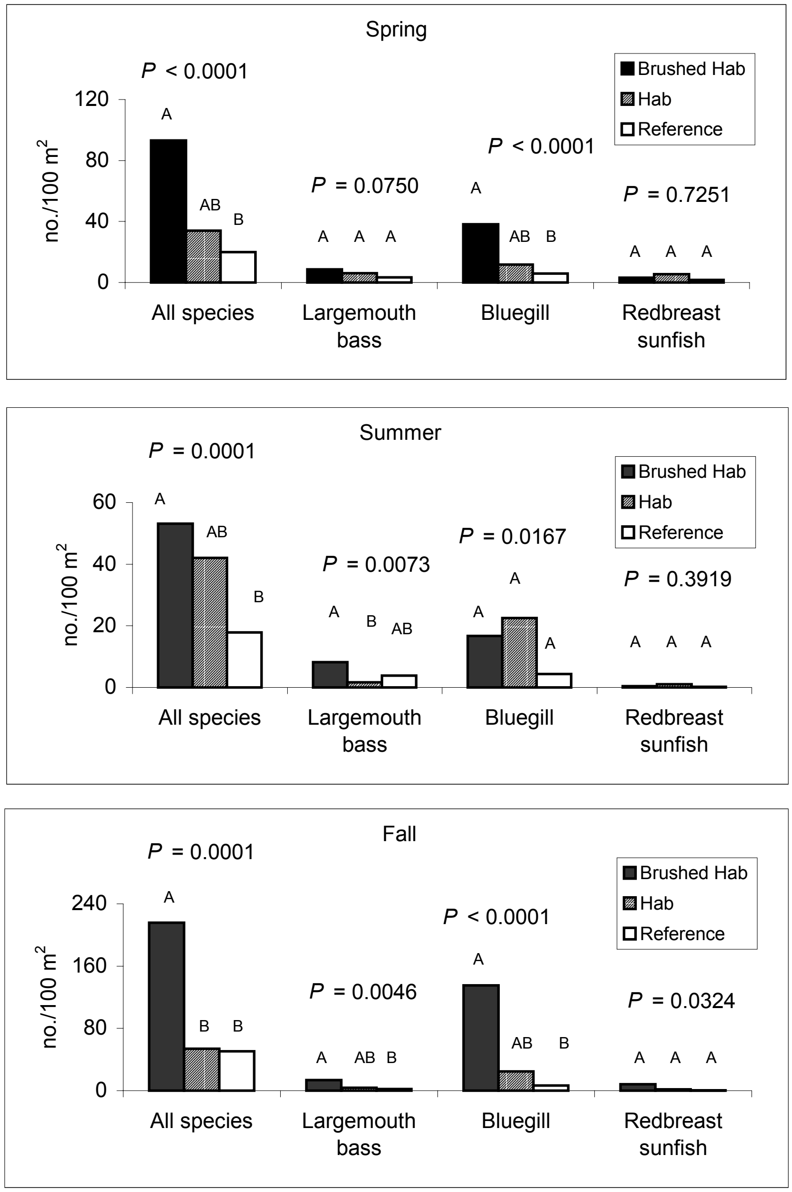

Figure 3: Catch rate by number (no./100 m^2) of all species, largemouth bass, bluegill, and redbreast sunfish collected from brushed hab piers, piers with habs, and reference piers during spring, summer and fall, on Fishing Creek Reservoir, 2001. Common letters within the chart indicate treatments that are not significantly different within each season and species (or total).

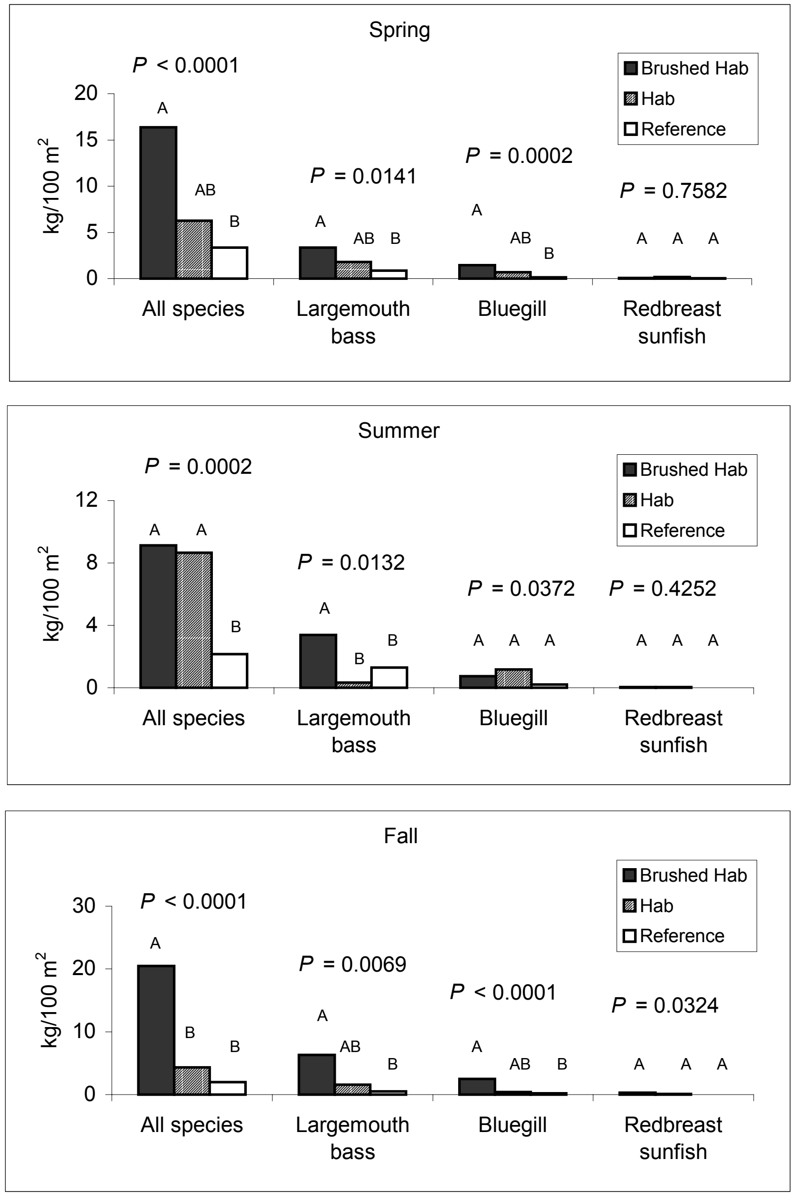

Figure 4: Biomass (kg/100 m^2) of all species, largemouth bass, bluegill, and redbreast sunfish collected from brushed hab piers, piers with habs, and reference piers during spring, summer, and fall on Fishing Creek Reservoir, 2001. Common letters within the chart indicate treatments that are not significantly different within each season and species (or total).

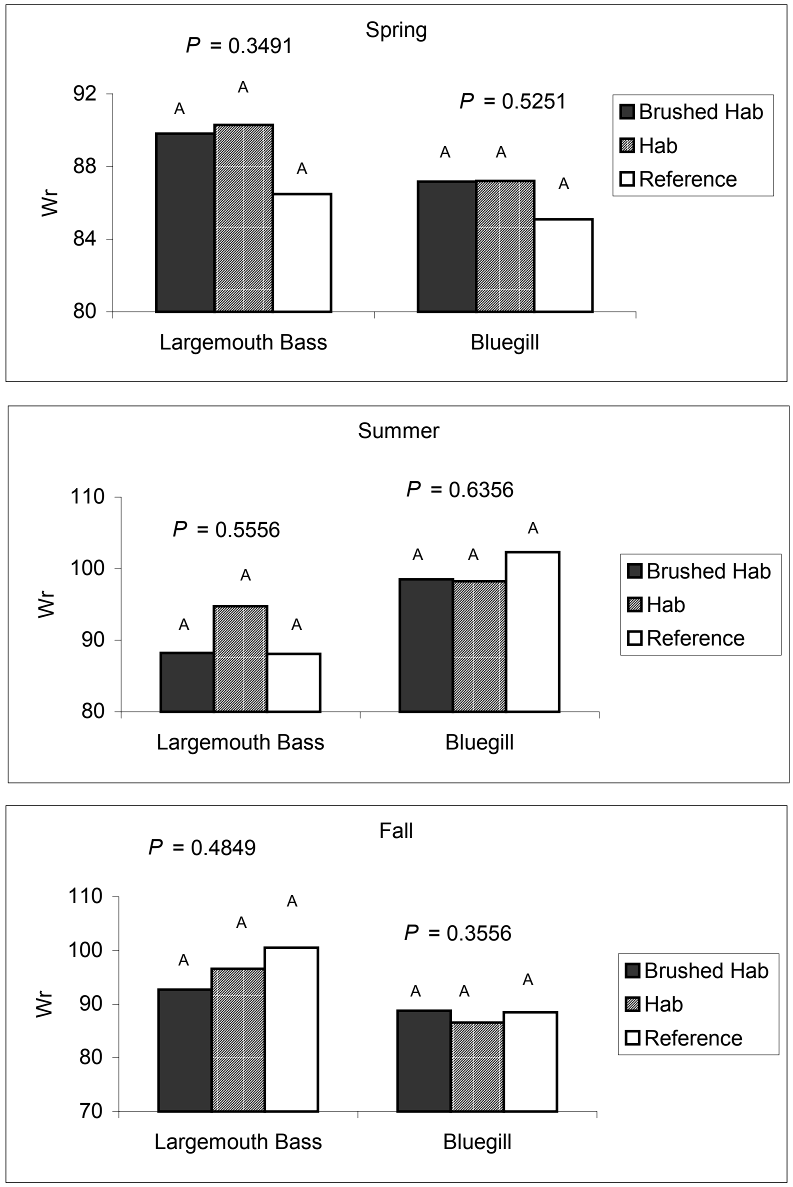

Figure 5: Relative weight of largemouth bass and bluegill collected from brushed hab piers, piers with habs, and reference piers during spring, summer, and fall on Fishing Creek Reservoir, 2001. Common letters within the chart indicate treatments that are not significantly different within each season and species.

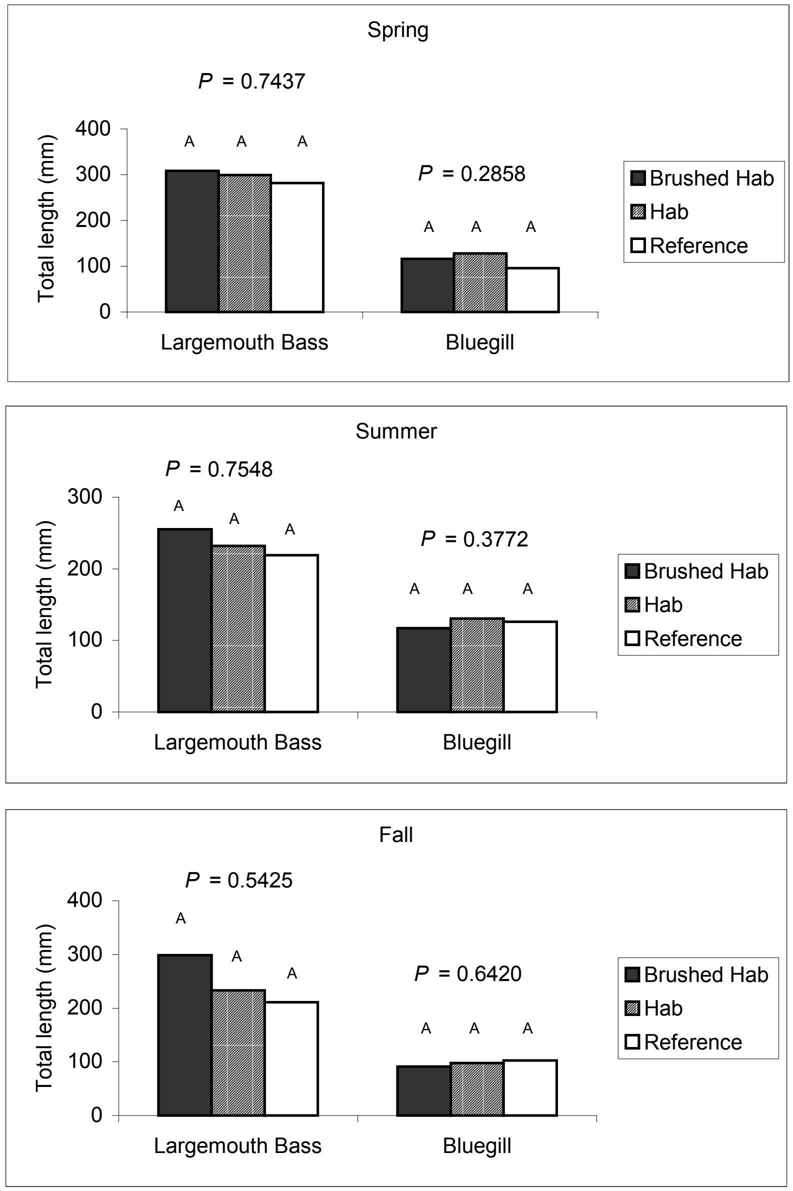

Figure 6: Mean length of largemouth bass and bluegill collected from brushed hab piers, piers with habs, and reference piers during spring, summer, and fall on Fishing Creek Reservoir, 2001. Common letters within the chart indicate treatments that are not significantly different within each season and species.

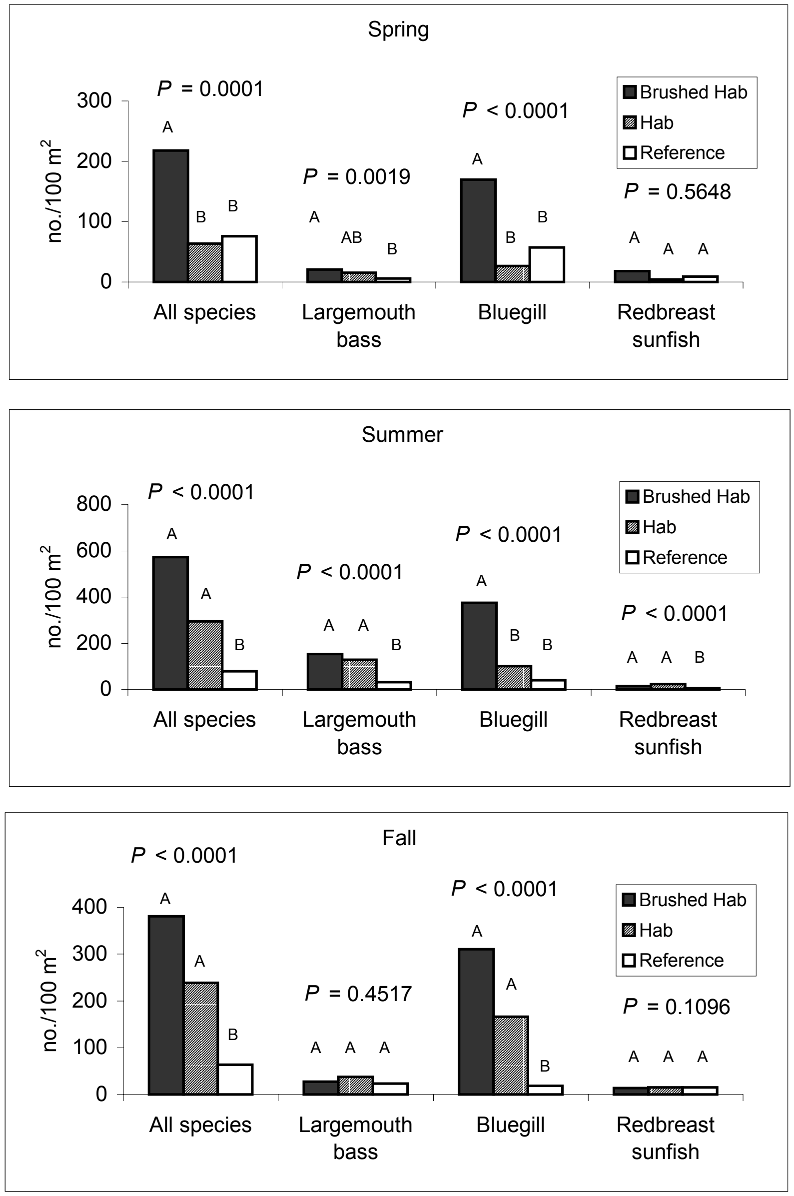

Figure 7: Catch rates by number (no./100 m^2) of all species, largemouth bass, bluegill, and redbreast sunfish collected from brushed hab piers, piers with habs, and reference piers during spring, summer, and fall on Lake Hickory, 2001. Common letters within the chart indicate treatments that are not significantly different within each season and species (or total).

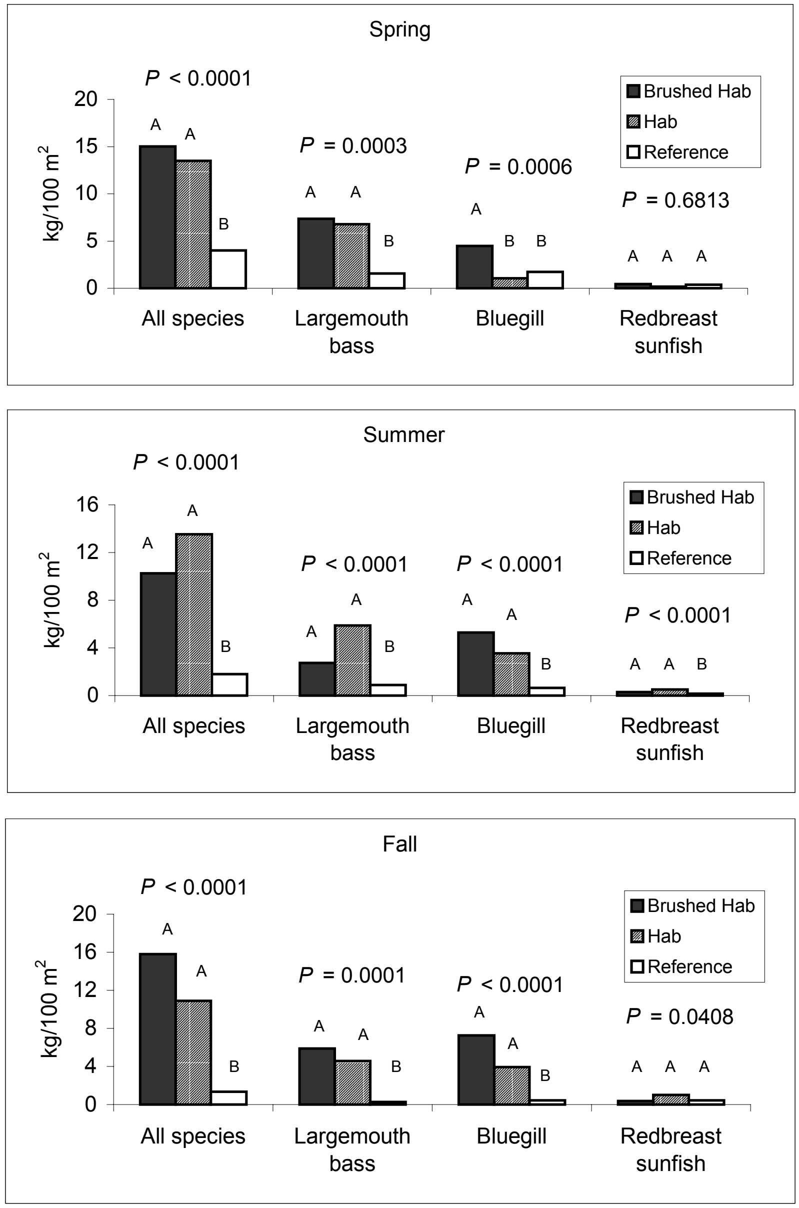

Figure 8: Biomass (kg/100 m^2) of all species, largemouth bass, bluegill, and redbreast sunfish collected from brushed hab piers, piers with habs, and reference piers during spring, summer, and fall on Lake Hickory, 2001. Common letters within the chart indicate treatments that are not significantly different within each season and species (or total).

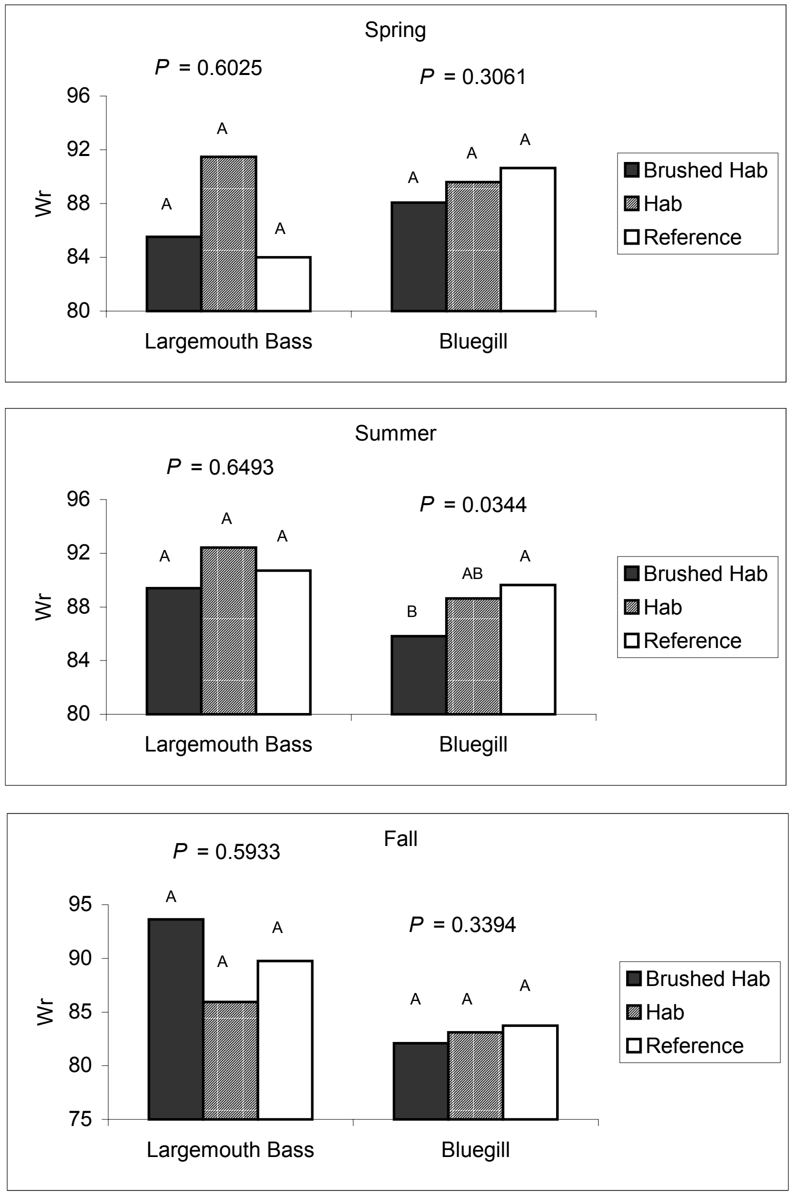

Figure 9: Relative weight of largemouth bass and bluegill collected from brushed hab piers, piers with habs, and reference piers during spring, summer, and fall on Lake Hickory, 2001. Common letters within the chart indicate treatments that are not significantly different within each season and species.

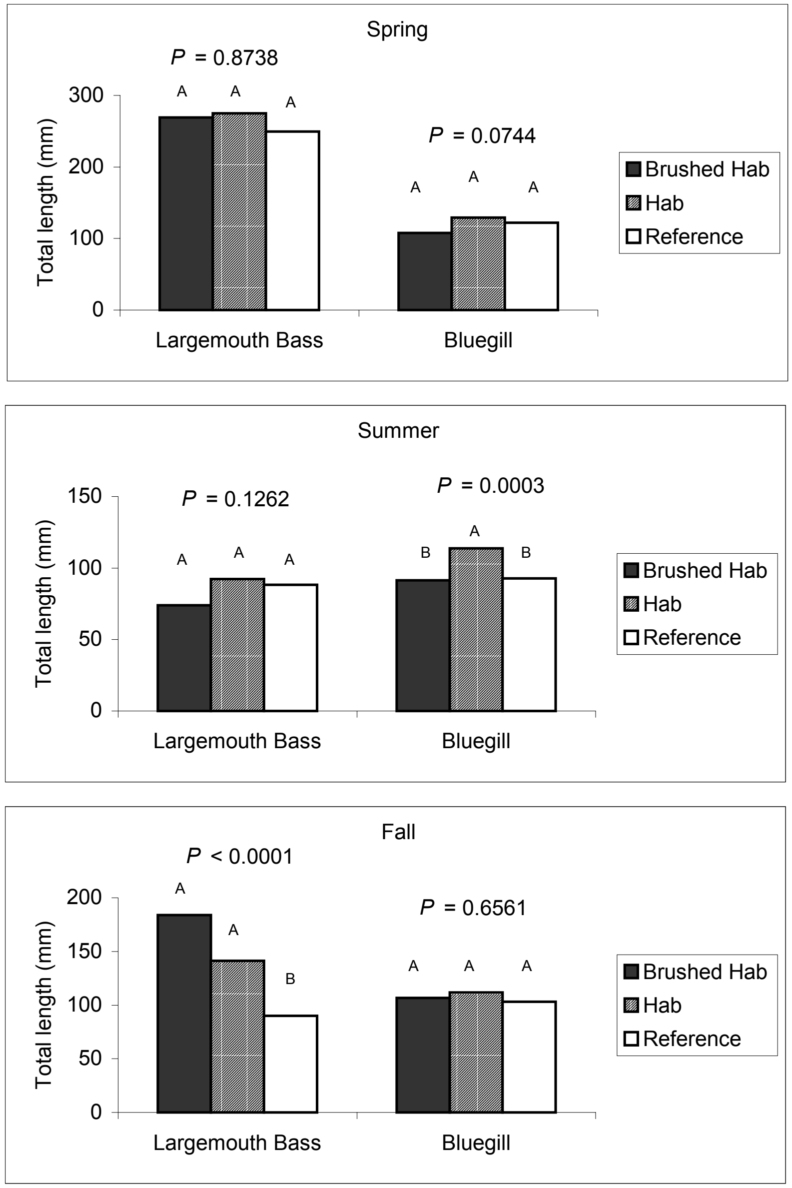

Figure 10: Mean length of largemouth bass and bluegill collected from brushed hab piers, piers with habs, and reference piers during spring, summer, and fall on Lake Hickory, 2001. Common letters within the chart indicate treatments that are not significantly different within each season and species.

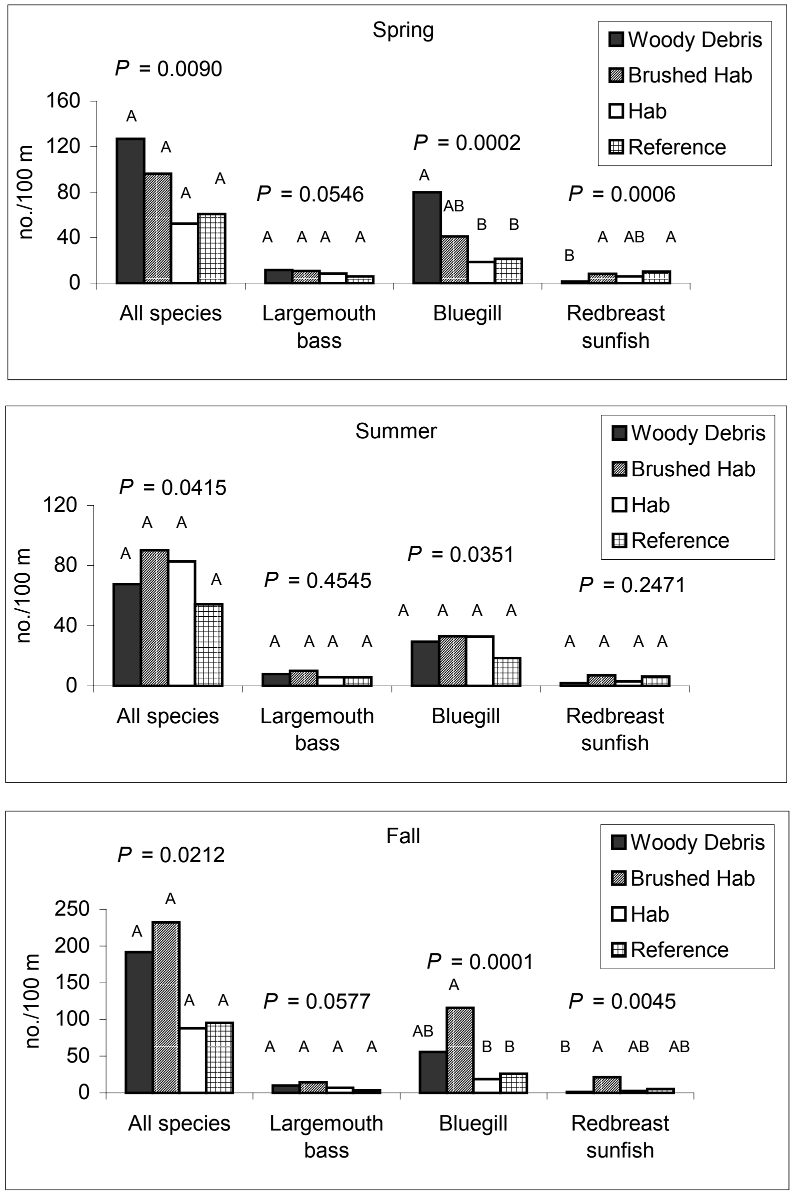

Figure 11: Catch rates by number (no./100 m) of all species, largemouth bass, bluegill, and redbreast sunfish from natural woody debris transects, brushed hab transects, transects with habs, and reference developed transects during spring, summer, and fall on Fishing Creek Reservoir, 2001. Common letters within the chart indicate treatments that are not significantly different within each season and species (or total).

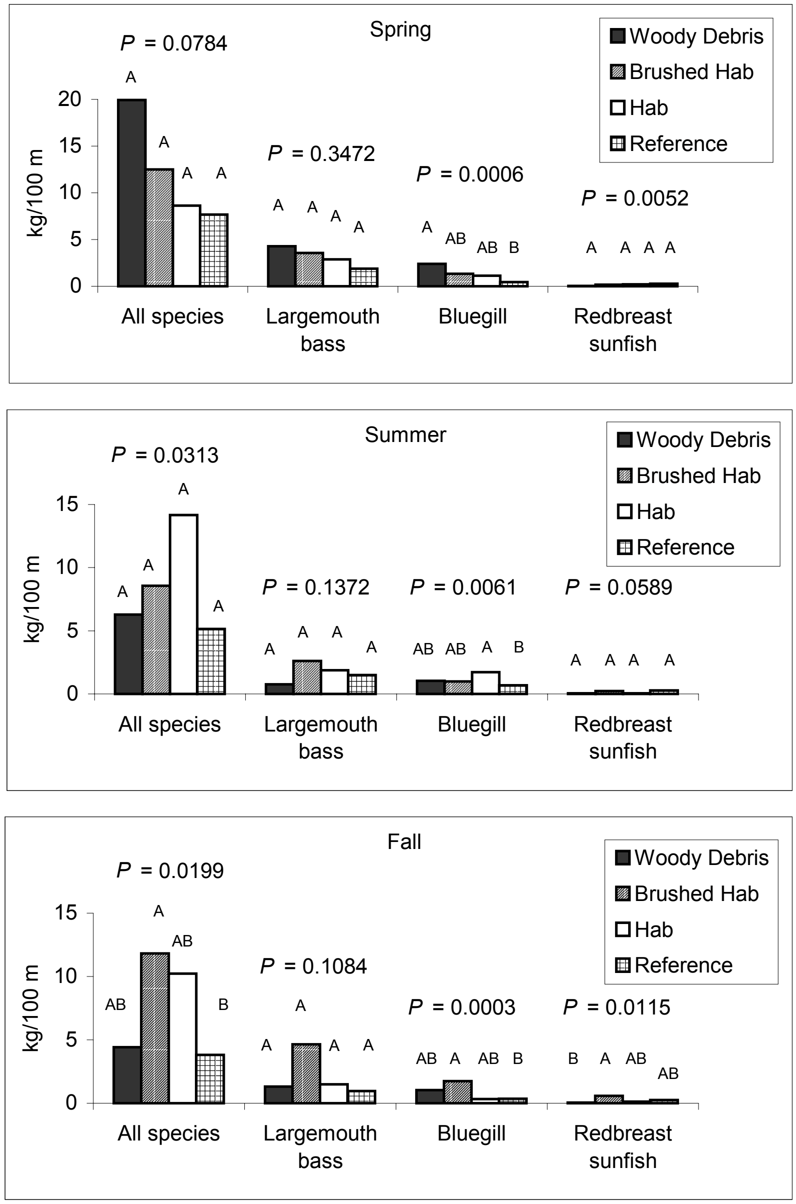

Figure 12: Biomass (kg/100 m) of all species, largemouth bass, bluegill, and redbreast sunfish from natural woody debris transects, brushed hab transects, transects with habs, and reference developed transects during spring, summer, and fall on Fishing Creek Reservoir, 2001. Common letters within the chart indicate treatments that are not significantly different within each season and species (or total).

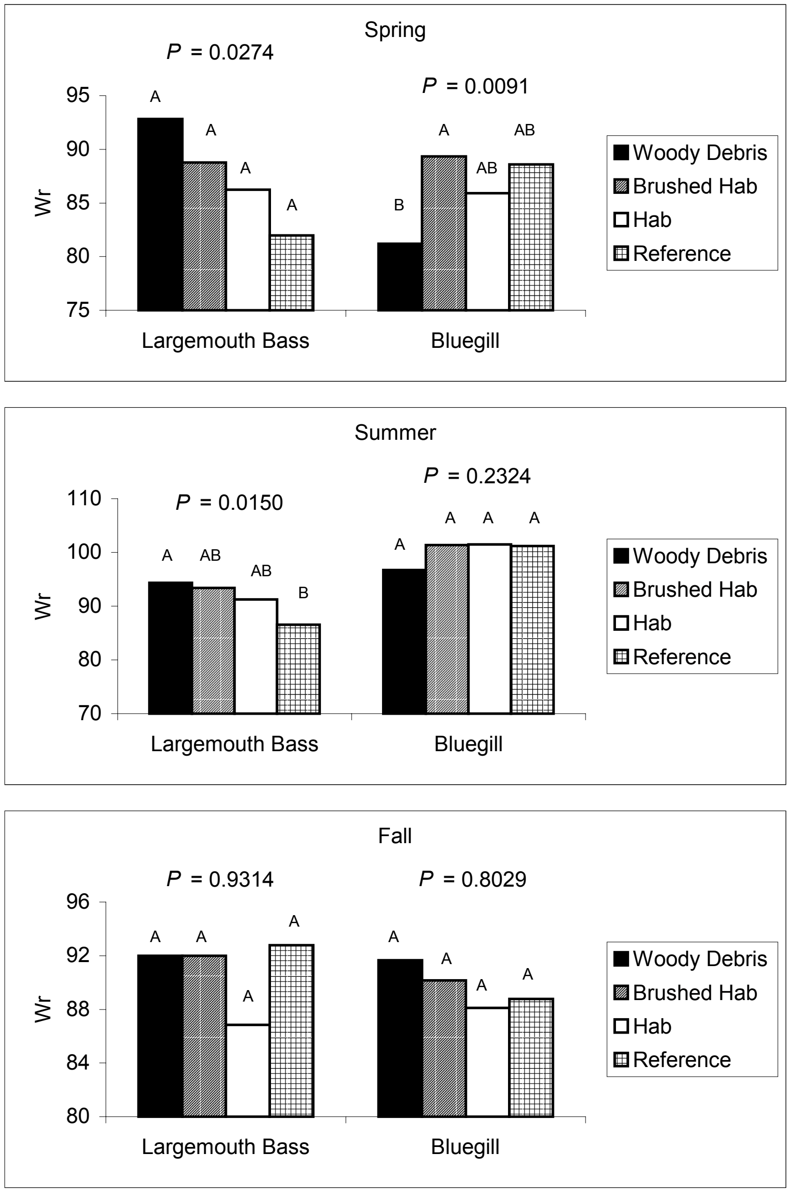

Figure 13: Relative weight of largemouth bass and bluegill collected from natural woody debris transects, brushed hab transects, transects with habs, and reference developed transects during spring, summer, and fall on Fishing Creek Reservoir, 2001. Common letters within the chart indicate treatments that are not significantly different within each season and species.

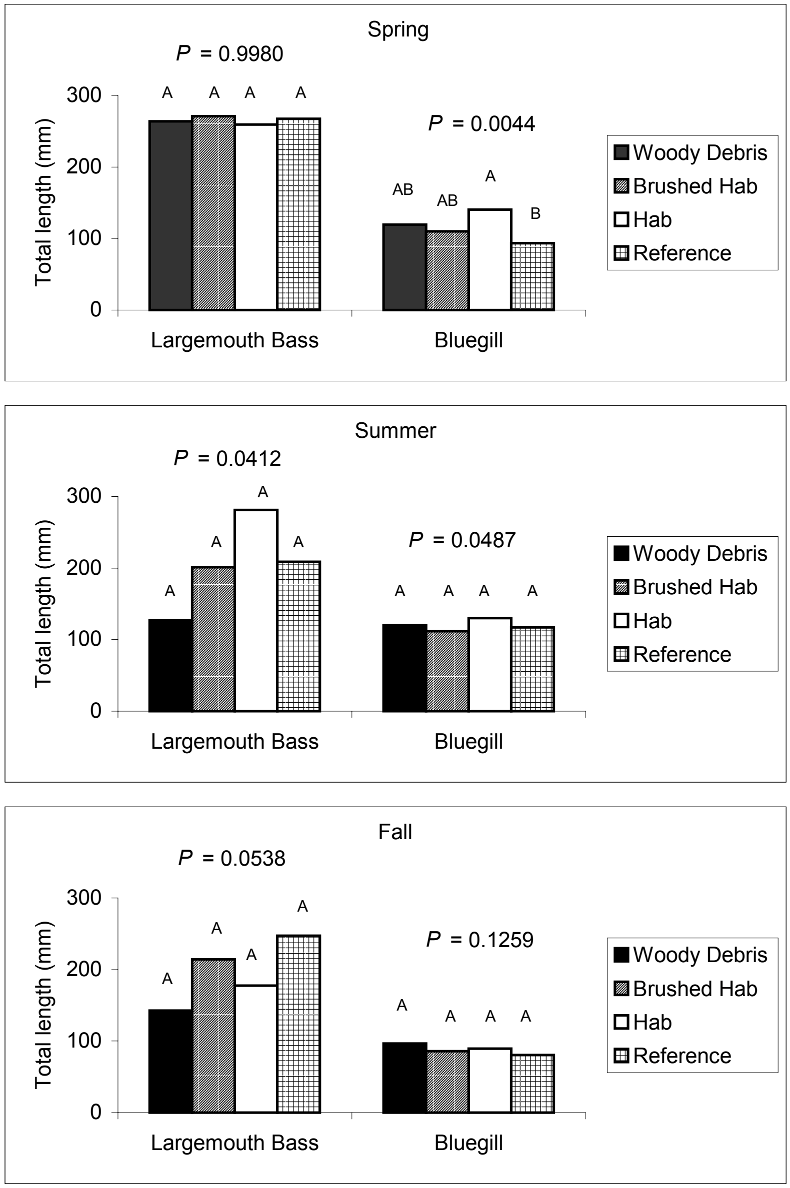

Figure 14: Mean length of largemouth bass and bluegill collected from transects with natural woody debris, brushed hab transects, transects with habs, and reference developed transects during spring, summer, and fall on Fishing Creek Reservoir, 2001. Common letters within the chart indicate treatments that are not significantly different within each season and species.

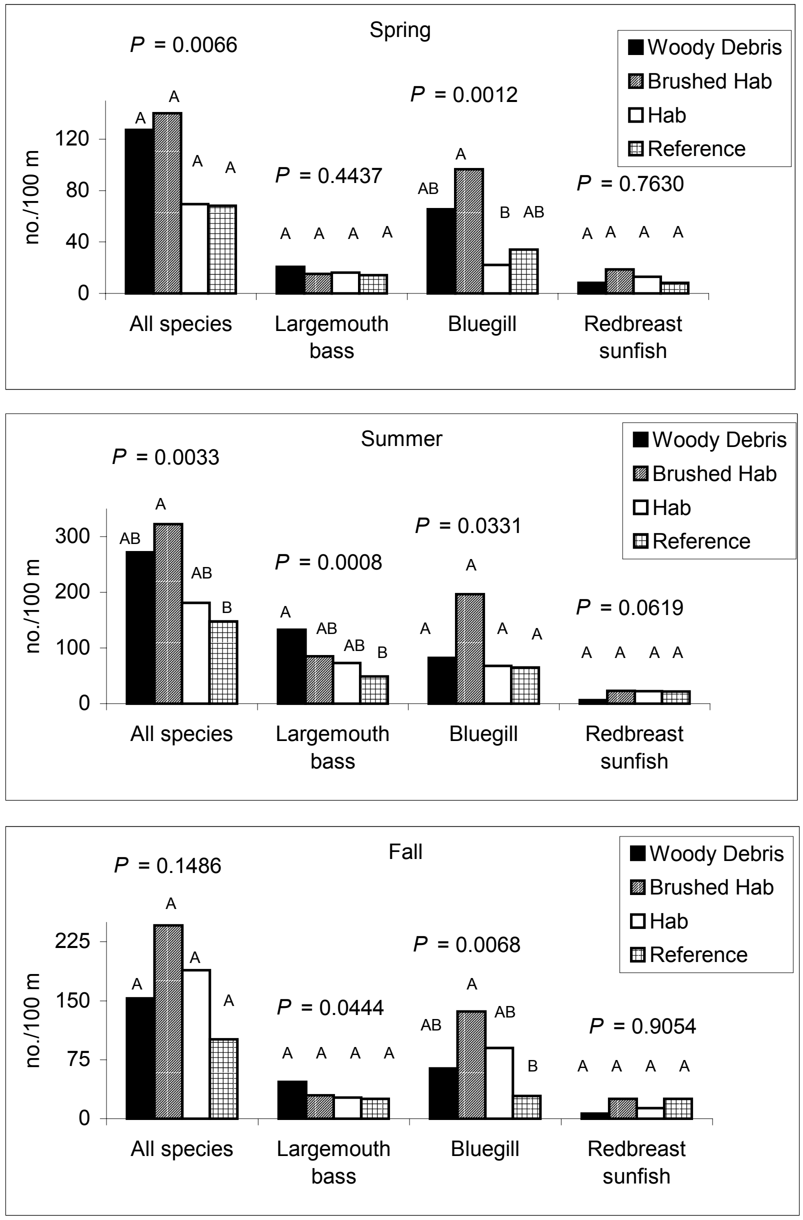

Figure 15: Catch rates by number (no./100 m) of all species, largemouth bass, bluegill, and redbreast sunfish from natural woody debris transects, brushed hab transects, transects with habs, and reference developed transects during spring, summer, and fall on Lake Hickory, 2001. Common letters within the chart indicate treatments that are not significantly different within each season and species (or total).

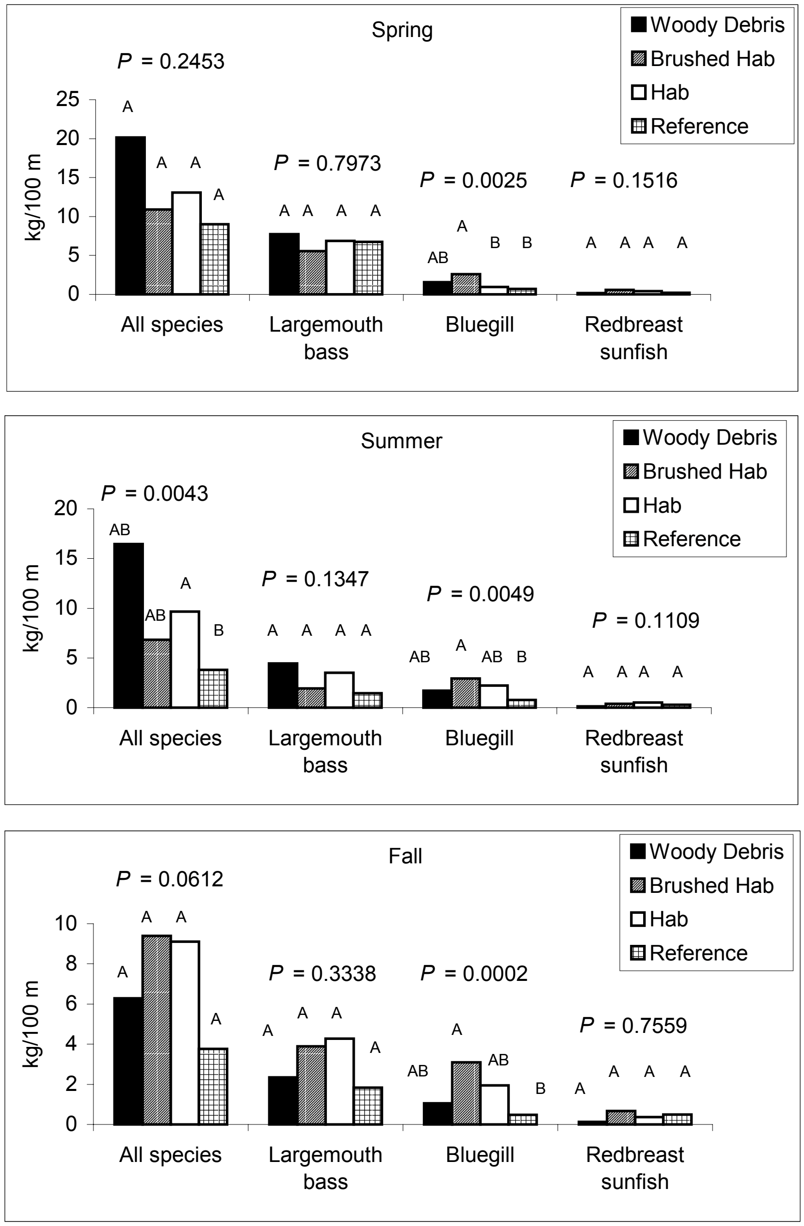

Figure 16: Biomass (kg/100 m) of all species, largemouth bass, bluegill, and redbreast sunfish from natural woody debris transects, brushed hab transects, transects with habs, and reference developed transects during spring, summer, and fall on Lake Hickory, 2001. Common letters within the chart indicate treatments that are not significantly different within each season and species (or total).

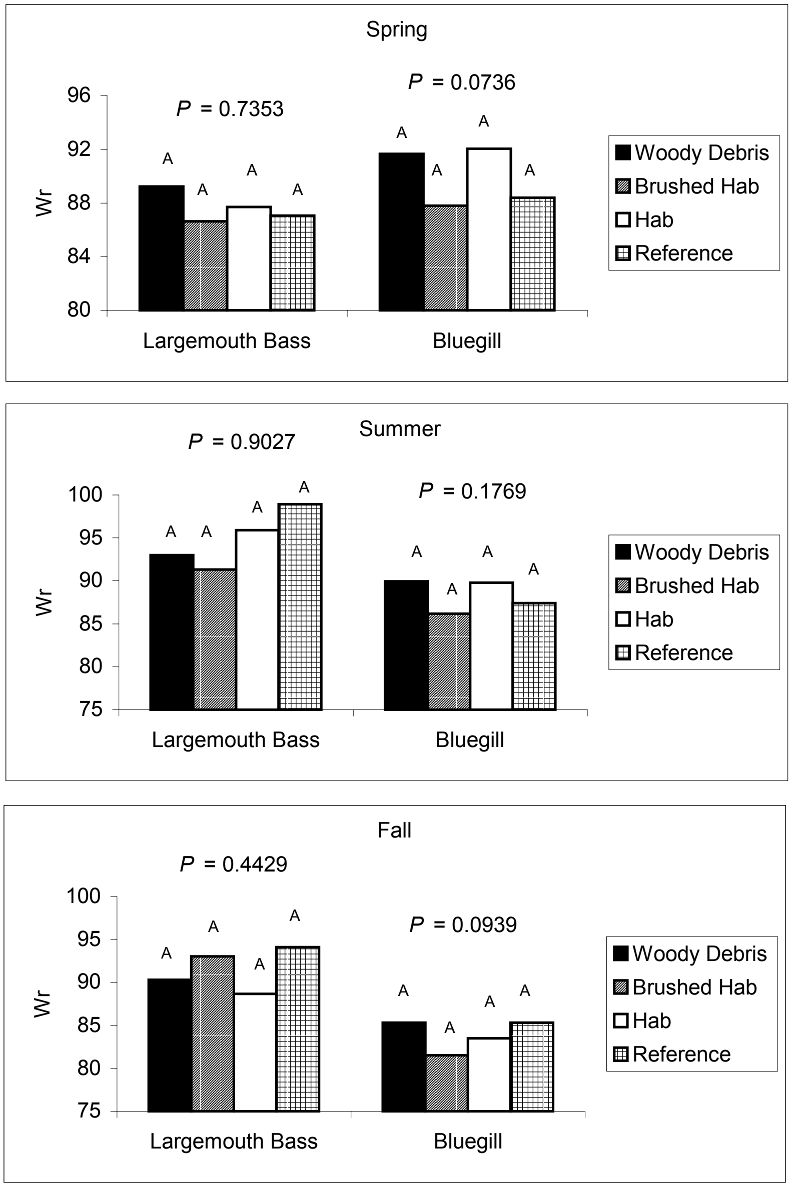

Figure 17: Relative weight of largemouth bass and bluegill collected from natural woody debris transects, brushed hab transects, transects with habs, and reference developed transects during spring, summer, and fall on Lake Hickory, 2001. Common letters within the chart indicate treatments that are not significantly different within each season and species.

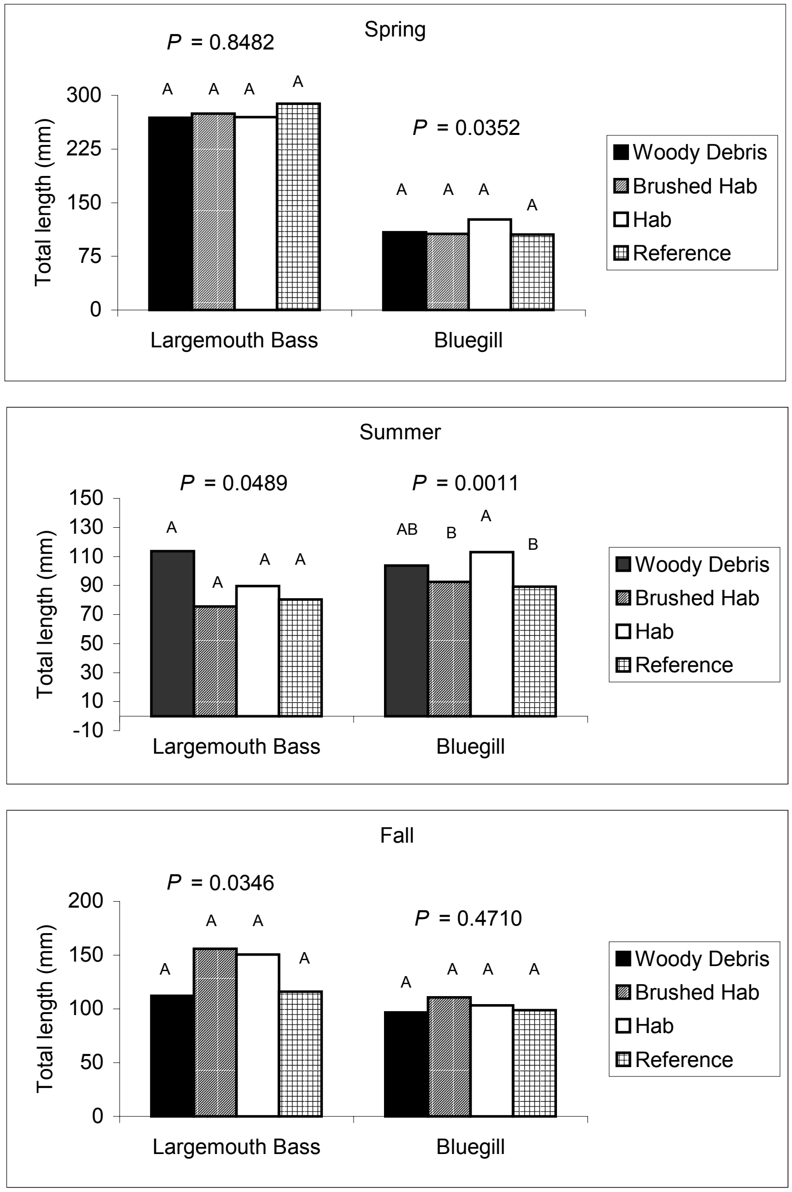

Figure 18: Mean length of largemouth bass and bluegill collected from natural woody debris transects, brushed hab transects, transects with habs, and reference developed transects during spring, summer, and fall on Lake Hickory, 2001. Common letters within the chart indicate treatments that are not significantly different within each season and species.

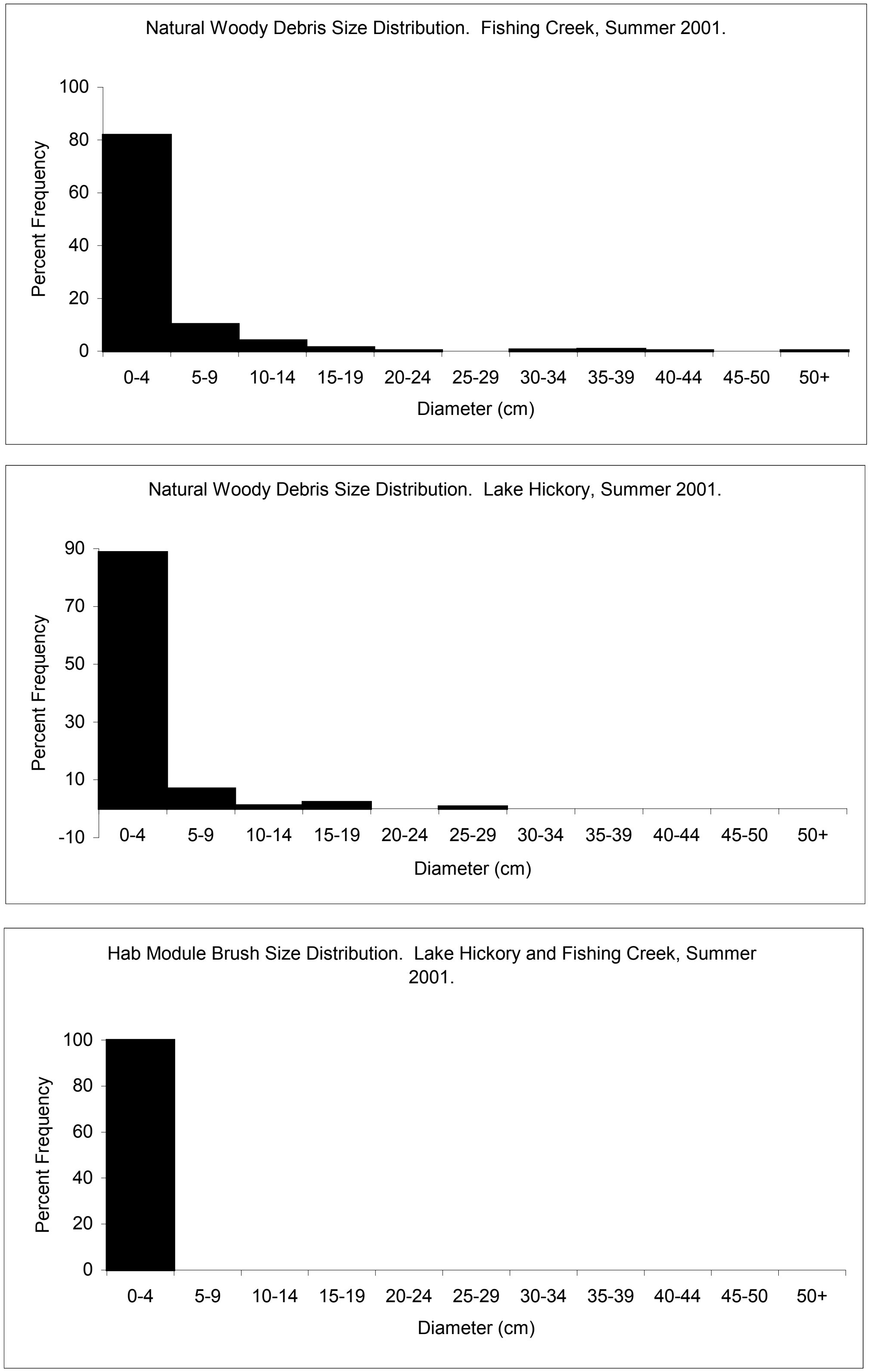

Figure 19: Diameter size distribution of natural woody debris sampled from study transects and brush incorporated into hab modules on Fishing Creek Reservoir and Lake Hickory during summer 2001.

Appendix

November 1, 2001

Memo to: Participants in the Duke Power-NC State University Fish-Friendly Pier Study

Re: Study completion

In October, we collected the last of the field data necessary for our evaluation of this project and I wanted to thank you for your help. I very much appreciate your cooperation in allowing us to install the habitat enhancement structures under your piers and allowing us to sample the fish populations associated with these piers. While it will be some time (maybe June 2002) before we have all the data analyzed and a final report prepared, you will receive a copy of the final report.

For this final report, there are a few questions that we would like to ask you. It would be very helpful for us to know your observations and feelings regarding this study. We not only value your responses, but your observations provide us with valuable information that will help us determine an appropriate habitat management strategy using this concept. I hope you will take a few minutes to complete the enclosed survey and return it to me in the envelope provided. As we discussed prior to the study, you are under no obligation to keep the structures under your pier. If you want them, they are yours. If you do not want them, simply indicate that on the survey and we will remove them.

Again, I want to thank each of you for your help in conducting this study. If you have any questions concerning the study, the surveys, or the disposition of the structures, please do not hesitate to give me a call.

Sincerely,

Hugh Barwick
Scientist

FISH-FRIENDLY PIER OPINION SURVEY
Duke Power and NC State University

In the following questions, please reply with your opinions regarding the habitat enhancement structures that were installed under your pier last winter. Please circle the most appropriate answer(s). Thank you for your time and cooperation to assist with management of our lakes.

1. Overall, how satisfied are you with the habitat enhancement structures under your pier(s).

    a. Satisfied.
    b. Not Completely Satisfied. Why not? ____

2. Have you experienced any problems with the enhancement structures under your pier(s)?

    a. Yes. Which types of problems ____
    b. No.

3. Have you noted any damage caused to your pier(s) by the enhancement structures?

    a. Yes. What kind of damage? ____
    b. No

4. For what uses does your pier serve? Please circle all that apply.

    a. Boat access
    b. Swimming
    c. Fishing
    d. Other ____

5. Do you, or members of your family fish from your pier(s)?

    a. Yes. Continue with question 6
    b. No. Go to question 8.

6. How often has your household fished from your pier in the last year?

    a. Less than 5 times
    b. 5-10 times
    c. 10-20 times
    d. More than 20 times

7. If you answered yes to the previous question, have you noticed better fishing success since the structures were installed?

    a. Yes
    b. No

8. Have you noted an increase in other anglers fishing your pier since the enhancement structures were installed?

a. Yes.
b. No.

9. Have you observed more fish around your pier since the enhancement structures were installed?

a. Yes
b. No
c. Don't Know

10. Have you observed more or different types of wildlife around your pier(s) (e.g., snakes, turtles, herons, geese) since the enhancement structures were installed?

a. Yes, which types ____

____

b. No

11. Do you feel that the enhancement structures alter the aesthetics of your property?

a. Yes. Improve___ or Diminish ___ (check one)
b. No.

12. Would you suggest this type of habitat improvement program to your friends or neighbors?

a. Yes.
b. No. Why not? ____

13. In your opinion, what could be done to improve the design of the enhancement to meet the needs of a pierowner?

____

____

____

14. Is there anything else that you would like to share with us? Please feel free to write in the space provided below.

____

____

____

15. Do you wish to keep the enhancement structures under your pier or would you like us to remove them?

a. I like them and wish to keep them.
b. I would like them to be removed.
    If so, why?

Thank you for your participation in the project and your time in completing this survey. Please return your completed questionnaire in the return envelope as soon as possible. Thank you.