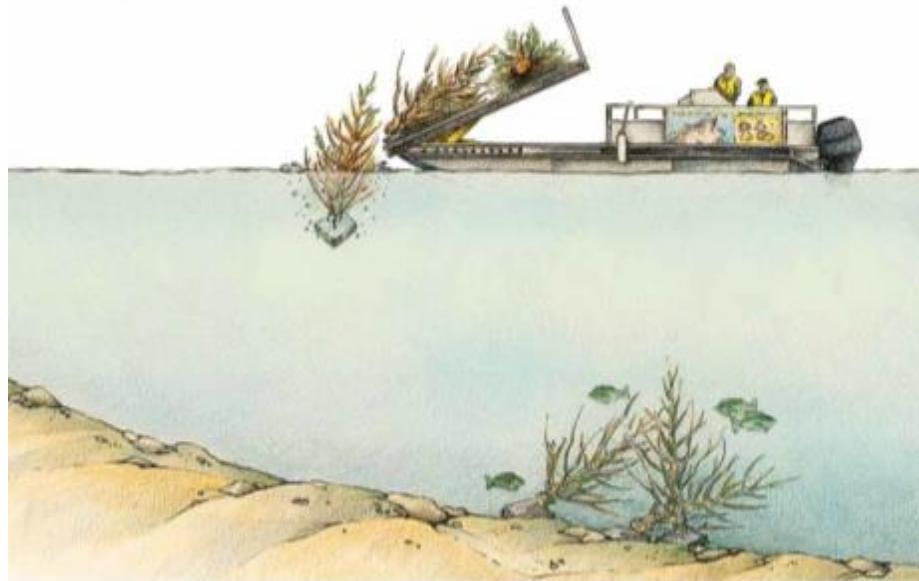


## Final Report

# A Comprehensive Approach to Reservoir Habitat Management in Table Rock Lake



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## Executive Summary

Table Rock Lake and Lake Taneycomo are located in the White River Hills region of the Ozark Plateau along the Missouri-Arkansas border. At conservation pool, Table Rock Lake encompasses 43,100 acres with 745 miles of shoreline and Lake Taneycomo covers just over 2,000 acres. Crappie, White Bass, Walleye and Paddlefish are among the primary sport fish in Table Rock; however, black bass receive the most attention and fishing pressure. Lake Taneycomo supports an excellent Rainbow Trout and Brown Trout fishery. The combined annual economic benefit of angling on Table Rock Lake and Lake Taneycomo is conservatively estimated at \$67 million.

In 2007, the Missouri Department of Conservation (MDC), in cooperation with Bass Pro Shops (BPS), the National Fish and Wildlife Foundation (NFWF), Arkansas Game and Fish Commission (AGFC), the United States Army Corps of Engineers (USACE), Table Rock Lake Water Quality Inc. (TRLWQ) and many other partners began the National Fish Habitat Initiative (NFHI) project to sustain and improve the degrading physical habitat within Table Rock Lake. These partners provided the funding and resources necessary to improve habitat and water quality within Table Rock Lake and its tributaries. The project began in October 2007 and continued through December 2013 with funding totaling four million dollars. During this timeframe, a total of 2,024 fish habitat structures were installed in Table Rock Lake; including 1,797 brush structures, 114 rock piles, 76 stump fields, 11 rock and stump combination structures and 26 shallow water rock fence structures. These structure locations were recorded by Global Positioning Systems (GPS) technology and are available to the public on the MDC website. Many different techniques and material types were used for the installation of these habitat structures which required the use of large machines and numerous personnel to implement them. Collecting and hauling of the materials for habitat structures was contracted to a local excavating company. This greatly improved the efficiency of the habitat work portion of the NFHI project. Two large boats, or barges, were used on the project to transport and place the materials in Table Rock Lake. These specialized watercraft made installation of habitat much easier and safer. Hardwood tree tops and cedar trees were the most common types of material used for the habitat structures but pine (Christmas) trees were also used when available. The use of contractors and large machines also allowed for placement of large rock structures and stump fields to add to the diversity of the habitat structures.

The MDC, in conjunction with the James River Basin Partnership and TRLWQ, implemented a program to improve water quality throughout Table Rock Lake. This program offered a \$50 incentive to landowners in the Table Rock Lake and James River watersheds for preventative pumping out of septic tanks before failure occurred. Over 2,000 septic tank pumpouts were completed equating to a potential reduction of two million gallons of septic effluent entering the Table Rock Lake watershed and helping to reduce the amount of nitrogen entering the lake by 550 pounds per year. The program also offered educational packets to each participating

landowner to increase their knowledge of the benefits of properly maintaining their septic systems. To reduce the amount of sediment transferred from the watershed to Table Rock Lake, MDC also worked with landowners to provide a cost share program to stabilize highly eroding streambanks. A total of eight (8) cost-share projects were completed in the Table Rock Lake watershed. This aspect of the NFHI project offered a cost share incentive of up to 95 percent to the landowners and were designed and built with the most effective techniques to stop erosion. Approximately 3,610 linear feet of streambank were stabilized and many more acres of riparian corridor were established.

Historically, Table Rock Lake has experienced dramatic lake stratification during the late summer and autumn. This stratification can reduce dissolved oxygen (DO) levels to less than four milligrams per liter near the dam turbine intakes for time periods of up to five months. A study conducted in 1999 identified a forebay liquid oxygen diffuser system as the best option for improving DO levels in Lake Taneycomo. Utilizing NFHI funding, a feasibility study for installing a forebay liquid oxygen diffuser system at Table Rock Lake was conducted in 2009. This system would oxygenate water in the Table Rock Lake forebay before it entered the penstocks of Table Rock Dam and flowed into Lake Taneycomo. As funding and water allocation becomes a priority, this study will inform decisions to improve water quality in Lake Taneycomo. Habitat improvements were also completed in the upper portion of Lake Taneycomo. Much of the habitat in the upper sections of Lake Taneycomo is comprised of homogenous gravel substrate. Boulder clusters were installed in the upper mile of Lake Taneycomo to add diversity of habitat to the lake, create improved feeding areas for trout and other species of fish and increase angling opportunities in Lake Taneycomo.

The NFHI project provided a unique opportunity to evaluate the effectiveness of habitat structures that were installed in Table Rock Lake. Four different evaluation techniques to determine fish and angler use of the habitat structures began in 2009. Electrofishing surveys of habitat treated coves showed that fish can be attracted locally to habitat structures for spawning but habitat structures are not likely to congregate fish from other areas of the lake. Self-Contained Underwater Breathing Apparatus (SCUBA) surveys of bass and crappie species were conducted on five of the main types of structures installed in Table Rock Lake (hardwood trees, cedar trees, pine trees, stump fields and rock piles). During these surveys, Largemouth Bass were observed on all of the structure types and observed most often on hardwood structures. Crappie species were observed on all structure types except rock piles and most often on cedar trees. Radio bio-telemetry of Largemouth Bass in the Kings River Arm of Table Rock Lake showed that the chances of fish using installed habitat structures were equal to or greater than the chances of fish utilizing natural habitat types. Finally, two types of angler surveys were utilized to determine angler use and opinions of installed habitat structures in Table Rock Lake. A roving-roving creel survey was used to determine if angler catch rates were improved as a result of habitat placement, as well as to assess angler opinions of the habitat project. A web-based survey was also conducted to determine opinions from the general angling public about the

installed habitat structures and the NFHI project. The information gained through both surveys indicated anglers do support installation of habitat structures in Table Rock Lake and also believe that the installed habitat structures in the lake improved their fishing. This combination of information was used to determine that the habitat structures installed in Table Rock Lake generally employed the most effective techniques and materials for fish and angler use.

The Table Rock Lake NFHI project builds upon a long-standing public/private partnership in southwest Missouri to improve and restore fish habitat in Table Rock Lake, Lake Taneycomo and their watersheds through cover augmentation, watershed management and other water quality-related projects. The MDC, NFWF, BPS, AGFC, USACE, the U.S. Fish and Wildlife Service, Southwestern Power Administration, TRLWQ, various non-government organizations, angler groups and private citizens all worked cooperatively to ensure the success of this project. This project was an excellent opportunity to proactively maintain and enhance fish habitat in and around two of the Midwest's most popular sport fisheries. This project has proven to be a national example of sustaining and improving reservoir sport fish populations through large-scale habitat improvements.

## Introduction

The United States has lost 20 percent of its fish and aquatic populations and nearly 40 percent of the nation's native fish species are in decline (Moyle 1992). Habitat loss and degradation is the primary factor contributing to this decline. In 2006, the National Fish and Wildlife Foundation (NFWF) joined federal and state agencies, conservation and angling organizations, and Bass Pro Shops (BPS) to establish the National Fish Habitat Action Plan (NFHAP) to help reverse this decline.

In conjunction with the creation of NFHAP and with BPS as the first corporate sponsor, NFWF launched the "More Fish Campaign" to help raise awareness and increase funding to protect, enhance and restore abundant and healthy populations of fish and aquatic species to our nation's waters. With funding from public and private partners, the "More Fish" grant programs invest in on-the-ground projects demonstrating innovative approaches to fish habitat conservation.

In 2007, Table Rock Lake was chosen as the first More Fish Campaign pilot project focused on reservoir habitats and the health of their watersheds. The Missouri Department of Conservation (MDC), Arkansas Game and Fish Commission (AGFC), United States Army Corps of Engineers (USACE), NFWF, BPS and other agencies embarked on the Table Rock Lake National Fish Habitat Initiative (NFHI) project to improve fish habitat and recreational opportunities in Table Rock Lake. Bass Pro Shops committed \$300,000 per year which was matched two-to-one by NFWF and its partners including the U.S. Fish and Wildlife Service (USFWS), the Missouri Department of Conservation (MDC), and Arkansas Game and Fish Commission (AGFC), for a grand total of \$4 million invested into this project.

Table Rock Lake and Lake Taneycomo are located in the White River Hills region of the Ozark Plateau along the Missouri-Arkansas border. At the top of conservation pool, Table Rock Lake encompasses 43,100 acres with 745 miles of shoreline. Lake Taneycomo covers just over 2,000 acres. Crappie (*Pomoxis spp.*), White Bass (*Morone chrysops*), Walleye (*Sander vitreus*) and Paddlefish (*Polyodon spathula*) are among the primary sport fish in Table Rock; however, black bass (*Micropterus spp.*) receive the most attention and fishing pressure. Lake Taneycomo supports an excellent Rainbow Trout (*Onchorhyncus mykiss*) and Brown Trout (*Salmo trutta*)

fishery. The combined annual economic benefit of angling on Table Rock Lake and Lake Taneycomo is conservatively estimated at \$67 million (Vitello and Armstrong 2008).

Table Rock Lake contains the necessary components of economic importance, heavy public use, and adequate fish densities to serve as a national model in sustaining and improving fish populations in aging reservoirs and watersheds. Table Rock Dam was built on the White River in 1958 and Table Rock Lake first reached conservation pool in 1959. Much of the landscape that was flooded to create the reservoir consisted of Ozark highland forest. As the reservoir began to fill rapidly, residents were unable to fully harvest trees and the remaining forest stood high in the water column. As the reservoir aged, the “standing timber” began to deteriorate, resulting in fewer habitats available for fish in the reservoir to utilize. The lake became known as a “tough” lake for anglers to fish. To further add to the degradation of the aging reservoir, human population increases and urbanization of the Table Rock Lake watershed began to have negative impacts on the water quality of Table Rock Lake.

Five main objectives for this project were established and brainstorming began to consider any techniques thought to fulfill these objectives. These objectives were: improve fish habitat within Table Rock Lake, improve water quality within Table Rock Lake and its tributaries, improve water quality and habitat within Lake Taneycomo, monitor the effectiveness and longevity of structures and projects employed, and develop a framework for a broader, national program focused on habitat protection and restoration in reservoirs and their watersheds.

### **Objective 1: Improve fish habitat in Table Rock Lake**

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Improving physical habitat for fish in Table Rock Lake was the primary focus of the NFHI project. The Missouri Department of Conservation has implemented a large scale program for improving fish habitat within Table Rock Lake and utilized several different techniques for installing the habitat. Multiple focus group meetings were held throughout the duration of the project to acquire angler and stakeholder input as to the locations and types of fish habitat that would be most effective. Since guides and avid anglers spend many days on the lake per year,

they know the reservoir and habits of the sport fish well. Their ideas and input were instrumental to the success of the habitat placement. Anglers were given the opportunity to provide biologists with insight about the locations fish could already be found and areas where habitat could improve fish holding ability. Anglers also provided guidance related to orientation, types of materials, and depths at which habitat would be most effective. United States Army Corps of Engineers personnel were also consulted during habitat placement to ensure that structures would not cause navigational hazards for boat traffic.

Many different types of materials were used to create fish habitat structures. Working with developers, contractors, private landowners and the USACE, MDC acquired hardwood tree tops and stumps, cedar trees, pine trees (Christmas trees), and rock/concrete material.

### **Vehicles**

Most of the habitat structures were placed in Table Rock Lake by way of boat. Bass Pro Shops and Tracker Marine designed and built a large, pontoon style habitat barge with a hydraulic platform mounted on the front half of the barge that can be raised from the midpoint (Figure 1.1). The habitat barge is 29 feet long and nine feet wide. It is powered by twin, 115 horsepower Mercury four-stroke outboard motors. This boat was used to place the cedar, pine, and hardwood tree tops in Table Rock Lake and operated by MDC personnel from a drivers console located in the rear half of the barge which contained all necessary controls for operations of the outboard motors and hydraulic system for placing habitat. The platform used for hauling and placing the habitat covered approximately half of the barge length, pivoted from the front, and the rear was raised by a hydraulic ram to allow the trees to slide off into the water at the front of the boat. The hydraulic system for the lift on the platform was operated by a Honda generator powering a hydraulic pump and controlled by electric switches located at the control console of the barge. The maximum weight limit for this habitat barge is approximately 4,000 pounds. For safety reasons, this barge was not used to place the stump or rock habitat in Table Rock Lake as one stump could have exceeded the weight limit.

This barge was transported on a heavy duty boat trailer which was pulled by a 1¾ ton truck (Ford F-550, 6.8 L V-10). This barge could be loaded into the water at all of the surrounding USACE boat ramps and most of the private ramps around the lake.



Figure 1.1: Table Rock Lake fish habitat barge.

Another barge was contracted to place fish habitat in Table Rock Lake (Figure 1.2). This barge was built and operated by ECS Midwest, Inc. This “rock barge,” nicknamed the “Hammerhead,” is 35 feet long and 14 feet wide. This barge was much larger and required heavy duty equipment to transport and launch. This barge was transported to the lake using a “lowboy” style, flatbed, semi-trailer. The barge was assembled while on the trailer and utilized hydraulic lifts to raise the barge and allow the trailer to be pulled away. The barge was then lowered onto the ground by the lifts, the lifts were taken off, and the barge was pushed into the water. Due to the fact that the rock barge and equipment used for loading and assembling the barge were much larger, the areas of the lake where rock and stump projects were completed had to be planned carefully. The rock barge was transported to the lake for each project by semi-trailer and assembled using a 200 class excavator, therefore, the area used for loading and assembling the rock barge was very large. The areas had to be of fairly shallow slope and the substrate composition of the loading areas had to be solid and relatively smooth. This limited the areas where the rock barge could be loaded. The barge is flat on the bottom and is operated by way of a diesel motor powering a hydraulic pump which operates the propellers, steering and hydraulic piston. The rock barge has the capacity to move 20 tons of material at one time, making it an optimal design to install the stump and rock type habitats. A large “basin” sits on the front of the barge that contains a large hydraulic piston at the rear. The basin was loaded with habitat materials and the barge transported the materials to the areas of the lake marked out by MDC personnel. When the rock barge reached the area, the piston pushed the material from the rear of the basin and off the front

of the barge. This design greatly increased stability with larger loads since the load was never raised from the level it was placed.



Figure 1.2: ECS Midwest's "Hammerhead" rock barge.

The majority of materials used for building habitat structures were collected from landowners, contractors, developers, and businesses who were already removing trees for management practices, timber sales, urban development, etc. This technique for collection of materials benefited all parties involved, as a means to dispose of tree tops, stumps, and rocks, enhance habitat in Table Rock Lake and also reduce the amount of materials to be removed from the environment. Biologists and contractors would meet with the appropriate personnel to acquire the materials and contractors would obtain the materials and deliver them to the area of Table Rock Lake designated by MDC biologists. Most of these materials were transported by way of flatbed trailers and heavy duty trucks. Semi-trucks and trailers were also used to haul larger stump and rock materials. Due to the costs associated with hiring contractors to assist with habitat work, MDC worked with the Missouri Office of Administration to write state contracts for the hauling and barge loading conducted by the contractor, as well as the work performed by ECS Midwest, Inc. The Missouri Department of Conservation utilized a local, Missouri-based excavation company as the primary contractor for the removal, transportation, and loading of the habitat materials. Hill and Hill Maintenance and Excavation of Shell Knob, Missouri, performed all of the work associated with collecting materials from removal sites, hauling and staging materials onsite, and loading the materials onto the habitat barges. Using one contractor for this

type of work throughout the project provided a great benefit. As the project progressed, the contractors utilized more efficient methods of transportation and processing materials to ensure the best and most cost effective habitat installation possible. A small percentage of the habitat placed in Table Rock Lake was obtained from the shoreline. Removing trees from the shoreline in the quantities needed for this project could have caused water quality and erosion issues. Furthermore, the USACE prohibits the removal of trees from the shoreline by the public; therefore utilizing this method was avoided as much as possible. The USACE was consulted and approval was obtained before using this method of habitat placement. The trees which were removed from shoreline were primarily Eastern Red Cedar (*Juniperus virginiana*) and American Sycamore (*Platanus occidentalis*) and were selected from glades and boulder areas where soil was relatively absent, thus minimizing erosion problems.

Multiple excavation machines were used for placing habitat on the barges, organizing materials at staging sites and cleaning areas where habitat projects had been completed. Most of the materials were lifted onto the barges with track-hoe type, excavation machines. The hardwood and cedar materials were loaded onto the MDC habitat barge using a 50-class, 10,000 pound capacity excavator with a hydraulic thumb attachment (Figure 1.3).



Figure 1.3: 50-class, 10,000 pound excavator handling trees to load onto the Table Rock Lake habitat barge.

This machine was well suited for this type of work. Its smaller size and weight capacity allowed it to maneuver into areas and access points where habitat material staging was staged, with

minimal disturbance to the vegetation, landscape and other area aesthetics. The larger stumps and rock materials were moved and placed onto the rock barge with a 200 class, 45,000 pound capacity excavator with a stationary thumb attachment (Figure 1.4).



Figure 1.4: 200-class, 45,000 pound excavator loading stumps onto the rock barge.

This machine also grabbed and lifted the materials and placed them onto the barge. The 200-class excavator was also used in assembling and disassembling the rock barge.

Smaller skid-steer type dozer machines were also used to move and organize materials during loading and staging. This type of machine was used when very large projects were in process. This machine was equipped with a pinch type attachment which could hold the materials while moving, rather than pushing it. These machines could move materials more quickly than the excavator type machines which reduced the amount of time required to move materials from staging locations to barge loading sites near the shore.

### **Anchors**

The habitat material utilized by the NFHI project was primarily composed of wood. In most cases, wood is less dense than water and will float when placed in the lake. Many different types of anchors were created to sink the materials. All of the anchors used for this project were comprised of concrete. Concrete is very dense which allows for a smaller volume of material to be used. Concrete is also made of natural materials and deteriorates very slowly; therefore, it

does not negatively impact water quality. Concrete is also readily available and easily manipulated prior to curing. Initial anchors were created using five gallon buckets. Concrete was poured into the buckets using a concrete mixing truck. These anchors varied in size and weight as a standard amount of concrete could not be established. This method also required a large crew and was very slow. Also, the buckets had to be washed with some form of release agent (diesel fuel) that would allow the concrete to be removed from the buckets after curing. The average weight for an anchor created in this manner was between 30 and 40 pounds, but varied from approximately 15 pounds to nearly 70 pounds. A method of creating anchors in more efficient manner and standardizing size was needed. Standard 8" X 8" X 16" cinder blocks were used as forms to create these anchors. The cinder blocks were laid out on a flat surface, with all edges touching another block and the hollow portions facing upward. Concrete was then delivered by truck and poured onto the "field" of blocks. When all of the hollow areas of the blocks were filled with concrete, anchor handles were placed in the wet concrete (Figure 1.5). These anchors weighed between 75 and 80 pounds.



Figure 1.5: Field of finished anchors.

Anchor handles were made of used guy wire, outdoor power line wire, or any other twisted aluminum and/or steel wire. Primarily, guy wire was used due to its high strength, pliability, and availability. White River Valley Electric Cooperative (WRVEC) in Reeds Spring, Missouri provided used guy wire, free of charge. When an electric pole was removed, replaced, or

repaired, the stabilizing guy wire would be replaced and discarded. Personnel at WRVEC placed a pallet near the disposal area to load guy wire to be used on the NFHI project. The wire was then cut into 30" sections and bent into a "C" (Figure 1.6) to be placed into the anchors.



Figure 1.6: Guy wire formed to be placed in wet concrete of anchors to create an anchor handle.

Another type of anchor used for this project was built by the hauling and loading contractor. These anchors were also made of concrete, but were much larger (>200 pounds) therefore requiring machinery to move them. A concrete form measuring 18" X 18" X 8" was used to build the anchors. The anchors were built with a central hole created by inserting a PVC pipe into the form before pouring the concrete. These anchors were then tethered to the materials using twisted, stainless steel cable and bolted cable clamps (Figure 1.7).



Figure 1.7: Larger concrete anchor made by contractors.

The type of anchors used for the structures was largely based on the type and size of the materials. If the material was smaller and was bundled together to create a larger structure, then the smaller, cinder block anchors were used and tied to the bundles with braided nylon rope. If the materials were large enough to support the weight of the anchor during barge loading, the larger anchors were used due to ease of movement and preparation with machines.

## Materials

Many different types of materials were used on the NFHI project. All of the materials used for habitat were comprised of natural materials that would not pose a risk of affecting water quality, interfering with operations of Table Rock Dam, or causing danger to aquatic life or persons using Table Rock Lake. All habitat structures placed in Table Rock Lake adhered to the policies and regulations put in place by the USACE Table Rock Lake Project Office. Other abiotic factors were considered in placement such as water clarity, dissolved oxygen levels, typical thermocline depths, vicinity of existing structures and bottom contours of the lake.

The use of natural materials for habitat structures during this project had multiple environmental benefits. Even though the trees were removed from the landscape, most were scheduled to be removed for other reasons anyway. Normally, trees and woody materials would have been turned into mulch or piled up on the property and burned. Using these materials for fish habitat

not only benefited the environment by keeping them from being discarded and burned, it benefited landowners and developers by giving them a convenient way to get their waste trees removed from their property

Each habitat type utilized different types of materials, which required different methods for installation and special considerations before creating habitat structures. Weight, densities, anchor attachment, transportation and longevity of structures all had to be taken into account before habitat structures were created.

A total of 2,024 habitat structures were placed into Table Rock Lake between 2007 and 2013. Of these structures, 1,797 were hardwood, cedar or pine trees, 76 were stump fields, 140 were rock structures, and 11 were a combination of rocks and stumps. The diversity of the types of structures placed in Table Rock Lake provided fish and anglers greater opportunity to use different types of structure in any area of the lake. Each type of material created a specific type of habitat structure and each type of material had to be handled and transported in different ways. The habitat types and the techniques used to create habitat structures in Table Rock Lake are described below.

#### *Hardwood trees*

A majority of the habitat that was used for the NFHI project was in the form of hardwood tree tops (Figure 1.8). The forests of the Ozark highlands in Missouri are composed primarily of oak and hickory (Fagaceae and Juglandaceae) trees. The typical types of hardwood trees obtained for habitat were red and white oaks (*Quercus* spp.), hickory (*Carya* spp.), elm (*Ulmus* spp.), and maple (*Acer* spp.). Landowners and developers who chose to clear timber or selectively log areas of land could donate the tops of the trees to MDC. Hardwood tree tops are not marketable and are normally discarded during logging and clearing operations. During clearing, trees were taken down by any means the landowner decided, at their expense. The tops of the trees were removed by the contractor and taken to a staging area, where they could be prepared for placement into Table Rock Lake. A 10,000-pound class excavator was used to consolidate the habitat material and allow MDC personnel to tie anchors to the material. Once the anchors were tied to the materials, the excavator then loaded the materials onto the habitat barge to be transported to habitat placement locations on Table Rock Lake.



Figure 1.8: Table Rock Lake habitat barge with hardwood trees.

Hardwood tree tops were typically easier to transport by land and water. Special safety considerations were made for heavier species of trees, such as hickory, when loading and transporting them on the habitat barge. For the Table Rock Lake habitat barge, a maximum of a 12" tree trunk diameter specification was placed on hardwood tree tops. Up to three bundles of material and anchors were loaded onto the habitat barge for each trip. Adjustments were made to the number of bundles loaded on the barge as the variation in sizes and shapes of trees would affect the safety and transport ability of the barge and materials. Hardwood tops typically transported well, but were more difficult to dump off of the habitat barge. The weight of the tops could have easily caused the front of the barge to be pushed under the water, causing the barge to be unbalanced fore and aft.

Hardwood top materials were placed in many different areas in the lake, generally in depths of 10-30 feet (905-885 feet above mean sea level (msl)). This allowed for fish to use the structures at different times of the year when the thermocline was located at different depths. Larger hardwood tops with larger diameter limbs were given preference, when available; to create simple structures which could be placed deeper, yet stand higher in the water column. This orientation provided fish that used the structures a greater range of depths. The USACE policy stated that no structures would be placed in a manner that would cause navigational hazards.

Since normal fluctuations of Table Rock Lake levels range from 920-910 msl, most structures placed in areas of high boat traffic were placed deeper than 900 msl.

#### *Cedar trees*

Cedar trees are very abundant in the Table Rock Lake watershed. Much of the Ozark highlands are composed of glades and rock covered hills. These areas provide optimal conditions for cedar tree growth. Cedar trees are a common material type used by fisheries biologists for habitat enhancement projects. Cedar trees can create very large and complex habitat structures with much less weight than a hardwood top of the same size. Landowners, developers and others readily remove these trees for glade restoration and land improvement projects. Transporting and loading of cedar trees was very similar to hardwood tops (Figure 1.9). Contractors reduced the diameter of the cedar trees prior to hauling by using machines to pull the trees through a large pipe and band and compress the trees. This allowed for larger trees to be transported by road without reducing size. The bands were cut to allow the tree to expand to its original size before being placed into the lake. The same type of equipment and process for loading the barge with hardwood tops was used for cedar trees.



Figure 1.9: Table Rock Lake habitat barge with cedar trees.

The density of a cedar tree is much less than a hardwood tree, which can make sinking cedar trees more difficult since more anchors are needed to weight them down. Many of the cedar

trees would float when offloaded from the barge, if the number of anchors attached to them was not sufficient. Anchors were carried on the habitat barge for these occurrences. When trees would float, members of the crew would attach two anchors together with a length of rope and then place the rope atop of the floating trees with anchors hanging down on each side of the tree. Additional anchors would be added to the trees until they sunk. The reduced weight of the cedar trees made loading and transporting cedar trees easier. The lighter cedar trees allowed more material to be placed on the barge and allowed the load to be transported at higher speeds to locations on the lake. This reduced the time and effort it took to place cedar tree fish habitats.

#### *Pine (Christmas) trees*

Pine trees, in this context “Christmas trees”, are readily used by a majority of fisheries biologists for habitat enhancement and restoration projects (Figure 1.10). Christmas trees are usually collected at drop off locations, where anyone wishing to discard a used tree may bring it to a specified location and leave it for fisheries biologists to place into a water body for fish habitat. For this project, BPS in Springfield, Missouri, along with The Boy Scouts of America, collected Christmas trees at the BPS store and delivered them to Table Rock Lake by the semi-truck load. Silver Dollar City, a Branson area attraction, also donated Christmas trees and delivered them to nearby areas of the lake. Once collection and delivery was accomplished, the trees were sorted and loaded onto the habitat barge by hand, and placed into Table Rock Lake.



Figure 1.10: Table Rock Lake habitat barge with pine (Christmas) trees.

The trees were usually loaded by hand because of the smaller size and lighter weight of the trees. These trees were light enough that one or two people could easily place them onto the barge and once on the barge, others would tie anchors to them. Six anchors were placed on the deck of the habitat barge. These anchors were placed in the middle of the barge and equally spaced in a line from the back to the front of the deck. Pine trees were then loaded onto the barge and then tied to the anchors. In most cases, a Christmas tree was approximately six feet tall. Three to five (usually four) trees were tied to each anchor. A usual barge load of pine trees consisted of 24 trees and a typical pine tree structure contained two barge loads. Loading the pine trees by hand reduced the costs associated with the projects but also increased the amount of time and personnel required to place structures. When time constraints were an issue, pine trees were weighted and loaded onto the barge using machinery in the same manner as hardwood and cedar trees. This increased the costs of using pine trees, but greatly reduced the amount of time for the projects. Due to the fact that pine trees deteriorate quickly, only 15 percent of the structures placed in Table Rock Lake were comprised of pine trees. Through Self Contained Underwater Breathing Apparatus (SCUBA) surveys, pine trees were observed to last only seven to eight years before deteriorating to sizes too small to be an effective fish attractor in Table Rock Lake (Figures 1.11-1.12). This would require fisheries biologists to organize habitat placement projects to replenish older pine tree structures rather than adding new structures throughout the lake.

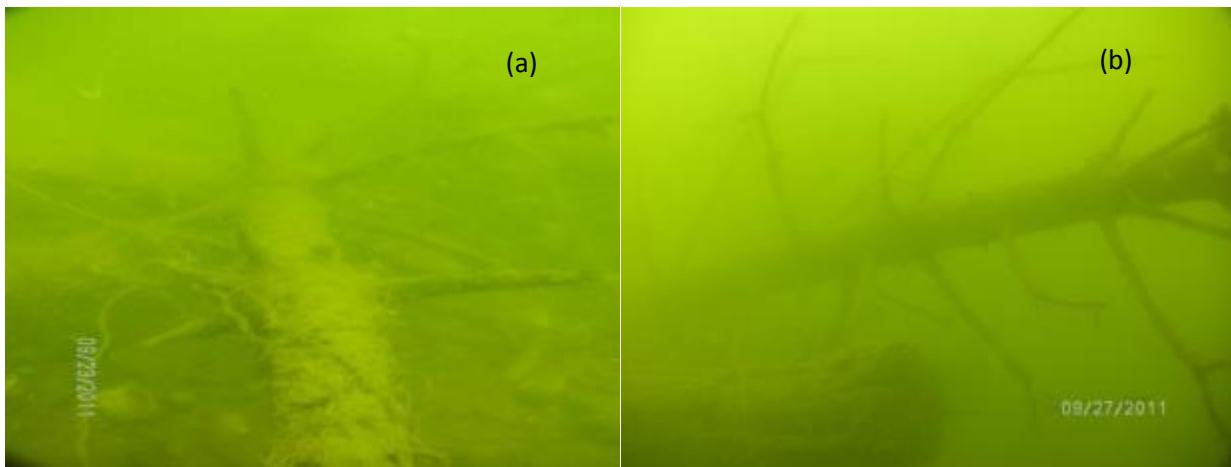


Figure 1.11: Pine tree deterioration in Table Rock Lake. Picture of trees, eight years post installation (a), seven years post installation (b).

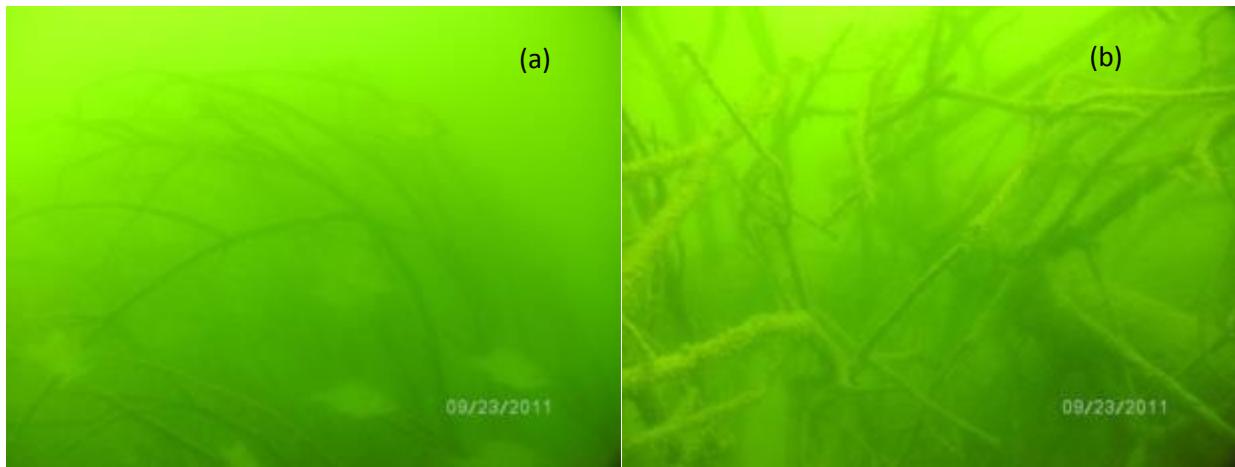


Figure 1.12: Pine tree deterioration in Table Rock Lake. Picture of trees, four years post installation (a), three years post installation (b).

#### *Stumps*

Large stump fields were created using the “rock barge”. These stumps were primarily hardwood stumps including the root ball and substrate material from where the stump was removed (Figure 1.13). The stumps could be small (six inches in diameter) and loaded many at a time, or very large (20”-30” in diameter) to make larger individual structures. The configuration of an individual stump varied from containing just a root ball to having a trunk length of five feet or more. Due to the substantially larger size of the stump structures which projected higher off of the bottom contour, there could be a possibility of stump structures causing navigational hazards to boaters and swimmers. For this reason, MDC and USACE established a minimum depth requirement for placing stump structures. The minimum depth of any structure composed of stumps placed in Table Rock Lake was 10 feet (905 msl) and any stump structure placed in areas of heavy boat traffic would be placed in no less than 20 feet (895 msl). This requirement greatly reduced the chances of these structures creating navigational hazards.



Figure 1.13: Stumps staged on shore before being placed in Table Rock Lake.

Structures composed of stumps were placed by slowly moving the “rock barge” while initiating its hydraulic ram pushing the stumps into the water. This spread the stumps out into a line and increased the benthic area covered. The “rock barge” could also remain relatively still and place the stumps into a pile creating a “mound” of stumps that would increase the height the structures stand in the water column. Marker buoys were placed in the lake by MDC personnel to indicate to the rock barge operator the location to place the structure. To indicate that a line of stumps was desired, two buoys were placed and the structure was spread out in a line between the buoys. A mound of stumps was created by placing stumps adjacent to a single marker buoy. Missouri Department of Conservation personnel observed the structures being placed and immediately marked the center of a structure using sonar and Global Positioning System (GPS) technology.

#### *Rocks*

Rock reef and rock pile structures were also created using the rock barge. Several different types of materials were used to create these structures. The majority of these structures were composed of quarry rock in multiple sizes ranging from 10” diameter up to 40” diameter (Figure 1.14). Structures were also created using concrete materials such as picnic tables, parking slabs, and cooking tables donated by the USACE that were originally used in their parks for campsites.

These structures were placed in the same manner as the stump structures and had the same depth requirements. Rocks placed in a line by moving the barge did not extend very high into the water column and were slightly harder to locate using a typical sonar graph. Rock “fence” structures were also created during the NFHI project. These structures were intended to provide a non-degrading, shallow water structure during certain times of the year, especially the spring spawning season. Table Rock Lake’s shoreline consists primarily of large gravel to boulder size rocks with a majority of the substrate consisting of cobble. This type of substrate can be useful for some species of baitfish and crayfish, but gives very little cover for larger species of fishes. Many of the Table Rock Lake fishing guides noted that fish utilize pre-existing rock fence structures as cover during the spring spawn and any other times when fish are located in shallow water.



Figure 1.14: Rocks staged on shore before being placed in Table Rock Lake.

The rock barge techniques for placing deeper rock type structures in Table Rock Lake did not work for creating shallow water habitat structures. In the late winter and before the spring rains, the elevation of Table Rock Lake can fall as much as 15 feet (900 msl). This situation can allow for terrestrial vehicles to be utilized, traveling along the shoreline on USACE property. Smaller, skid steer type dozer machines were used to move the top layer of cobble sized material into a pile which extended from the approximate conservation pool of 915 msl to the low water level at that time, or at a diagonal towards that water level (Figure 1.15). The rock fence structures

varied in length from 50-100 feet in length and were raised to a height of approximately four feet tall. The length of shoreline that was exposed to useable gravel substrate for the structures varied from 100-300 feet.



Figure 1.15: Complete rock fence structure.

Adding these structures greatly increased the fish holding capability of the substrate and added a structure for baitfish and sport fish to utilize. A second benefit to creating these structures was the removal of the larger cobble substrate and exposing the smaller gravel beneath which increased the amount of potential spawning areas for sport fish.

## Discussion

Many of the types of materials used for this project were due to the availability of materials and relative ease of placement. When considering habitat projects, personnel must take into account the types of material that are available, means of transportation, fish assemblage of the reservoir, substrate in the reservoir, and budget for the specific projects. If possible, using different types of habitat materials to create multiple structure types should be considered to benefit fish and anglers.

When the NFHI project began in 2007, much of the work on placing habitat structures was completed by shoreline cuttings. This method was limited by many factors which made it unsuitable for the project on Table Rock Lake. The USACE Table Rock Project office had

certain restrictions, mostly related to shoreline stabilization and erosion control issues, on the locations available to remove trees from the shoreline. The number of trees that could be taken was limited to only a few trees within each mile of shoreline. This added to the amount of time that it would take to gather sufficient materials to create structures and also increased the amount of on-lake travel time to each structure location. When the proper amount of material was located on the shoreline, all of the personnel on the barge would be involved in removing the trees and placing them on the barge and attaching anchors to them. This also greatly increased the amount of time to create structures. In order to make this process more efficient, contracts were developed through the State of Missouri Office of Administration to enlist a company with skilled equipment operators to handle and transport materials from the surrounding area to staging locations on the lake for habitat placement. Using this type of contract and these types of machines for habitat work should be considered when planning habitat enhancement projects. The operators were very skilled at working with all of types of materials and could handle them with minimal damage, therefore enabling biologists to create structures with very little waste. Using these machines and operators greatly reduced the amount of MDC staff time required to prepare materials for habitat installation. Efficiencies of all of the staff involved increased as the project progressed. Biologists were able to spend more time determining the proper locations for structures to be placed and equipment operators became more knowledgeable in the types of materials and specific equipment needed to manage materials and create habitat structures.

Adding different types of habitat structures to a reservoir such as Table Rock Lake is important since there are many different types of fisheries within the reservoir. The lake contains multiple species of sport fish, and species-specific anglers utilize the habitat resources differently. Many bass and crappie anglers typically use brush structures more than other types of structures. Walleye and catfish anglers tend to concentrate angling efforts more on the rock and stump structures placed in the lake. Each type of material was used to create specific types of structures and orientations to attract multiple fish species and encourage use by a variety of anglers.

One of the main reasons for installing habitat structures in a reservoir is to improve angling opportunities and angler catch rates. As the biologists determine the best biological placement for habitat structures, the knowledge for the most requested and most effective manner of placement for anglers was needed. Focus group meetings were held to gather this input. Anglers

are usually receptive to habitat improvements but are fairly secretive about locations and orientations that could improve fishing. One technique that was developed during these meetings was to create a map of the area where each project was to take place. These maps gave anglers the opportunity to “draw” locations and indicate depths where habitat structures would be most affective to improve angling. These locations were left anonymous so that others would not “steal” certain individual’s locations.

To improve the opportunities for anglers to use the installed habitat structures, each structure was marked using GPS technology. Each of these GPS locations was recorded at the time of habitat placement to ensure the most accurate location information possible. Immediately after a structure had been placed in the lake, the barge driver would move the barge directly over the new structure and record the location on a handheld GPS device. These locations were then downloaded to computers and placed in a database along with information related to each structure including: structure type, installation date, depth, lake region, and number of barge loads taken to the structure. The structure GPS location information was taken to the USACE Table Rock Lake Project Office Geographic Information System (GIS) Specialist who took the raw information and created database and mapping information that could easily be shared with the public. This information was then shared with the MDC GIS specialist who placed it on the MDC website to be easily accessed by the public. The website has also been linked to multiple other public websites related to Table Rock Lake and recreational angling. The address for the Table Rock Lake fish habitat website is: <http://egis.mdc.mo.gov/fishattractorstablerocklake/>. This website has given anglers the opportunity to locate these structures while angling on Table Rock Lake and potentially improved fishing experiences on Table Rock Lake. Fish attractor signs were also placed on the shoreline near 100 of the habitat structures (Figure 1.16).



Figure 1.16: Fish attractor sign placed on Table Rock Lake

These structures were created specifically for fish attractor signs. The structures were mostly cedar tree structures and were made larger than normal structures to be easier to find on normal “fish finder” electronics. Many tourists visit the lake annually and a large percentage of those visitors explore the lake in rental boats that may not be equipped with the best technologies for locating habitat structures. The fish attractor signs provide these anglers with a starting point to improve their angling experience. An additional benefit to placing fish attractor signs is heighten awareness of the project.. These signs are highly visible and many visitors stop and read these signs, therefore increasing their knowledge of fish habitat enhancement efforts on the lake.

### **Objective 2: Improve water quality within Table Rock Lake and its tributaries**

Water quality is a critical component of fish habitat. In addition to improving physical habitat by structure placement, MDC worked to improve the water quality of Table Rock Lake by working in the watershed. Nitrogen and nutrient levels were higher than recommended for Table Rock Lake, which prompted the Missouri Department of Natural Resources to place Table Rock Lake onto the 303d list of impaired waters. The Missouri Department of Conservation in conjunction with other partners, implemented septic tank pump-outs and remediation of failing septic systems in the watershed to reduce nutrient loads leaching into the lake and its tributaries. MDC also worked with landowners to provide a cost share program to stabilize highly eroding

streambanks to reduce the amount of sediment transferred from the watershed to Table Rock Lake.

### **Reduce nutrient loads**

**Gopala Borchelt**  
Executive Director  
Table Rock Lake Water Quality Inc.

#### **Background**

The Septic Pumpout Rebates Program in the local watershed started with the James River Basin Partnership's (JRBP) "Pump-a-Million" initiative to bring public awareness to the need for regularly maintaining septic systems and ensuring long-term effective wastewater treatment. Pumping out septic systems every three to five years will ensure that the drain fields of the systems are not clogged with solids thus causing failure. Through the NFHI project funding, this project was expanded to reach many more residences around Table Rock Lake. From 2007-2013, the NFHI funding offered education and \$50 pumpout rebates to nearly 2,000 homes in the Table Rock Lake watershed. This equated to approximately two million gallons of waste removed from residential septic tanks and properly disposed of at area wastewater treatment facilities. More importantly, the people who participated in this program also received information on how to regularly maintain their septic tanks in the future and help preserve water quality.

Promotion of better alternatives to the failing septic systems in the local watershed was started by Table Rock Lake Water Quality Inc.(TRLWQ) through an Environmental Protection Agency (EPA) grant project (2002 to 2007) testing various types of onsite wastewater systems. This project installed and monitored systems to determine the best system to install around Table Rock Lake. Table Rock Lake Water Quality, Inc. found that the best system in the shallow and non-existent soils surrounding the lake was a pre-treatment tank with a drip irrigation drain field. This type of system pre-treats the wastewater by introducing air into the system to promote the growth of aerobic bacteria that is much more efficient in breaking down the waste than the anaerobic bacteria normally found in traditional septic tanks. The wastewater is then pressurized using pumps to regularly saturate a drain field, often installed into imported soils, to spread out the liquid and capture nutrients in the soil and plants. This type of system also requires electrical

power to run the air inputs and pumps as well as additional maintenance that includes regular cleaning of the filters and drip irrigation lines. In conjunction to the septic study project (Onsite Wastewater Demonstration Project), TRLWQ also worked with the Stone County Health Department, the local wastewater regulator, to promote education about regular maintenance and better wastewater treatment systems for the Table Rock Lake watershed. This led to the promotion and adoption of an ordinance in Stone County that requires a septic system inspection and provision for any needed repairs at the time of transfer of ownership of property. This ordinance went into effect in 2009 and has been very successful in promoting the remediation of failing systems in the County.

### **Cooperators**

The NFHI funding allowed for excellent partnership activities to develop in the Table Rock Lake watershed to help protect water quality. Table Rock Lake Water Quality Inc. and JRPB have worked together on water quality issues involved with onsite wastewater treatment systems or septic systems. Both organizations are non-profit and are dedicated to protecting water quality and providing public education about our local water resources. Through this partnership, JRPB and TRLWQ conducted educational visits with citizens resulting in almost 2,000 septic tanks pumped out as a continuation of the “pump-a-million” campaign to encourage this essential, but often lacking, regular maintenance of home wastewater systems. In addition, TRLWQ was able to provide cost-share funding for ten critically failing wastewater treatment systems near the lake to be replaced with adequate systems for wastewater treatment.

Ozarks Water Watch (OWW), a nonprofit foundation dedicated to protecting the Upper White River, also entered a partnership with TRLWQ using the NFHI funds to provide no-interest loans and grants to people in the watershed that needed to replace or repair failing septic tanks. Through this partnership, OWW was also able to leverage one million dollars of additional funding from the Missouri Department of Natural Resources through the state revolving fund for wastewater treatment systems. This has allowed the local partnerships to help replace or repair and additional 51 failing septic systems in the Table Rock Lake watershed through this partnership. Table 2.1 shows the contracts, costs and numbers of septic systems pumped out or remediated.

Table 2.1: Septic tank pump-out and remediation costs and figures.

MDC-TRLWQ-JRBP contract agreement period	Septic Tank Pumpouts, Education and \$50 Rebates	Septic Tank Replacement or repairs (Cost-share)	Cost to NFHI Project (MDC contract)	Matching DNR SRF funding	Matching private \$
July 1, 2011 to July 1, 2013	300	51	\$175,000	\$172,965.76	\$291,710.24 (\$75 per pumpout)
March 2010 to October 2010	110	10	\$57,000		\$77,076.14
July 2008 to July 2009	700		\$55,100		\$52,500 (\$75 per pumpout)
April 1, 2008 to Sept 2008	225		\$15,750		\$16,875 (\$75 per pumpout)
July 2007 to March 2008	530		\$31,000		\$39,750
<b>Totals</b>	<b>1,865</b>	<b>61</b>	<b>\$333,850.00</b>	<b>\$172,965.76</b>	<b>\$477,911.38</b>

## Methods

Table Rock Lake Water Quality, Inc. and JRBP advertised in local papers and on local television about the septic pumpout rebate programs. The public would call the JRBP offices and set up appointments to have a staff person visit with them at their home. This visit would include a presentation on the benefits and procedures of properly maintaining septic systems, including the protection of drinking water and surface waters. A rebate tracking form was then signed and presented to the homeowner with a list of local pumping contractors and instructions to use a contractor from the list and also have the contractor complete the rebate tracking form. Pumping contractors on the list for the rebate program were those which agreed to allow JRBP or TRLWQ to check with the establishment or wastewater treatment facility that they take their waste load to and confirm the reception of this load from the contractor. This was to ensure that the pumpout program was not allowing for illegal dumping of waste in the watershed. In addition to the pumpout rebate form, homeowners also answered a few survey questions about septic systems

and water quality in order to gauge the public knowledge of how these two items were connected and affected each other.

Table Rock Lake Water Quality, Inc. and OWW worked with local county health departments and septic system contractors to advertise the septic remediation assistance. Once a homeowner in need of this assistance contacted OWW, their personnel dedicated to this program worked with them to determine financial need, structured a loan or grant agreement, and coordinated with a licensed contractor to do the work. Depending on the homeowner's income, up to 90 percent of the cost was funded utilizing either grant, or a no-interest loan. Any loan money paid back by the homeowners that participated in this program was then reinvested into assistance for additional homeowners for septic remediation.

### **Benefits**

The main benefits of the septic remediation and pumpout programs were the increased awareness of the impact to water quality that a failing septic system, or other wastewater treatment system, could have. One of the survey questions asked as part of the septic pumpout rebate process was, "Where you aware that not maintaining your septic system could cause water quality problems and lateral line failure?" Thirty-three percent of participants from 2007 through 2008 indicated they were unaware of this water quality connection and the need to maintain a septic system prior to participation in the project (Figure 2.1). Through a massive media and word-of-mouth campaign on septic maintenance and wastewater treatment associated with this project, the answers to this same question began to change. In the 2010 survey results, only one percent of the participants did not know that lateral system failure and water quality problems could result from lack of maintenance of their septic system (Figure 2.2).

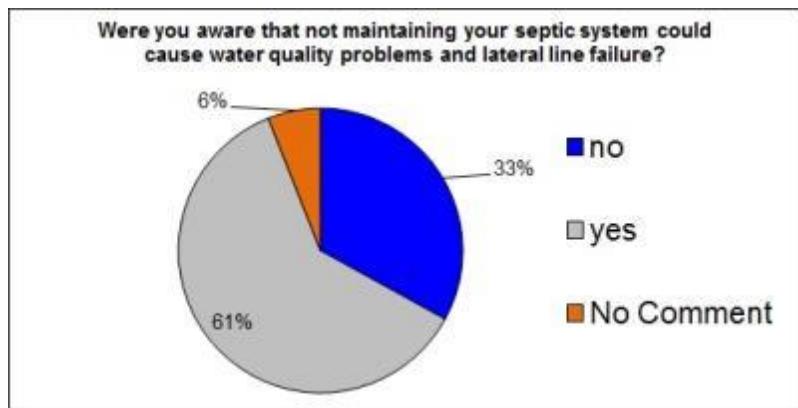


Figure 2.1: Survey results from pumpout program 2007-2008.

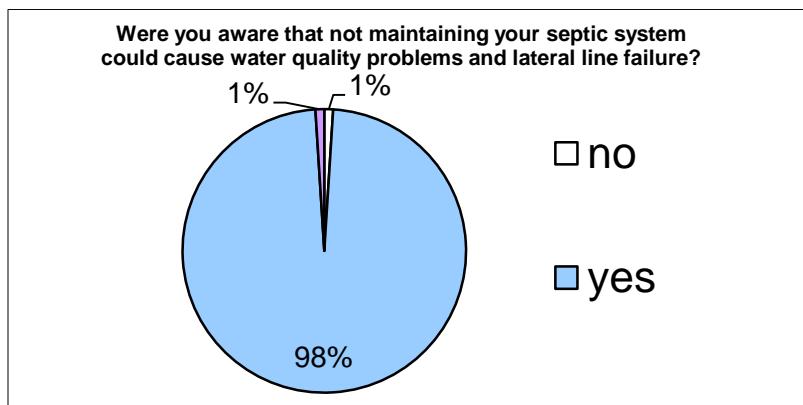


Figure 2.2: Survey results from pumpout program 2010.

Another benefit of this program was the removal of potential nutrient contamination into Table Rock Lake and its tributaries posed by numerous failing septic tanks. This project has potentially prevented nearly 550 pounds of nitrogen (ammonia) and 120 pounds of phosphorus per year from entering the tributaries and Table Rock Lake. This amount of nutrient has the potential to provide for the growth of 12,000 pounds of “blue-green” algae (cyanobacteria) per year.

#### **Reduce sediment transfer**

**Michael Allen**  
 Fisheries Biologist  
 Missouri Department of Conservation

Sediment transfer is an issue that many reservoirs are experiencing. Due to urban sprawl and improper land use management, many reservoirs have experienced sedimentation to levels high

enough to affect aquatic organism movement and create terrestrial environments that divide reservoirs into smaller sections. One of the goals of the NFHI project was to reduce sedimentation into the Table Rock Lake watershed. A cost share program of up to 95 percent was initiated to repair highly eroding stream banks in the Table Rock Lake watershed. The projects that were completed using NFHI funding were engineered to be the most effective at stabilizing the streambanks and therefore minimizing erosion and sediment transfer.

## **Methods**

Landowners in the Table Rock Lake watershed were given the opportunity to participate in cost share projects of up to 95 percent through the Table Rock Lake NFHI project. Landowners with highly eroding streambanks could contact MDC personnel and request a consultation. Biologists and MDC Stream Unit staff would meet with the landowners and determine if a streambank stabilization project was feasible. Many landowner visits resulted in the recommendation to improve riparian corridor repair through tree plantings and restrict livestock access to the stream, rather than install a bank stabilization structure.

Through NFHI funding, eight streambank stabilization projects were completed in the Table Rock Lake watershed (Figure 2.3). With the cooperation of the landowners, MDC contracted engineers to survey the erosion and develop the methods for stabilizing the streambanks. The cooperating landowners signed an agreement with MDC that required them to plant a riparian buffer of at least 100 feet, remove and restrict livestock from the planting and stabilization project, and maintain these practices and the project for 30 years. Each project was intended to stabilize the eroding section of streambank but completing these projects in this manner “locked” in many more miles of riparian corridor. Each of these streambank projects was built by MDC Design and Development Division personnel using MDC equipment.

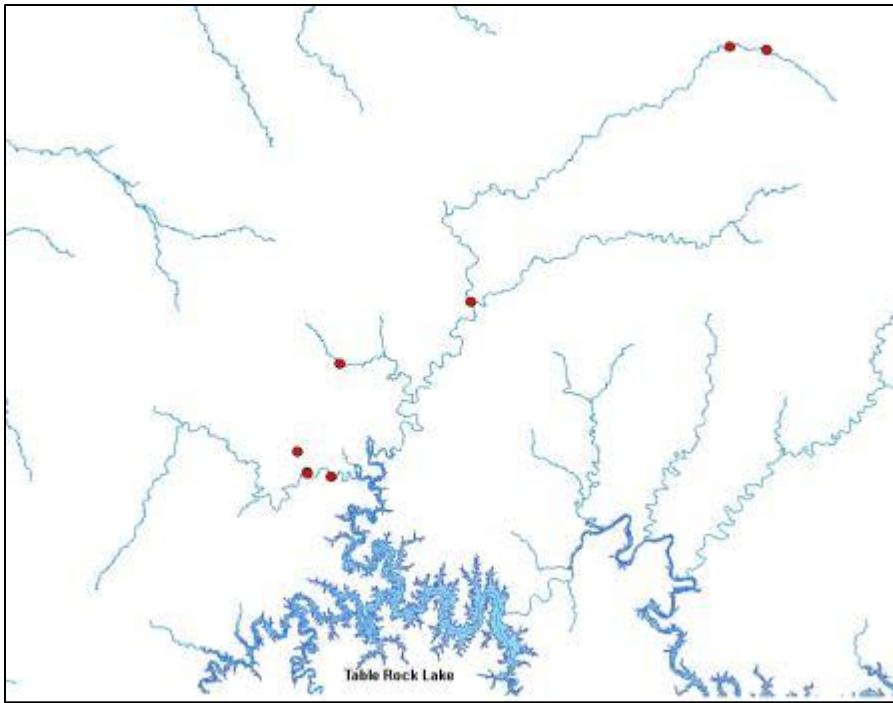


Figure 2.3: Map of NFHI streambank projects within Table Rock Lake watershed.

*Bank Stabilization Project Number 42-54-00*

This project was located in Stone County, Missouri. The eroding bank was located at the confluence of the James and Finley rivers. This area had become very unstable due to removal of riparian vegetation. The area had also been routinely mowed and vehicles had been allowed to access areas near the streambank. The streambank of concern was an 80 feet long section of bank (Figure 2.4) that had become vertical and had heights of up to six feet.

The stabilization design for the project was to stabilize the entire 80 feet of streambank with a rock blanket. This type of protection covered the entire length and height of the streambank to eliminate additional streambank erosion. After the rock blanket was installed and the toe of the streambank had been stabilized, riparian corridor plantings began. Corridor plantings extended 100 feet from the shoreline, or as far as needed to connect to existing corridor. This project reduced the amount of sediment being transferred downstream by eliminating the erosion taking place in this area. This project also increased the amount of connectivity of riparian corridor in both the James and Finley rivers.



Figure 2.4: Pictures of streambank before and after completion of stabilization of project 42-54-00.

*Bank Stabilization Project Number 42-54-01*

This project was located in Webster County, Missouri on the upper James River. This streambank had become very unstable and was experiencing accelerated erosion after high flow events in 2008. The riparian area surrounding the 150 foot long streambank (Figure 2.5) was devoid of suitable woody vegetation and root mass to maintain the stability of the bank. The streambank of concern had heights of near 12 feet and was becoming near vertical or undercut in places.

This project was stabilized using longitudinal peak stone toe protection (LPSTP) along the entire eroding streambank as well as two 25' X 6' X 3' bendway weirs to divert the stream channel away from the unstable bank to slow the flow of water that could reach the bank. Once the project was in place, the landowner planted riparian trees and shrubs to increase and repair the riparian corridor in this area.



Figure 2.5: Pictures of streambank before and after completion of stabilization of project 42-54-01.

#### *Bank Stabilization Project Number 42-54-02*

This project was located in Stone County, Missouri on Flat Creek which flows into Table Rock Lake. This bank had become very unstable due to the removal of riparian vegetation suitable to protect the bank from erosion during high flow events. The landowner had experienced accelerated soil loss due to a nearby power line right-of-way that had been treated with herbicide to remove trees, instead of being selectively trimmed. A combination of the loss of bank-holding vegetation and high flow events in 2008 accelerated the bank erosion. The project was 400 feet long (Figure 2.6) and had heights of up to ten feet.

This project was stabilized by creating a rock vane located in front of the streambank to re-direct the flow away from the streambank. Along with the rock vane, four bendway weirs were created to re-direct the flow away from the bank and also reduce the amount of energy from stream flows. LPSTP was installed to stabilize the streambank further. Once the project was complete, the landowner, along with MDC personnel, planted the riparian corridor with a 100 foot buffer of native trees and shrubs behind the stabilization project.



Figure 2.6: Pictures of streambank before and after completion of stabilization of project 42-54-02.

#### *Bank Stabilization Project Number 42-54-03*

This project was located in Webster County, Missouri in the James River. The landowner had two different streambanks on his property that had experienced accelerated erosion. The landowner had previously attempted to reduce the amount of erosion in the areas by planting a woody riparian corridor. Unfortunately, high flow events in 2008 destroyed the trees before roots suitable to stabilize the bank could become established. The streambanks had a combined length of 950 feet (Figure 2.7) and heights near ten feet.

The upper portion of this project was engineered and stabilized by installing three bendway weirs and one rock vane to direct the flow of the river away from the eroding shoreline and back to the main channel. In addition, LPSTP was installed in the outside bend of the river to further protect the streambank. These engineered structures also collect sediment and gravel along with reducing the intensity of flows during flood events.

The lower portion of this project was engineered and stabilized by installing two bendway weirs and one rock vane to direct the flow of the river away from the eroding shoreline and back to the main channel. These engineered structures also collect sediment and gravel along with reducing the intensity of flows during flood events. Along with the engineered rock structures on both

sections of streambank, willow stakes and other riparian trees and shrubs were planted to hold the soils that could experience additional erosion. These additional trees accompanied the existing plantings to form a mixed age riparian corridor.



Figure 2.7: Pictures of streambank before and after completion of stabilization project 42-54-03.

#### *Bank Stabilization Project Number 42-54-04*

This project was located in Barry County, Missouri on Carney Creek. Carney Creek is a tributary of Flat Creek, which flows into Table Rock Lake. The landowner had attempted to repair his eroding bank by armoring the bank with large boulders and chunks of concrete. After realizing that the methods used were not sufficient, the landowner requested assistance from MDC to determine a better solution to the problem. The unstable streambank was 740 feet long (Figure 2.8) and had heights of approximately three feet. The eroding streambank had become an issue not only with the landowner, but had implications for a power company and the county road department. The electric company had relocated power poles before the erosion caused the loss of the poles and damage to the power lines. The streambank was also becoming an issue to the road department as the eroding bank was causing concern with a road bridge over the creek.

This project was stabilized by using an upstream rock vane to divert flow back into the main channel and slow down major flow events. The project was also engineered to utilize LPSTP on both sides of the stream to reduce erosion on the landowner's and county's road side of the stream. The landowner planted a 100 foot corridor of riparian trees and shrubs behind the stabilization project to further reduce the loss of soil.



Figure 2.8: Pictures of streambank before and after completion of stabilization project 42-54-04.

#### *Bank Stabilization Project Numbers 42-54-09 and 42-54-10*

Projects 42-54-09 and 42-54-10 were located in Barry County, Missouri on Flat Creek. These two projects were completed in conjunction with each other as the two landowners had eroding banks directly across the creek from one another. The decision was made to stabilize both banks at the same time as completing one project alone would definitely alter the other bank dramatically. The streambank on project 42-54-09 (Figure 2.9) was very tall (up to 12 feet) and 350 feet long. This streambank was visited by MDC Stream Unit staff in 2007 but was not determined to be eroding at a rapid rate. Significant flooding in 2008 altered the streambank directly across the creek which in turn caused accelerated erosion to occur at this site. The streambank on project 42-54-10 (Figure 2.10) was experiencing accelerated erosion issues before

the major floods of 2008. Project 42-54-10 had a length of 450 feet, bank heights of up to 12 feet, and a sharp bend in the bank which was rapidly eroding and pushing flows directly against the adjacent bank, 42-54-09. The riparian corridor of both of these streambanks had been removed for many years, which led to the bank instability. LPSTP and bendway weirs were designed into both projects to reduce flow velocities and protect both banks simultaneously. A large gravel bar had been deposited in the middle of the stream between both projects. The projects were also designed to move the channel away from the streambanks, scour the gravel bar and move the sediment to the sides of the channel near the streambank. Both landowners worked with the Natural Resources Conservation Service to plant 100 foot riparian corridors on both streambanks behind the stabilization projects.



Figure 2.9: Pictures of streambank before and after completion of stabilization project 42-54-09.



Figure 2.10: Pictures of streambank before and after completion of stabilization project 42-54-10.

#### *Bank Stabilization Project Number 42-54-11*

This project was located in Stone County, Missouri on Crane Creek. At this site, Crane Creek is a 4<sup>th</sup> order stream with highly variable flows and high flow events from the floods of 2008 had

seriously impacted the streambank on this property. Crane Creek is also an MDC Blue Ribbon Trout Area that has a naturally reproducing Rainbow Trout population. Two areas on this property were of concern to the landowner, but only one was determined to be suitable for a stabilization project. This area of the stream had experienced major erosion from high flow events and a lack of riparian vegetation. The stream channel had changed dramatically and created a large “hook” in the bend. The landowner had lost approximately 130 feet of land after the flooding in 2008. This eroded streambank was 400 feet long (Figure 2.11) and had bank heights of six to ten feet.

The landowner had attempted to reduce the erosion by excluding cattle from the area and allowing the vegetation on the streambank to grow. Even with this effort, the streambank was not stable enough to withstand the high flows of 2008. Engineers from MDC surveyed the streambank and determined that the best course of action would be to try and recreate the original streambank utilizing LPSTP, creating baffles behind the channel to dissipate flows and allow sediment to collect before reaching the unstable portion of the streambank. The landowner also worked with MDC to plant a 100-foot riparian buffer of trees and shrubs to help maintain the streambank behind the rock improvements.



Figure 2.11: Pictures of streambank before and after completion of stabilization project 42-54-11.

## Results

Through the Table Rock Lake NFHI project, eight streambank erosion control projects were completed (Figure 2.3). Each of these projects utilized rock-based streambank stabilization techniques and included the planting and maintenance of a riparian buffer for a minimum of 30 years. The combined total linear footage of streambank stabilized was 3,610 feet (Table 2.2).

With the riparian corridor plantings for each project, many more miles of continuous riparian corridor was created.

Table 2.2: Costs of NFHI streambank projects and linear footage of reduced erosion.

<u>Project</u>	<u>MDC Cost</u>	<u>Total feet of streambank</u>
42-54-00	\$7,690.00	80
42-54-01	\$33,399.42	240
42-54-02	\$37,196.43	400
42-54-03	\$41,750.31	950
42-54-04	\$22,587.24	740
42-54-09	\$53,656.59	350
42-54-10	\$32,308.72	450
42-54-11	\$25,649.69	400
<b>TOTAL</b>	<b>\$254,238.40</b>	<b>3,610</b>

### **Objective 3: Improve water quality and habitat within Lake Taneycomo**

**Michael Allen**  
Fisheries Biologist  
Missouri Department of Conservation

#### **Background**

Lake Taneycomo was formed by the construction of Powersite Dam in 1913 and is Missouri's oldest hydroelectric reservoir. The lake is owned and operated by Empire District Electric Company (EDEC), and the fishery is managed by MDC. The USACE, in cooperation with Southwestern Power Administration (SWPA), controls the flow of water through Table Rock Dam where Lake Taneycomo begins. Lake Taneycomo is riverine in nature, 22 miles in length and encompasses 2,080 surface acres. Prior to 1958, it supported a valuable warm-water fishery. This changed in 1958 when Table Rock Dam was completed to create Table Rock Lake. Table Rock Dam began discharging cold, hypolimnetic water from Table Rock Lake into Lake Taneycomo. The discharge of cold water changed Lake Taneycomo into a cold-water environment, providing conditions for coldwater fish species such as trout.

Rainbow Trout (*Oncorhynchus mykiss*) and Brown Trout (*Salmo trutta*) were first stocked into Lake Taneycomo in 1958 and 1980, respectively. Since that time, more than 20 million Rainbow Trout and 375,000 Brown Trout have been stocked. Lake Taneycomo is Missouri's largest and most popular trout fishery. It annually receives in excess of 140,000 fishing trips and anglers catch an estimated 500,000 trout annually. The economic value of Lake Taneycomo is conservatively estimated at 15 million dollars (Vitello 2002).

Water levels in the upper reaches of Lake Taneycomo are controlled by releases for hydroelectric power generation from Table Rock Dam except for flood control operations when water is released over the spillway. Table Rock Dam has four hydroelectric generators which release water into Lake Taneycomo. Water levels and flows fluctuate depending on the number of generation units that are in operation. Water levels can fluctuate up to ten feet on a daily basis (700-710 msl). Discharge can also range from 200 to 15,100 cubic feet per second (cfs) daily.

### **Improve Water Quality**

Historically, Table Rock Lake has experienced dramatic lake stratification during the late summer and autumn reducing dissolved oxygen (DO) levels to less than four milligrams per liter (mg/L) near the dam turbine intakes for time periods of up to five months. During this period, water being released can contain DO levels low enough to cause concern to the downstream aquatic life in Lake Taneycomo. This reduction of DO levels in Lake Taneycomo prompted the Missouri Department of Natural Resources to list the lake on the 303d list of impaired waters in Missouri for low dissolved oxygen. During these periods of low DO, the turbines in Table Rock Dam have been operated at reduced capacity to aspirate air through the vacuum breaker system. This can increase the DO levels in the tailwater significantly, but is costly due to reduced efficiency and loss of peak capacity. The SWPA markets power generated at this dam and other projects in the region. Four, 50-megawatt per hour (MWh) generating units provide approximately 640,000 MWh annually. The typical peak flow for the facility is 13,000 cfs. The maximum turbine discharge is 15,100 cfs. Table Rock is also utilizing an existing oxygen system, which injects liquid oxygen into the penstocks of Table Rock Dam. The penstock aeration system has an estimated efficiency of 50 percent oxygen transfer. It was reported that the Table Rock Dam project office was injecting 2.5 tons of oxygen per hour to add 0.5 mg/L to

the reservoir releases of 13,000 cfs, which equates to an oxygen flow rate of approximately 1,000 standard cubic feet per minute (scfm).

This level of aeration and oxygen injection had proven to be insufficient to maintain the required four mg/L DO in the upper reaches of Lake Taneycomo without damaging effects to the efficiencies of power generation through Table Rock Dam. At DO levels below four mg/L, chronic negative effects on trout can occur. Proctor et al. (1999) determined that the most effective method of improving DO in Lake Taneycomo was to install a forebay liquid oxygen diffuser system in Table Rock Lake. Utilizing Table Rock NFHI project funding, MDC and USACE requested the Tennessee Valley Authority (TVA) conduct a feasibility study for a forebay liquid oxygen diffuser system in Table Rock Lake. Aeration diffuser systems have been in operation at other projects since 1993 and have been installed in ten TVA reservoirs, one Duke Energy project, and one USACE project (Perry 2009). These systems were reported to achieve efficiencies of 85-90 percent oxygen transfer. The system that was proposed for Table Rock Lake would increase the DO levels released from Table Rock Dam to at least six mg/L, 97 percent of the time during the low DO season. The line diffuser is a two-pipe system, consisting of a gas supply header pipe and a buoyancy chamber pipe (Figure 3.1).

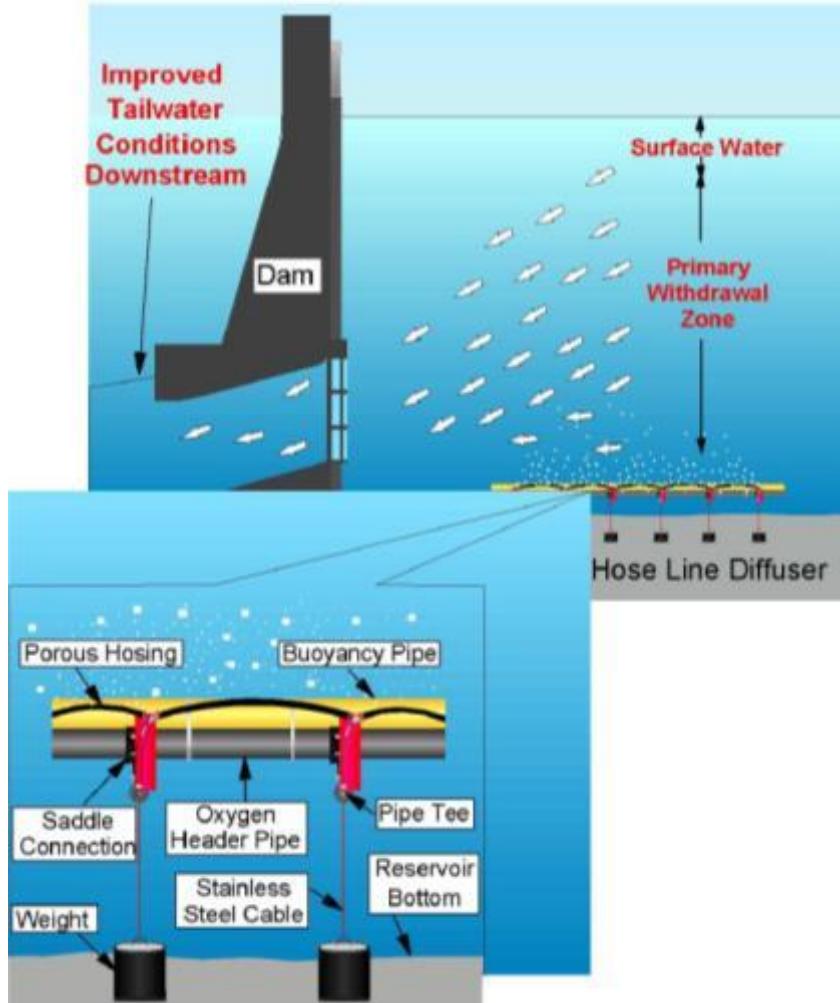


Figure 3.1: Oxygen diffuser line setup.

Once installed near the bottom of the lake, oxygen can be pumped through the supply pipe and diffused into Table Rock Lake, in areas upstream of the intake pipes of Table Rock Dam. This diffuser system should add approximately 1.5 mg/L of oxygen to turbine releases of 13,000 cfs, with the same oxygen flow rate as penstock injection. A forebay liquid oxygen diffuser would be approximately three times more efficient than the penstock injection system.

The optimum target of DO releases from Table Rock Dam was six mg/L, which is the required minimum water quality criterion for coldwater fisheries. The minimum target of four mg/L is the threshold for chronic negative impacts. This study proposed three options for oxygen diffuser systems. Option 3 was determined by TVA to be the best option for Table Rock Dam and Lake Taneycomo.

Option 1: 40 tons of oxygen per day or 700 scfm system.

This system would be capable of meeting the target DO of six mg/L, coupled with turbine venting, 90 percent of the time during the low DO season.

Option 2: 100 tons of oxygen per day or 1600 scfm system.

This system would be capable of meeting the target DO of six mg/L, coupled with turbine venting, 100 percent of the time during the low DO season.

Option 3: 72 tons of oxygen per day or 700-1200 scfm system

This system would be capable of meeting the target DO of six mg/L, coupled with turbine venting, 97 percent of the time during the low DO season.

This study provided a comprehensive look at one of the most promising options for improving DO levels in upper portions of Lake Taneycomo.

#### **Improve habitat in Lake Taneycomo**

**Michael Allen**  
Fisheries Biologist  
Missouri Department of Conservation

Managing Missouri's coldwater habitat for a diversity of high-quality, sustainable fisheries is an important responsibility of the Missouri Department of Conservation (Kruse et. al. 2003). The upper mile of Lake Taneycomo contains minimal adult trout habitat, yet it receives the highest amount of fishing pressure in the entire lake (Kruse 2003). This area is managed for large trout and remains very popular among wade anglers and fly-fishing enthusiasts. Periods of heavy hydropower generation increase the water flow in this area, leaving trout vulnerable to swift currents and limiting fishing access for wade and bank anglers. Deeper pools, overhead structure and feeding niches are limited. The installation of boulder clusters should provide trout with additional areas for resting and feeding (Shuler et al. 1994). In addition, these structures will provide anglers with more accessible fishing habitat during all periods of generation. Habitat structures should also create scours directly downstream, increasing habitat and holding areas for trout and in turn, increasing angler success (Hunt 1988).

## **Background**

Through meetings and correspondence with the USACE, SWPA, and EDEC, MDC was given the appropriate permissions and permits to proceed with the habitat project on upper Lake Taneycomo. A meeting was conducted between MDC and AGFC biologists to gain additional knowledge of the projects that were completed in the tailwaters of Beaver Lake and Bull Shoals Lake dams in Arkansas. Information was shared regarding regulations and limitations by the USACE and SWPA. Biologists from AGFC provided information on the logistics of structure installation and stated that public views of the habitat were good and that anglers had been catching fish near the installed habitat.

In addition to meetings held between government and non-government agencies, MDC biologists also conducted a public meeting with local trout anglers, guides, and other interested parties to obtain more information and gauge public perception of habitat placement in upper Lake Taneycomo. Overall, anglers were supportive of trout habitat improvements and offered suggestions on habitat placement locations and design of the habitat structures.

## **Methods**

Large boulders and woody structures have been used as trout habitat improvements for many years including recent projects below the Bull Shoals Lake and Beaver Lake Dams in Arkansas. Quinn and Kwak (2000) noted that Rainbow Trout distribution shifted into the modified reaches after habitat structures were installed into the Beaver tailwater. Boulder clusters have historically been effective in increasing the density of salmonid populations, and have been preferred by Brown Trout when compared to single boulders and wingdams (Van Zyll De Jong et al. 1997; Shuler et al. 1994). Boulder clusters placed in areas that remain inundated at all generation levels were used to create fish habitat below Table Rock Dam. Boulders measured approximately three to six feet in diameter and were placed in the lake using a 200 class, 45,000 pound excavator (Figure 3.2). Boulders were delivered to areas near the shoreline to reduce the amount of in-stream travel by the excavator. The materials were also transported and organized by a 605 class dozer outside of the water line, when possible (Figure 3.2).



Figure 3.2: Machines used for Lake Taneycomo habitat project.

The operator and biologists monitored the travel paths to ensure that minimal disturbance of the original substrate occurred. In-stream travel was also limited to the more compacted gravel areas when possible.

Boulder complexes were composed of three to five boulders for each structure (Figure 3.3) and varied in design based on environmental conditions and placement locations.



Figure 3.3: Lake Taneycomo habitat boulder cluster.

A variety of depths and areas were utilized for placement of structures. Some boulder complexes were concentrated in the thalweg portion of the channel in order to create scours and restore areas that had been filled in with gravel over time. Other boulder complexes were placed along the wetted perimeter at zero units of generation in order to create fishable habitat during periods of zero to two units of generation. Areas of loosely compacted gravel were given preference for placement of the boulders, allowing the increased velocity to more effectively scour and increase water depth.

Water levels and flows rise and fall dramatically in Lake Taneycomo depending upon the number of generators in use at Table Rock Dam. Many boaters wait until two or more generators have been turned on before they boat to areas near the dam. Habitat structures were placed in areas least likely to be travelled by boaters and/or in areas where they were submerged when two or more generators are in use.

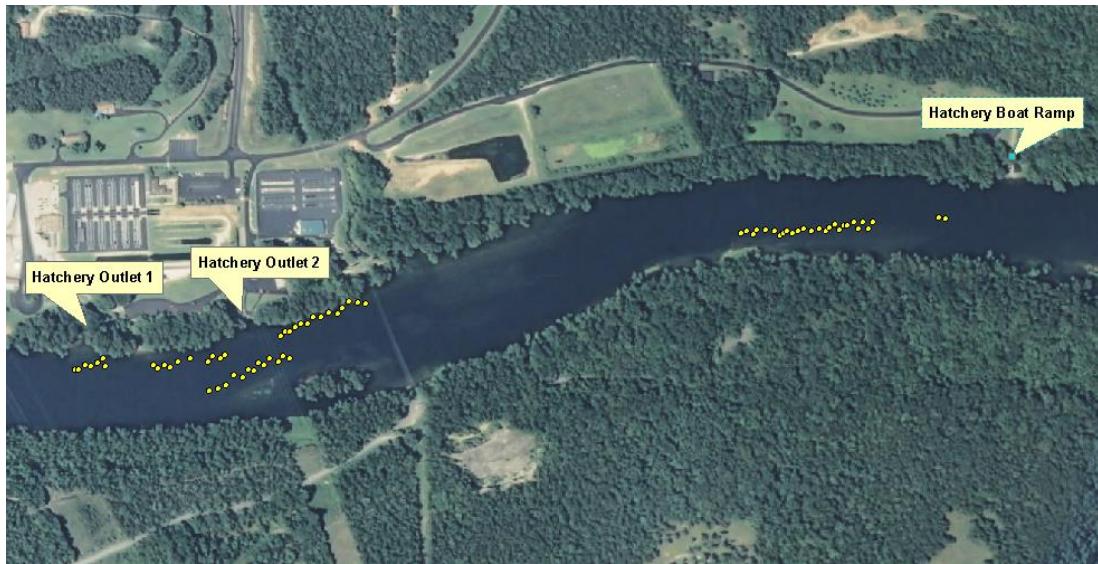


Figure 3.4: Lake Taneycomo habitat locations (GPS).

Additionally, structures were placed a minimum of 30 feet apart to ensure boating safety (Figure 3.4). Signs warning boaters of new habitat structures and boating hazards were also posted at boat ramps lakewide (Figure 3.5)



Figure 3.5: Lake Taneycomo habitat information sign.

## **Cooperators**

Cooperation between the many agencies involved with water level and natural resource management was key to the success of this habitat project. Permits for installation of the habitat structures were obtained from USACE and the Missouri Department of Natural Resources. Permission was granted from USACE and also Shepherd of the Hills Fish Hatchery personnel to stage the materials on the shoreline near the lake.

The EDEC had issued a special operations request from the USACE and SWPA for low, near zero, generation during the time frame of this project to perform repairs and additions to the outside of Powersite Dam. Using this request allowed all parties involved to complete two large projects during the same time period and allowed for a reduction of the impact to water quality, fisheries, flood risk management and power generation.

## **Benefits**

Adding in-stream habitat to Lake Taneycomo provided resting and feeding niches for trout at different water levels and flows. This habitat also created additional fishing areas for anglers, which should lead to increased angler use (Hunt 1971). Reports from anglers indicate that the most effective conditions to fish these structures are when Table Rock Dam is operating one or two generators (flow levels). These structures should increase the depth in smaller, more specific areas of the tailwater by scouring the gravel in the areas adjacent to the clusters. This project helped to reduce crowding of anglers and diversified fishing opportunities.

## **Objective 4: Monitor the effectiveness and longevity of structures and projects employed**

The Table Rock Lake NFHI project was a pilot project focused on habitat enhancement and restoration in large reservoirs. Because substantial effort, time, and money were directed toward this project through many different partners and agencies, evaluation of the techniques used on this project was a high priority. The results from this project needed to be evaluated to give MDC and partners the proper answers to questions regarding the techniques used. A primary goal of this project was to answer questions about the effectiveness of large scale habitat restorations on reservoirs. Information needed to be gathered related to increased production of sport fishes, congregation of fish to specific areas, species use of different habitat types, and

angler catch rates and opinions of habitat types and placement. MDC Fisheries and Resource Science divisions worked together to answer as many of these questions as could be answered and determined four different techniques to evaluate this project. Treatment and monitoring of standardized electrofishing coves was selected to monitor the ability of habitat enhancements to congregate fish to specific areas of the lake. SCUBA survey techniques were selected to monitor the effectiveness of the different types of structures to attract bass and crappie. A bio-telemetry study was selected to track movements and habitat use of Largemouth Bass on a daily and annual basis. Finally, two angler surveys have been created to obtain angler opinions and catch rates regarding habitat placement.

### **Electrofishing**

**Michael Siepker**  
Resource Scientist  
Missouri Department of Conservation

Typical of an aging reservoir, there has been a precipitous decline in the abundance of fish habitat in Table Rock Lake since its impoundment. As existing woody cover deteriorates, fish are left with a bottom substrate composed primarily of limestone rock and gravel with little to no aquatic vegetation or woody cover. Annual water levels vary from 895 to 935 msl as a result of the flood control authorization and hydropower demands. These fluctuations occasionally allow shoreline terrestrial herbaceous vegetation and hardwood trees to become available to fish as shoreline habitats are inundated during high water periods. High water periods on large reservoirs have been shown to increase recruitment in Largemouth Bass (Ploskey et al. 1996; Siepker and Michaletz 2013). At this time, it is not known if enough habitat structures can be installed in littoral waters to mimic the increased availability of cover that occurs during high water. If biologists are able to attract adults, increase nesting, and ultimately recruitment, adding habitat structures to shallow littoral areas may be a way to improve recruitment of sport fish during years of low or average water levels. The specific objectives of the electrofishing evaluation included: 1) comparing catch rates of sport fish in coves with and without installed habitat structures, and; 2) comparing the size structure of sportfish in the coves with and without installed habitat structures. Understanding how placement of habitat structures in reservoirs affects the fishery is important to successful management. To that end, the results of this study

will be useful for providing management agencies with direction for placing habitat structures to maximize their benefit for reservoir fisheries.

## Methods

Annual electrofishing surveys have been conducted on Table Rock Lake since 1975 as part of a long-term fish population monitoring program. Electrofishing survey methods used on Table Rock Lake have remained consistent through time. An electrofishing control box (Type VI-A, Smith-Root, Inc.) set to produce 530 volts and operating within a range of four to five amps was operated on a 19-foot aluminum boat fitted with two Wisconsin-style ring anode arrays with 10 stainless steel droppers each and the boat hull acting as the cathode. Electrofishing crews always consisted of two netters and a boat operator and followed MDC standard protocols for reservoir sampling (Jennings 1987). In general, electrofishing crews would sample parallel to the shoreline at fixed sites within the reservoir during the spring spawning season when water temperatures ranged from 13°C to 24°C (55° to 75°F).

For this evaluation, a subset of all coves sampled as part of the long-term fish population monitoring program on Table Rock Lake were selected to receive treatments of shallow water habitat structures while others were designated as controls. Coves were selected in the James River ( $N = 4$ ; Figure 4.1), White River ( $N = 4$ ; Figure 4.2), Kings River ( $N = 6$ ; Figure 4.3), and Long Creek arms of the lake ( $N = 2$ ; Figure 4.4).

### James River Arm Sampling Coves

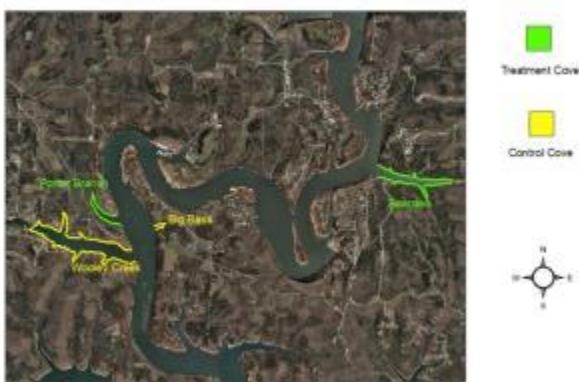


Figure 4.1: A map showing long-term electrofishing coves within the James River Arm of Table Rock Lake. Those selected to receive habitat treatments are shown in green whereas those serving as controls are outlined in yellow.

## White River Arm Sampling Coves



Figure 4.2: A map showing long-term electrofishing coves within the White River Arm of Table Rock Lake. Those selected to receive habitat treatments are shown in green whereas those serving as controls are outlined in yellow.

## Kings River Arm Sampling Coves

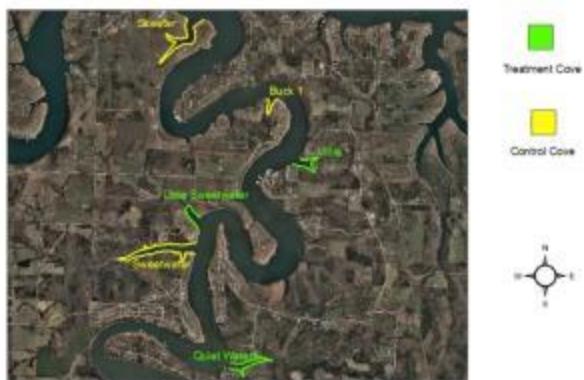


Figure 4.3: A map showing long-term electrofishing coves within the Kings River Arm of Table Rock Lake. Those selected to receive habitat treatments are shown in green whereas those serving as controls are outlined in yellow.

## Long Creek Arm Sampling Coves



Figure 4.4: A map showing long-term electrofishing coves within the Long Creek Arm of Table Rock Lake. Those selected to receive habitat treatments are shown in red whereas those serving as controls are outlined in yellow.

Installation of habitat structures in the treatment coves occurred during the autumn and winter of 2008. Habitat structures were comprised of cedar trees and hardwood tree tops. When possible, simple woody structures, such as tree trunks with few branches were combined with complex woody structures, such as branches, tree limbs, and cedar trees. These habitat structures were added to treatment coves by placing structures perpendicular to the shoreline from the water's edge to 15 feet of water when Table Rock Lake was at a conservation pool elevation of 915 msl. We attempted to maintain spacing among structures of 100 feet; however, this spacing varied among coves and was greater if boat docks or other structures were present.

### Analysis

Catch rates (number/hour of electrofishing effort) of Largemouth Bass and Spotted Bass were compiled for both control and treatment sites. To minimize the potential effect of changes to gear efficiency over time, we limited our examination of historic data to that collected from 2000 until 2008, the sampling season prior to the habitat installation. Post-treatment assessment began during the spring of 2009, and is currently underway. In addition to catch rates, proportional size distributions (PSD) were also calculated for Largemouth Bass and Spotted Bass to investigate any potential changes in size distributions of fish related to habitat structure installations.

Proportional size distributions were calculated as

$$\text{PSD-}X = \frac{\text{Number of fish} \geq \text{specified length}}{\text{Number of fish} \geq \text{minimum stock length}} \times 100$$

where the length category of interest (i.e., specified length) is indicated by  $X$  (Neumann et al. 2012). In this assessment, we examined PSD and PSD-P for Largemouth Bass and Spotted Bass. Following stock, quality, and preferred length categories proposed by Neumann et al. (2012), we used 8", 12", and 15" length values when calculating PSD- $X$  values for Largemouth Bass and 7", 11", and 14" values for Spotted Bass calculations, respectively.

When attempting to analyze this data, we were limited by the number of years of data collected since the habitat structures were installed. In all study sites, we have only collected four or five years of post-data. This limits our ability to run more complex analyses of the data at this time. Therefore, the following analyses will be simple and preliminary in nature. As time goes on and we are able to collect additional electrofishing data from these sites, we will conduct additional analyses. At this time, we examined the data by simply plotting trends through time and using simple analysis of variance (ANOVA) techniques.

## Results

We pooled both control and treatment sites and plotted Largemouth Bass CPUE, PSD, and PSD-P data for each through time, denoting with a black line when the habitat installations occurred (Figure 4.5). Using a simple two-way ANOVA, we tested the effect of site (i.e., control or treatment) as well as the effect of time period (i.e., before or after habitat installation occurred) and their interaction on the three response variables. Treatment applied to the cove and time period did not interact to influence Largemouth Bass CPUE ( $F = 0.06, P = 0.81$ ). The CPUE of Largemouth Bass was significantly ( $F = 7.01, P < 0.01$ ) different between control and treatment sites; however, time period also significantly ( $F = 6.42, P = 0.01$ ) influenced catch rates of Largemouth Bass. Proportion size distribution and PSD-P of Largemouth Bass was not influenced by site or the interaction of site and time; however, PSD ( $F = 42.15, P < 0.01$ ) and PSD-P ( $F = 43.63, P < 0.01$ ) did vary through time (Figure 4.5).

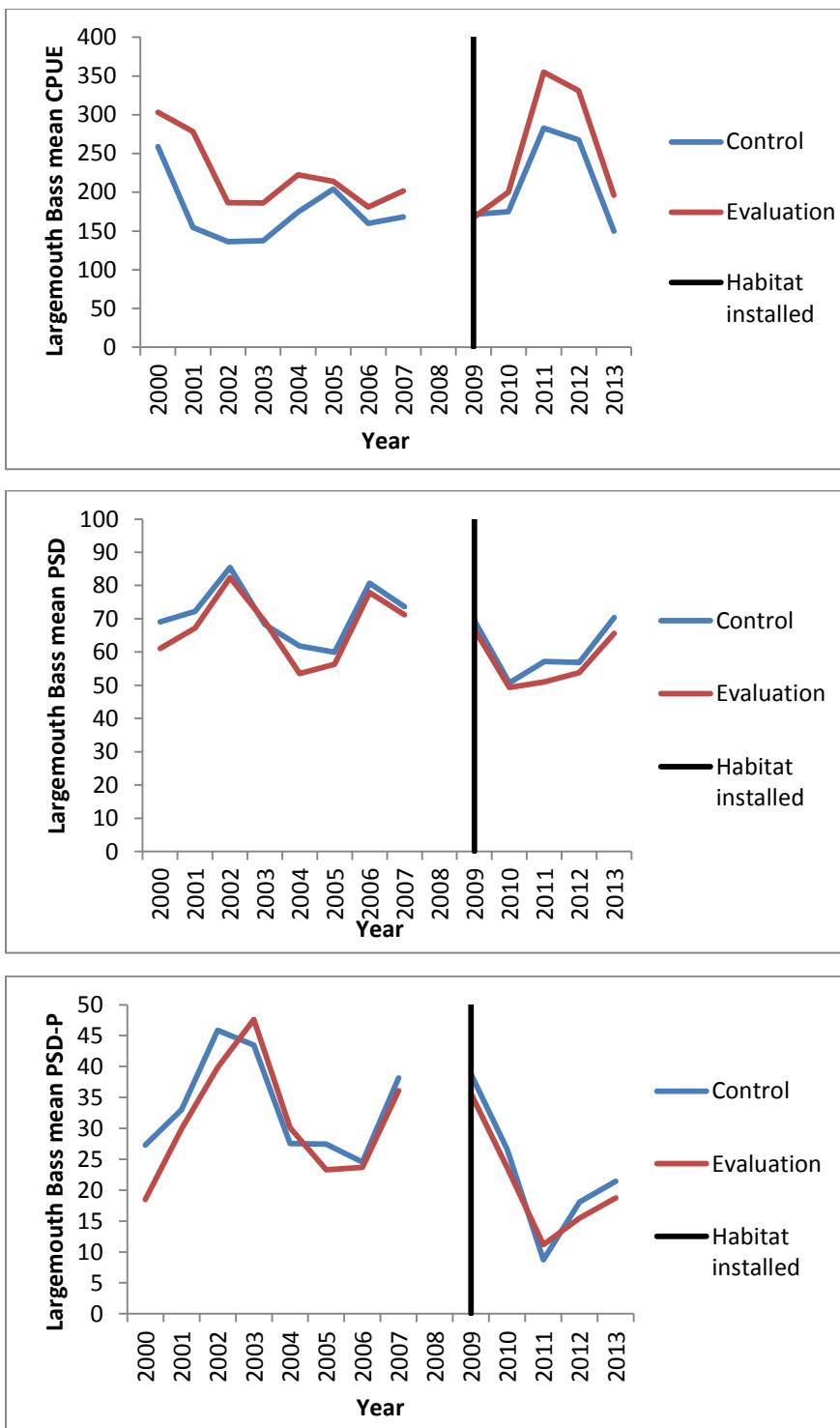
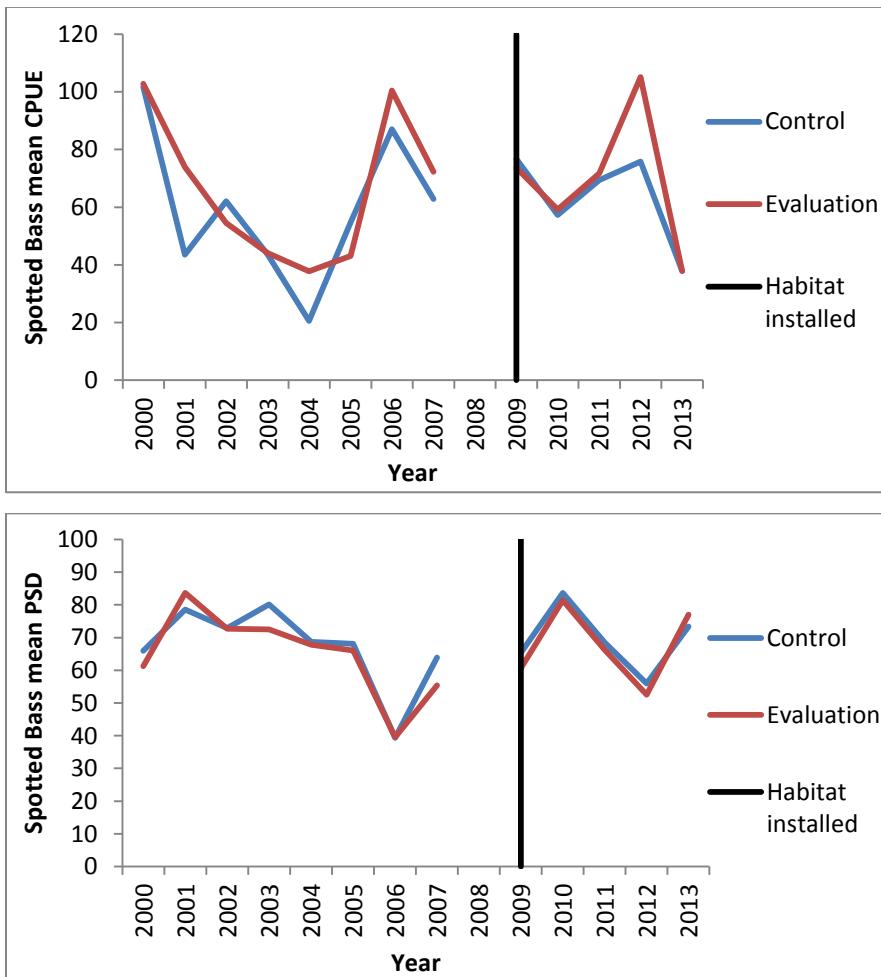


Figure 4.5: Data on catch per unit effort (CPUE), proportional size distribution of quality length (PSD) and preferred length (PSD-P) Largemouth Bass were collected during annual electrofishing surveys on Table Rock Lake from 2000 to 2008 (pre-installation) and then from 2009 to 2013 (post-installation) in treatment and control coves.

We also pooled both control and treatment sites and plotted Spotted Bass CPUE, PSD, and PSD-P data through time, denoting with a black line when the habitat installations occurred (Figure 4.6). As done with Largemouth Bass, we used a simple two-way ANOVA to test the effect of site, the effect of time period, and their interaction on the three response variables. Site and time period did not interact to influence Spotted Bass CPUE ( $F = 0.08, P = 0.78$ ). Spotted Bass CPUE did not differ between control and treatment sites ( $F = 1.79, P = 0.18$ ), nor did time period influence ( $F = 0.16, P = 0.69$ ) catch rates of Spotted Bass. Spotted Bass PSD and PSD-P did not vary between sites, through time, or as a result of the interaction between site and time (Figure 4.6).



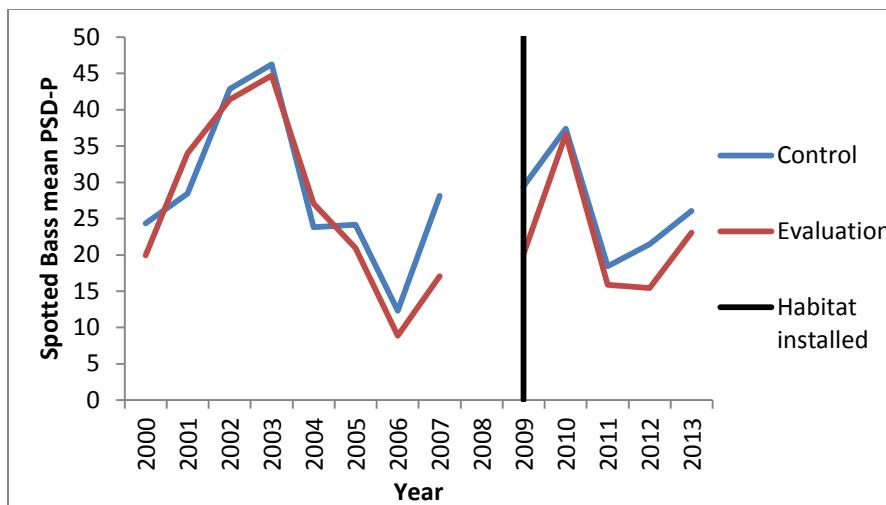


Figure 4.6: Data on catch per unit effort (CPUE), proportional size distribution of quality length (PSD) and preferred length (PSD-P) Spotted Bass were collected during annual electrofishing surveys on Table Rock Lake from 2000 to 2008 (pre-installation) and then from 2009 to 2013 (post-installation) in treatment and control coves.

## Discussion

At this time, it is too early to formulate any definitive conclusions from this study. The lack of data collected since the habitat installation occurred limits our ability to appropriately analyze our data set. As more data are collected, we will be able to move away from simple data plots and ANOVA analyses and use more complex analyses such as before-after-control-impact (BACI) designs. We can, however, still visually examine our limited data set (Figures 4.5, 4.6). At this time, it does not appear that the addition of habitat into coves increased our electrofishing CPUE of either Largemouth Bass or Spotted Bass. Trends in CPUE after habitat structures were installed appear to mimic those present prior to the installation. Likewise, trends in PSD and PSD-P do not appear to change after the installation of habitat structures.

Although it is difficult to provide in-depth discussion of these findings due to their preliminary nature, it is worth noting that the installed structures do appear to concentrate bass. During electrofishing surveys, staff noted increased numbers of bass immediately around the installed structures. Electrofishing surveys, however, suggest that we are not increasing the abundance or size of fish located within coves by adding structures, but these structures may improve angler catch rates by concentrating fish at the local level. The presence of these structures seems to improve anglers' perception of the fishery and improve the quality of their fishing trip (see creel section of report). This may very well be the case, especially in the spring, since these shallow structures have been shown to attract black bass during their nesting period (Vogele and

Rainwater 1975; Hoff 1991; Patrick 1996; Hunt et al. 2002; Wills et al. 2004; Siepker et al. 2013). Additional monitoring of study sites will provide further insight on the benefits of installing habitat structures in littoral waters of large reservoirs like Table Rock Lake.

### **SCUBA (Self-Contained Underwater Breathing Apparatus)**

**Michael Allen**  
Fisheries Biologist  
Missouri Department of Conservation

Few studies have effectively surveyed artificial habitat structures to determine and compare fish use, although diver counts are closely related to actual fish abundances (Dibble 1991). Bassett (1994) reported on several habitat structures that were evaluated by divers and found that wooden structures were effective at attracting several species of fish. Graham (1992) also visually documented Bluegill *Lepomis macrochirus* use of artificial structures by diving in a Virginia reservoir and Rold et al. (1996) monitored fish use of habitat structures in a Kentucky strip mine impoundment. Unfortunately, the effectiveness of diver counts as an accurate survey technique is limited by water clarity (Dolloff et al. 1996).

Of concern to biologists and anglers alike is whether fish use of installed structures varies by habitat structure type during the summer recreational angling season. To better understand fish use of different installed habitat structure types, we monitored fish use of structures installed in Table Rock Lake, Missouri. We sought to understand if: 1) black bass *Micropterus* spp. and crappie *Pomoxis* spp. use installed habitat structure types differently, 2) if usage varies among installed habitat structure types, and 3) if use of installed habitat structures varies by fish size.

### **Methods**

Habitat structures installed in the White River Arm of Table Rock Lake were evaluated with SCUBA survey techniques due to limited water clarity in other areas of the lake. Habitat structures were examined three times throughout the summer recreational angling season (June-July: early, July-August: mid, and August-September: late) during two consecutive years (2010 and 2011). Five types of structures were chosen to be evaluated: pine trees, cedar trees, hardwood trees, stump fields, and rock piles. Ten of each habitat type were selected equaling a

total of 50 structures. Structures were selected from a pre-existing database of GPS points. The database was filtered to only include structures placed in the clearer portion of the lake during the NFHI habitat improvement project. The points were then sorted by structure type and sites were randomly selected from the resulting list of structure types.

A modified SCUBA survey technique described by Bohnsack and Bannerot (1986) was used to quantify sport fish use of habitat structures installed in Table Rock Lake. Graham (1992) and Magnelia et al. (2008) modified the technique to successfully survey fish use of installed artificial structures in reservoirs. Two divers were randomly assigned one of two observation locations (near shore and offshore) at each habitat structure. Divers simultaneously descended to the structure and positioned themselves at a location adjacent to the structure that was close enough to the structure to allow the divers to effectively monitor fish numbers, but as far as possible from the structure to limit disturbance of fish. Structures were large enough that diver positions did not allow fish to be simultaneously counted by both divers. Once in position, divers independently recorded the total number of fish and number of legal-sized black bass (15 in.) and crappie (10 in.) present at three and five minutes after descent. The reason for two time counts was to limit the effect of any fish fright response on counts (Graham 1992).

Instantaneous counts were taken to limit the amount of duplicate counts. Divers then added their counts together for a total count after each dive. Surveys were only conducted between 0930 and 1400 hours to maximize diver visibility. At each site, divers also recorded several covariates including: depth of the structure, water temperature at the structure, dissolved oxygen levels at the structure, and visibility at the structure using a horizontal Secchi reading between divers. Although we examined several potential covariates, a large number of covariates could lead to spurious affects during the analysis; therefore, we limited the analysis to two covariates (depth and visibility) because other potential covariates were strongly correlated with depth and because visibility was not correlated with any other covariates.

#### *Black bass*

We considered the average total number of black bass between the three and five minute counts and the maximum total number of black bass observed between the three and five minute counts at each structure. Further analysis of black bass count data revealed that the averages between the three minute and five minute fish counts were highly correlated ( $r > 0.96$ ) with the maximums

from the same three and five minute counts for both years (Table 4.1). This relationship also held true when we averaged counts across seasons (Table 4.2).

Table 4.1. Estimated correlation (all p-values were less than 0.01) between average and maximum number of black bass observed between counts at 3 minutes and 5 minutes, for sublegal, legal, and all black bass, for all data collected in 2010 and 2011 during SCUBA surveys of habitat structures in Table Rock Lake.

Black bass size group	2010	2011
Sublegal	0.97	0.98
Legal	0.98	0.97
Combined (all)	0.98	0.98

Table 4.2. Estimated correlation (all p-values were less than 0.01) between average and maximum number of black bass observed between counts at 3 minutes and 5 minutes, for sublegal, legal, and all black bass, and averaged across summer seasons by site for 2010 and 2011 during SCUBA surveys of habitat structures in Table Rock Lake.

Black bass size group	2010	2011
Sublegal	0.99	0.99
Legal	0.99	0.97
Combined (all)	0.99	0.99

As a result, we utilized the maximum black bass counts at each structure in our analysis. Since the maximum of the three and five minute count was used, a generalized linear model (GLM) was employed in the analyses. However, in approximately 17 percent of the dives, no black bass were observed at structures, and in approximately 30 percent of the dives, no legal sized black bass were observed at structures (Figure 4.7), resulting in many zeroes in the dataset leading to concerns that a Poisson error would result in over-dispersion; therefore, we used a quasi-Poisson link function (in the statistical software package R) which incorporates an over-dispersion

parameter when estimating errors. All tests were considered significant at the  $\alpha = 0.10$  level.

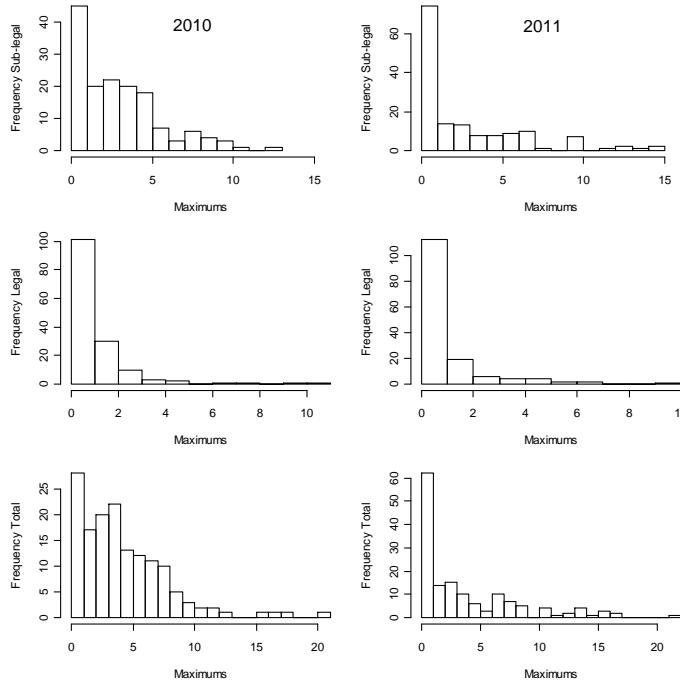


Figure 4.7: Histograms of maximum black bass (between 3 and 5 minute counts) observed at each site for sub-legal, legal, and total black bass in 2010 and 2011.

### *Legal black bass*

We compared legal black bass counts across structure types with a full generalized linear model (GLM) that included year, season nested within year, structure visibility, structure depth, and structure type and all two-way interaction terms including structure type and depth, structure type and year, structure type and visibility, year and structure depth, structure visibility and depth, and structure visibility and year. When the year term had significant interaction with another covariate, 2010 and 2011 were analyzed separately.

We reexamined all single and pairwise interaction terms to evaluate all components in both 2010 and 2011. In the full model for legal black bass in 2010 and 2011, we included structure type, structure visibility, structure depth, and season. We also included interaction terms of structure type and depth, structure type and season, structure type and visibility, structure depth and visibility, structure depth and season, and structure visibility and season.

To provide additional information on legal black bass use of structures we examined with analysis of variance (ANOVA) the maximum number of legal black bass observed at structures

averaged over seasons, specifically during the entire summer. Once again, we started with the full model containing the single covariates of structure type, depth, visibility, and year and all two-way interaction terms including structure type and depth, structure type and visibility, structure type and year, structure depth and visibility, structure depth and year, and structure visibility and year. As with the above analysis, when the year term had significant interaction with another covariate, 2010 and 2011 were analyzed separately. For 2010 and 2011 data, all individual terms including structure type, depth, and visibility and interaction terms including structure type and depth, structure type and visibility, and structure depth and visibility were considered in the model. We then compared number of legal black bass observed among structure types using Tukey multiple comparisons (Bretz et al. 2010).

#### *Total black bass*

Similar to the analysis of legal black bass, we used a GLM with all single terms and two-way interactions to evaluate the number of total black bass observed at each structure type. When the year term had significant interaction with another covariate, 2010 and 2011 were analyzed separately. Also, we attempted to provide additional information on total black bass use of structure types examined by using an analysis of variance (ANOVA) and maximum number of total black bass observed at structures averaged over seasons, specifically the entire summer.

#### *Crappie*

We compared the number of legal crappie and total numbers of crappie among structure types and between years using an ANOVA. To stabilize the variance of the counts when utilizing the ANOVA, we used square root-transformed maximum counts. We also examined the number of crappie by year separately for both 2010 and 2011. We used Tukey multiple comparisons to test for differences in number of crappie observed among structure types (Bretz et al. 2010). Also, since no crappie of any size were observed in over half the observations (which limited our ability to examine correlations), no covariates besides year and structure type were included in the analyses.

## Results

### *Black bass*

#### *Legal black bass*

Significant model terms from the GLM included structure type ( $\chi^2 = 22.82$ ,  $df = 4$ ,  $P < 0.01$ ), structure visibility ( $\chi^2 = 5.235$ ,  $df = 1$ ,  $P = 0.02$ ), structure type  $\times$  year interaction ( $\chi^2 = 13.15$ ,  $df = 4$ ,  $P = 0.01$ ), and structure depth  $\times$  year interaction ( $\chi^2 = 13.98$ ,  $df = 1$ ,  $P < 0.01$ ). Due to the significant year interaction terms, it was necessary to analyze the years separately. All single terms in the 2010 GLM significantly influenced legal black bass numbers except season. The structure type  $\times$  season, structure visibility  $\times$  depth, and structure depth  $\times$  season interactions were also significant (Table 4.3). We then removed the non-significant terms, except season because some interaction terms with season were significant, before rerunning the GLM. All terms continued to be significant, and season continued to be non-significant.

Table 4.3. Results of statistical analyses of black bass use of installed structures in Table Rock Lake.

Year	Model Term	Legal Black Bass		Total Black Bass		Legal Black Bass		Total Black Bass	
		$\chi^2$ (df)	P-value	$\chi^2$ (df)	P-value	F value(df)	P-value	F value (df)	P-value
<b>2010</b>									
	Season	2.290(1)	0.318	8.426(2)	0.015	N/A	N/A	N/A	N/A
	Structure type	30.193(4)	< 0.001	18.975(4)	< 0.001	4.703(4,34)	0.004	2.945(4,34)	0.034
	Structure depth	7.682(1)	0.006	0.069(1)	0.793	4.295(1,34)	0.046	0.203(1,34)	0.655
	Structure visibility	18.543(1)	< 0.001	39.051(1)	< 0.001	9.415(1,34)	0.004	21.118(1,34)	< 0.001
	Structure type $\times$ structure depth	5.268(4)	0.261	5.516(1)	0.238	1.418(4,34)	0.249	1.142(4,34)	0.354
	Structure type $\times$ season	24.057(8)	0.002	10.765(8)	0.215	N/A	N/A	N/A	N/A
	Structure type $\times$ str. visibility	5.772(4)	0.217	18.172(4)	0.001	1.664(4,34)	0.181	1.928(4,34)	0.128
	Structure depth $\times$ str. visibility	9.884(1)	0.002	14.320(1)	< 0.001	10.327(1,34)	0.003	16.269(1,34)	< 0.001
	Structure depth $\times$ season	7.147(2)	0.028	16.521(2)	< 0.001	N/A	N/A	N/A	N/A
	Structure visibility $\times$ season	1.272(2)	0.530	1.683(2)	0.431	N/A	N/A	N/A	N/A
<b>2011</b>									
	Season	13.040(2)	0.002	16.962(2)	< 0.001	N/A	N/A	N/A	N/A
	Structure type	14.610(4)	0.006	12.611(4)	0.013	2.907(4,34)	0.036	2.689(4,34)	0.048
	Structure depth	7.037(1)	0.008	22.213(1)	< 0.001	0.603(1,34)	0.443	4.867(1,34)	0.034
	Structure visibility	1.103(1)	0.294	1.955(1)	0.162	10.790(1,34)	0.002	15.031(1,34)	< 0.001
	Structure type $\times$ structure depth	12.352(4)	0.015	12.310(4)	0.015	4.891(4,34)	0.207	0.908(4,34)	0.471
	Structure type $\times$ season	20.457(8)	0.009	14.076(8)	0.080	N/A	N/A	N/A	N/A
	Structure type $\times$ str. visibility	9.213(4)	0.056	2.918(4)	0.572	2.998(4,34)	0.443	0.634(4,34)	0.642
	Structure depth $\times$ str. visibility	1.451(1)	0.228	0.615(1)	0.433	0.058(1,34)	0.811	2.478(1,34)	0.125
	Structure depth $\times$ season	3.941(2)	0.139	8.766(2)	0.013	N/A	N/A	N/A	N/A
	Structure visibility $\times$ season	1.01(2)	0.605	1.145(2)	0.564	N/A	N/A	N/A	N/A

In 2010, hardwood structures had more legal black bass observed on them than other structures (Figure 4.8), though not significantly more. However, this trend was strongly influenced by the four high (> five individuals observed) values of legal black bass that were documented at hardwoods early in the summer (Figure 4.9); these observations occurred during high water at a time when average visibility and depths were greater. We then reanalyzed the 2010 legal black bass data after removing all hardwood structure data. The full model, as described above, resulted in only structure depth  $\times$  visibility ( $\chi^2 = 9.44$ ,  $df = 1$ ,  $P < 0.01$ ) and structure depth  $\times$  season ( $\chi^2 = 5.31$ ,  $df = 2$ ,  $P = 0.07$ ) interactions being significant. All single terms were not significant (structure type,  $\chi^2 = 0.99$ ,  $df = 3$ ,  $P = 0.80$ ).

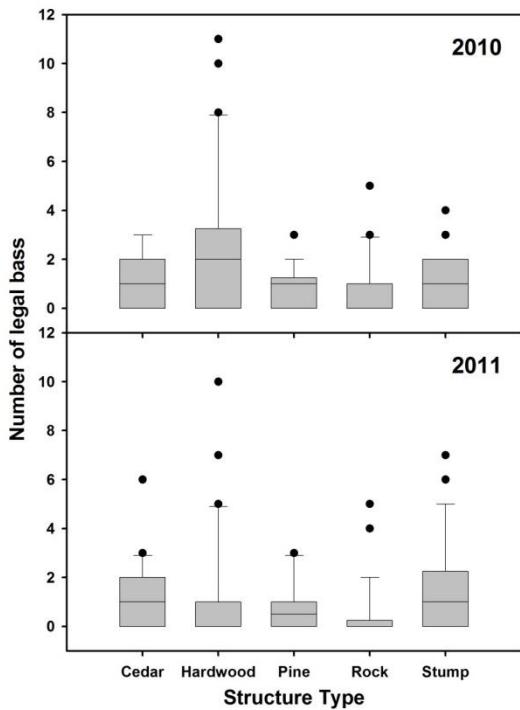


Figure 4.8: Boxplots of the number (maximum between three and five minute observations) of legal black bass, observed at different structure types, in 2010 and 2011. The median, 25<sup>th</sup> and 75<sup>th</sup> percentiles, 10<sup>th</sup> and 90<sup>th</sup> percentiles (error bars), and outliers (circles) are shown for the number of legal black bass observed at each structure type.

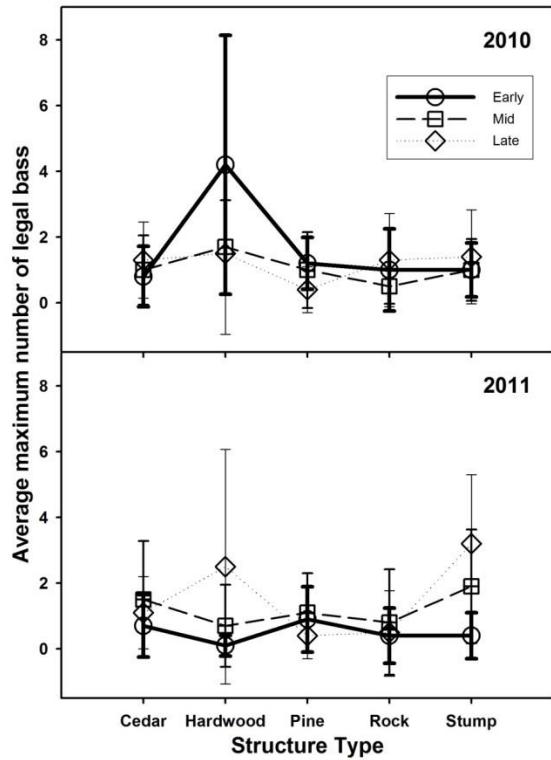


Figure 4.9: Average of the number (maximum between three and five minute observations) and standard deviation of legal black bass observed, by structure type and season in 2010 and 2011.

All single terms in the 2011 model were significant except for structure visibility. Structure type  $\times$  season, structure type  $\times$  depth, and structure type  $\times$  visibility interactions were also significant (Table 4.3). After removing all non-significant terms, except for visibility because some interaction terms with visibility were important, we re-ran the GLM. All terms significant in the previous analysis continued to be significant, while visibility continued to be non-significant.

Rock structures appeared different than the other structures since only four of 30 dives (13.3 percent) on that habitat type documented legal size black bass (Figure 4.8). Therefore, we removed rock structure data and re-ran the analysis. All single terms (structure type:  $\chi^2 = 8.78$ ,  $df = 3$ ,  $P = 0.03$ , structure depth:  $\chi^2 = 3.76$ ,  $df = 1$ ,  $P = 0.053$ , season:  $\chi^2 = 20.34$ ,  $df = 2$ ,  $P < 0.01$ ) influenced legal black bass counts with the exception of structure visibility. Structure type  $\times$  season ( $\chi^2 = 20.34$ ,  $df = 6$ ,  $P < 0.01$ ), structure type  $\times$  depth ( $\chi^2 = 7.78$ ,  $df = 3$ ,  $P = 0.05$ ), structure type  $\times$  visibility ( $\chi^2 = 9.16$ ,  $df = 3$ ,  $P = 0.03$ ), and structure depth  $\times$  season ( $\chi^2 = 5.00$ ,  $df = 2$ ,  $P = 0.08$ ) interactions were also significant. The structure type  $\times$  depth interaction

decreased in significance, whereas season increased (Figure 4.9). Due to the large amount of variation in lake covariates and the number of legal black bass seen, there are no clear trends other than legal black bass were seen at all structures, though rarely at rock structures, in varying amounts. Further, rarely (< 15 percent) were more than two legal black bass recorded during any of the dives (Figure 4.7).

When examining the average number of legal black bass using structures throughout the summer, significant model terms from the ANOVA included structure type ( $F = 4.08$ ;  $df = 4, 77$ ;  $P < 0.01$ ) and visibility ( $F = 12.36$ ;  $df = 1, 77$ ;  $P < 0.01$ ), while the interaction terms structure type  $\times$  visibility ( $F = 3.49$ ;  $df = 4, 77$ ;  $P = 0.01$ ), structure type  $\times$  year ( $F = 2.89$ ;  $df = 4, 77$ ;  $P = 0.03$ ), and structure depth  $\times$  year ( $F = 4.12$ ;  $df = 1, 77$ ;  $P = 0.05$ ) were the significant interaction terms. As with previous analyses, year was significant in some interaction terms and was therefore analyzed separately. In 2010, all individual terms influenced legal black bass counts, but only the interaction term structure depth  $\times$  visibility was significant (Table 3). Boxplots of legal black bass counts by structure type for 2010 showed hardwood structures were generally greater than other structure types in the number of legal black bass observed on average over the summer (Figure 4.10). On average, more legal black bass used hardwood structures than pine structures ( $t = 3.07$ ,  $df = 42$ , *adjusted P* = 0.03), however there were no significant differences between fish use of other structure types. Structure type and visibility were the only two significant terms in the 2011 ANOVA (Table 4.3). Boxplots for legal black bass by structure type in 2011 showed stump structures generally had more legal black bass than other structure types over the summer, while rock structure seemed to have less (Figure 4.10). On average, stump structures attracted more legal black bass than rock structures ( $t = 3.48$ ,  $df = 44$ , *adjusted P* = 0.01) and pine structures ( $t = 2.77$ ,  $df = 44$ , *adjusted P* = 0.0598); however, no differences existed between number of legal black bass attracted by other structures. In general, legal black bass were found at all structures though less often at pine and rock structures. Across structure types, the variability in lake conditions influenced our ability to detect legal black bass.

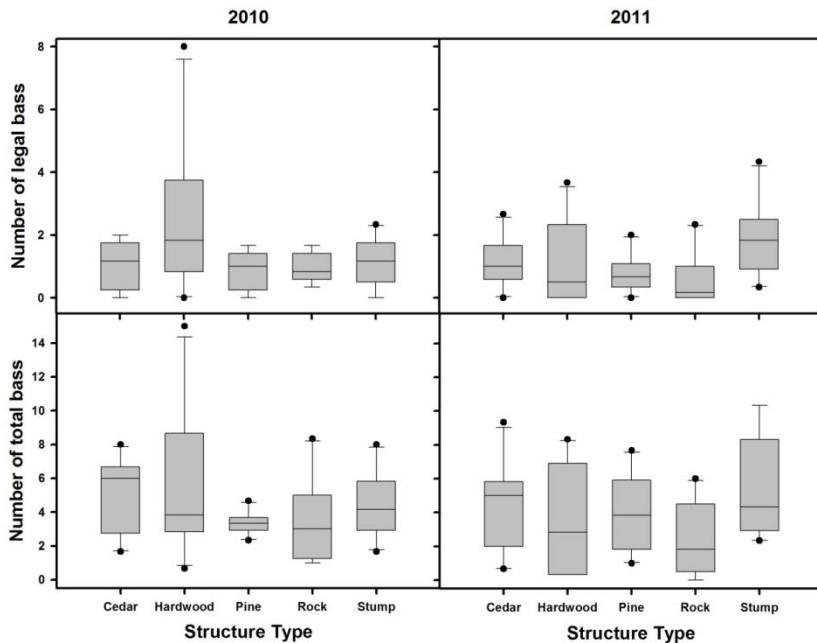


Figure 4.10: Boxplots of the number (maximum between three and five minute observations) of legal black bass during 2010 and 2011, and total black bass during 2010 and 2011, averaged over seasons, observed at different structure types. The median, 25<sup>th</sup> and 75<sup>th</sup> percentiles, 10<sup>th</sup> and 90<sup>th</sup> percentiles (error bars), and outliers (circles) are shown for the average number of legal black bass across summer seasons observed at each habitat structure.

#### *Total black bass*

Within our GLM model, structure type ( $\chi^2 = 14.84$ ,  $df = 4$ ,  $P < 0.01$ ), structure depth ( $\chi^2 = 17.74$ ,  $df = 1$ ,  $P < 0.01$ ), and structure visibility ( $\chi^2 = 9.33$ ,  $df = 1$ ,  $P < 0.01$ ) significantly influenced the total number of black bass observed; the interactions structure type  $\times$  year ( $\chi^2 = 8.00$ ,  $df = 4$ ,  $P = 0.09$ ) and structure depth  $\times$  year ( $\chi^2 = 17.50$ ,  $df = 1$ ,  $P < 0.01$ ) were also significant; therefore, years were analyzed separately. In 2010, the total number of black bass observed varied by structure type, structure visibility, and season; the interaction terms structure type  $\times$  visibility, structure depth  $\times$  visibility, and structure depth  $\times$  season were also significant (Table 4.3). Any comparisons between different structure types were difficult due to heterogeneity of slopes for total black bass observed versus structure visibility by structure type (Figure 4.11). Both pine and hardwood structure data likely contributed to the problem; total black bass counts at hardwoods were more affected by visibility whereas counts at pine structures did not appear to be affected by visibility. Some structures tended to have more total black bass than others in

2010, although it varied with lake conditions (specifically turbidity, which may have been a function of detectability not actual number at the structure; Figure 4.12).

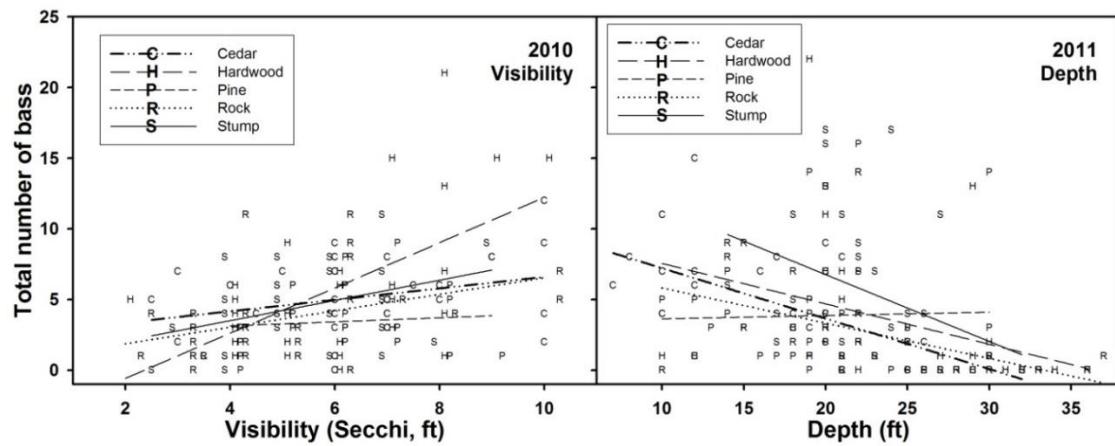


Figure 4.11: Scatterplots of structure visibility versus number (maximum between three and five minute observations) of total black bass observed, with points and lines by different structure types, during SCUBA evaluations conducted in 2010 and 2011.

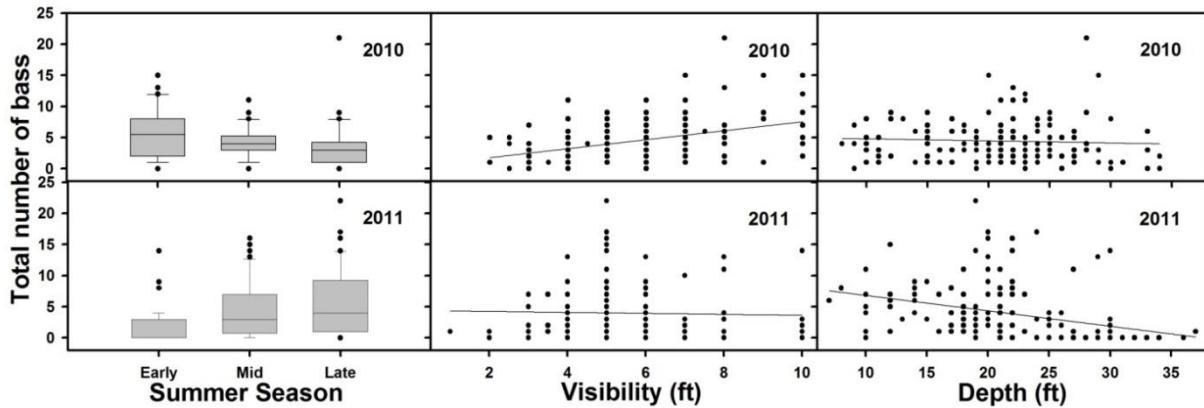


Figure 4.12: Relationship between number (maximum between three and five minute observations) of total black bass observed by summer season, structure visibility, and structure depth during 2010 and 2011.

For the 2011 data, structure type, depth, and season significantly influenced total number of black bass observed, and the interactions structure type  $\times$  depth, structure type  $\times$  season, and structure depth  $\times$  season were also significant (Table 4.3). When we removed the non-significant model terms, including structure visibility (since it and none of its interaction terms were significant) and re-ran the quasi-Poisson model, all terms remained significant except structure type  $\times$  season; therefore, we removed the structure type  $\times$  season interaction term. Total black bass observed increased with season, and decreased slightly as visibility at the structure

increased (Figure 4.12). There was also a definitive decrease in total black bass counts with increasing depth of structure (Figure 4.12). The significant interaction between structure type and depth with respect to total black bass observed is likely due to pine structures (Figure 4.11). Though not exactly parallel or having the exact same ranges, other structure types had similar trends in depth versus number of total black bass observed. When considering different seasons, total black bass counts at rock structures varied little through the summer when compared to the other structure types (Figure 4.13). Due to the large variation in lake covariates within and between years, we could make no strong conclusions for structure types utilized by black bass during the summer, other than they can be found at all structure types.

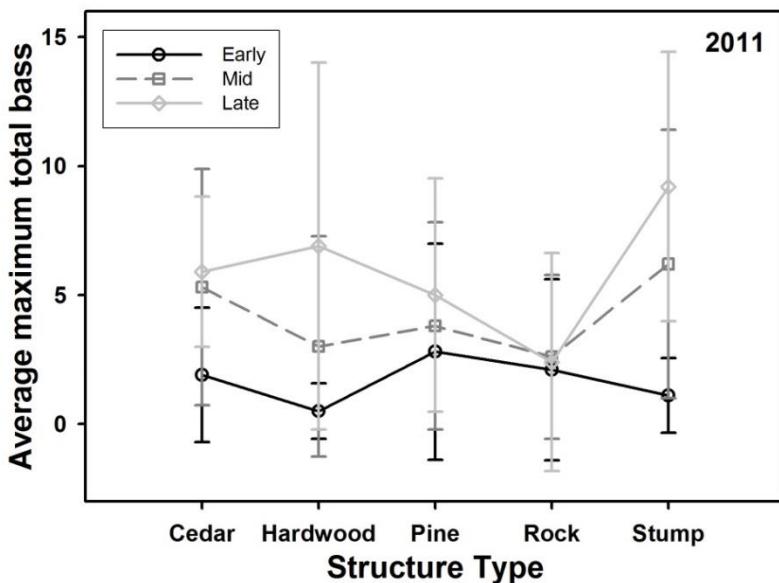


Figure 4.13: Average of the number (maximum between three and five minute observations) and standard deviation of total black bass observed, by structure type and season, in 2011.

Within our full ANOVA model examining total black bass averaged across seasons, structure type ( $F = 2.94$ ;  $df = 4, 77$ ;  $P = 0.03$ ), structure depth ( $F = 4.45$ ;  $df = 1, 77$ ;  $P = 0.04$ ), and structure visibility ( $F = 20.83$ ;  $df = 1, 77$ ;  $P < 0.01$ ) significantly influenced total black bass counts; the only significant interaction term was structure depth  $\times$  year ( $F = 3.98$ ;  $df = 1, 77$ ;  $P = 0.05$ ). As a result, we analyzed data from 2010 and 2011 separately. In 2010, structure type structure visibility and the interaction of structure depth  $\times$  visibility significantly influenced total black bass numbers. Only hardwood structures, however, had significantly ( $t = 2.61$ ,  $df = 42$ , *adjusted P* = 0.09) higher total black bass counts than pine structures (Figure 4.10). In 2011,

structure type, structure depth, and structure visibility all influenced total black bass numbers; no interaction terms were significant in the model. Total black bass observed at stump structures was significantly ( $t = 3.39$ ,  $df = 43$ , *adjusted P* = 0.01) higher than at rock structures (Figure 4.10).

### *Crappie*

Crappie use patterns of installed structures differed compared to black bass use. Crappie were never observed on rock structures during this study; therefore, we removed rock structures from the analysis. For every other structure type, no crappie of any size were observed in over half the dive observations (Table 4.4). When crappie were observed at structures, there were typically less than four crappie utilizing individual structures although as many as 35 crappie were observed using one cedar structure during the study (Figure 4.14).

Table 4.4: Frequencies and percentages for the count of crappie observed on installed habitat structures by year for sub-legal size, legal size, and total crappie observed during SCUBA surveys in Table Rock Lake.

		Number of crappie observed					
		0	1	2	3	4	> 5
2010							
Sub-legal	136 (91%)	6 (4%)	3 (2%)	3 (2%)	1 (1%)	0 (0%)	1 (1%)
Legal	130 (87%)	6 (4%)	4 (2%)	3 (2%)	3 (2%)	1 (1%)	3 (2%)
Total	126 (84%)	8 (5%)	4 (2%)	4 (3%)	1 (1%)	0 (0%)	7 (5%)
2011							
Sub-legal	138 (92%)	4 (3%)	1 (1%)	1 (1%)	1 (1%)	0 (0%)	5 (3%)
Legal	136 (91%)	4 (3%)	2 (1%)	5 (3%)	2 (1%)	0 (0%)	1 (1%)
Total	129 (86%)	5 (3%)	2 (1%)	4 (3%)	2 (1%)	2 (1%)	6 (4%)

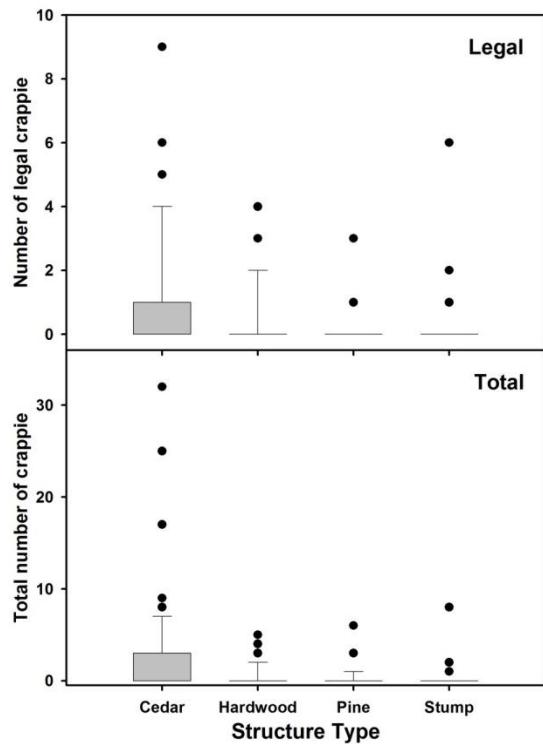


Figure 4.14: Boxplots of the number (maximum between three and five minute observations) of total crappie and legal crappie observed at different structure types during all dive surveys in both 2010 and 2011. The median, 25<sup>th</sup> and 75<sup>th</sup> percentiles, 10<sup>th</sup> and 90<sup>th</sup> percentiles (error bars), and outliers (circles) are shown for the number of total crappie observed at each habitat structure.

#### Legal crappie

Overall, structure type ( $F = 3.76$ ;  $df = 3, 72$ ;  $P = 0.01$ ) significantly influenced the number of legal crappie observed. When data were pooled for 2010 and 2011, significantly more legal crappie were counted at cedar structures than at pine structures ( $t = 3.11$ ,  $df = 75$ , *adjusted P* = 0.01) and more at cedar than at stump structures ( $t = 2.74$ ,  $df = 75$ , *adjusted P* = 0.04; Figure 4.14). When analyzed by year, the number of legal crappie observed in 2010 significantly varied by structure type ( $F = 2.45$ ;  $df = 3, 36$ ;  $P = 0.08$ ); however, there were no differences in 2011 (Figure 4.15). Among all the structure types monitored in 2010, numbers of legal crappie varied the most between pine and cedar structures ( $t = 2.34$ ,  $df = 36$ , *adjusted P* = 0.11). As with legal black bass, the number of legal crappie observed at structures was low. Cedar structures had the most legal crappie observed, but only in 2010 were more than half the observations greater than zero (Table 4.4). However, at least some legal crappie were observed at each structure type (except rock) at least once in both years.

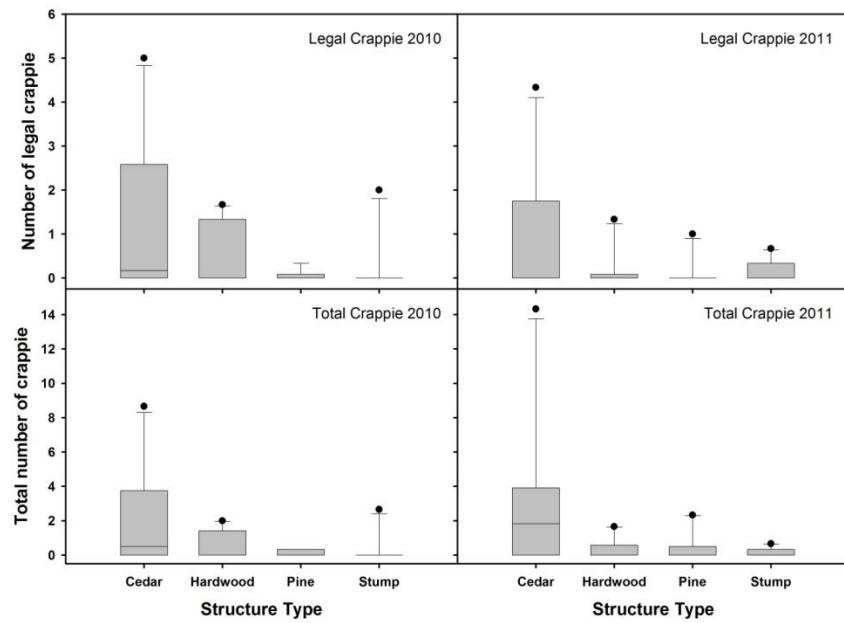


Figure 4.14: Boxplots of the number (maximum between 3 and 5 minute observations) of legal crappie during 2010 and 2011 and total crappie during 2010 and 2011 observed at different structure types, averaged across seasons. The median, 25<sup>th</sup> and 75<sup>th</sup> percentiles, 10<sup>th</sup> and 90<sup>th</sup> percentiles (error bars), and outliers (circles) are shown for the average number of legal crappie across summer seasons observed at each habitat structure.

### Total Crappie

As with legal crappie, structure type ( $F = 6.19$ ;  $df = 3, 72$ ;  $P < 0.01$ ) significantly influenced the total number of crappie observed. Across both years, significantly more crappie were observed at cedar structures than at hardwood structures ( $t = 2.99$ ,  $df = 75$ , *adjusted P* = 0.02), pine structures ( $t = 3.56$ ,  $df = 75$ , *adjusted P* < 0.01), or stump structures ( $t = 3.91$ ,  $df = 75$ , *adjusted P* < 0.01; Figure 4.14). When we examined data by year, the number of total crappie observed varied significantly by structure type in both 2010 ( $F = 2.55$ ;  $df = 3, 36$ ;  $P = 0.07$ ) and 2011 ( $F = 3.82$ ;  $df = 3, 36$ ;  $P = 0.02$ , Figure 9). In 2010, more crappie were observed on cedar structures than on stump structures ( $t = 2.49$ ,  $df = 36$ , *adjusted P* = 0.08) and in 2011, more crappie were observed on cedar structures than on hardwood structures ( $t = 2.65$ ,  $df = 36$ , *adjusted P* = 0.06), pine structures ( $t = 2.67$ ,  $df = 36$ , *adjusted P* = 0.05), or stump structures ( $t = 2.94$ ,  $df = 36$ , *adjusted P* = 0.03).

Crappie were observed at all structure types, except for rock, at least once per year (Table 4.4). Crappie were only observed utilizing stump structures once each year whereas crappie were observed at cedar structures in over half of the dive surveys, though typically in low numbers. Over 60 percent of all crappie observed over both years of the survey were at cedar structures. Furthermore, over 40 percent of all crappie observed at cedar structures were at a single structure site. The greatest number of crappie observed on a single dive was also recorded at that same site in both 2010 and 2011. We were interested in the effect of this single structure site on our results, so we removed the site and re-ran our ANOVA. Structure type remained a significant factor in our model ( $F = 3.93$ ;  $df = 3, 70$ ;  $P = 0.01$ ), and there were still more crappie observed at cedar structures than at pine structures ( $t = 2.82$ ,  $df = 73$ , *adjusted P* = 0.03) or stump structures ( $t = 3.22$ ,  $df = 73$ , *adjusted P* = 0.01).

## Discussion

In lakes such as Table Rock, where natural cover is limited or deteriorating, installed structures appear to provide suitable cover for sport fishes. Concentrating sport fish near cover likely will increase angler catch rates (Wege and Anderson 1979). Typically, increased angler catch rates are the objective of habitat installation projects, however, they could result in overexploitation if angling pressure is extremely high and appropriate regulations are not implemented to limit harvest. Currently, Table Rock Lake black bass and crappie populations are managed with minimum total length limits of 15" and 10", respectively, as well as daily creel limits of 6 and 15, respectively, so overexploitation of the sport fishery is unlikely. Our results support the continued installation of habitat structures as a means to potentially maintain or improve angler catch rates in large reservoirs like Table Rock Lake. As in previous work by Wege and Anderson (1979), black bass in our study seemed to use hardwood habitat structures more than other structure types. Crappie were observed most often utilizing cedar habitat structures. Rold et al. (1996) also found that crappie were attracted to cedar structures. Regardless of habitat structure type, all were utilized by black bass, crappie, or both at some time during our study. Sport fish may be attracted to habitat structures because they experience improved foraging efficiency that ultimately leads to increased growth rates (Crowder and Cooper 1979; Wege and Anderson 1979); however, we did not examine those responses in this study.

Most black bass observed at habitat structures were highly mobile, and would disappear and reappear several times during the observational period. Instantaneous counts were taken at three and five minutes to reduce the chance that a single fish would be counted more than once by observers, or counted by each observer. By using the maximum number of fish observed by both divers at either the three or five minute count, we eliminated the chance that a single fish was counted more than once, but this approach may have also reduced the likelihood that all fish using a structure were counted during the observation period. As a result, counts should not be viewed as actual counts of the total number of fish utilizing a particular structure, but instead as a relative index of fish use among structure types.

Reservoir conditions were quite different during the two years of our evaluation. In 2010, Table Rock Lake summer (June-September) water levels averaged 916 msl (range = 913-917 msl) whereas in 2011 water levels were more variable, averaging 919 msl (range = 914-930 msl). These increases in water levels resulted in many structures being located in deeper water during 2011 (Figure 4.12), including some structures located at or below the thermocline. This may have influenced the number of fish observed at the structures, contributed to the differences between years, and increased the importance of covariates. Both legal and sub-legal black bass utilized all the different structure types we installed in Table Rock Lake; however, the total number of black bass utilizing the different structure types varied by season and by year (Figure 4.13). Clear relationships between fish size and structure type use were difficult to determine due to the influence of covariates.

The likelihood of black bass being documented at a specific structure was dependent, at a minimum, on visibility and depth in addition to the structure type (Figure 4.12). Visibility may have been important in detecting black bass at a structure during a dive survey, rather than negatively impacting whether black bass are present and using the structure. Even in a system such as Table Rock Lake that typically has adequate water clarity (relative to other Missouri reservoirs) for SCUBA surveys, visibility can fall to levels that negatively affect the detectability of fish. Visibility during our dive surveys ranged from 0.5 to 10 feet (Figure 4.12) and this influenced black bass counts at the structures. We were unable to determine if these differences were due to detectability of black bass at the structure, or perhaps some change in use as water clarity changed. For example, as the visibility increased, the number of black bass observed on

hardwood structures increased. This could be related to the orientation of hardwood structures and the larger amount of overhead cover a hardwood structure creates compared to the other structure types. Furthermore, the variations in what was observed may be due to other factors such as dissolved oxygen, which is related to both water temperature and depth, but was confounded in our analysis due to the co-linearity between these variables and missing data due to equipment failures. Visibility is important to the success of any dive survey and should be considered early in the planning process. Guidelines that would limit observations if visibility was reduced beyond some predetermined level may be valuable to include in future project plans.

Black bass use of structures also varied by water depth, specifically in 2011 (Figure 4.12). Of all the structures surveyed during July through September of 2011, those found in water depths  $\geq$  30 feet had DO levels at the structure of two mg/L or less. Only three of those 15 structures attracted black bass; only one individual was observed at each of the three structures. Placing structures in a way that ensures they are not a hazard to boaters is important during any habitat improvement project; however, structures must not be placed too deep or they might not be utilized by fish if below the thermocline. Complimentary work by Harris (2013) found that Largemouth Bass in Table Rock Lake utilized intermediate depths, between 6.5 and 23 feet throughout the year. Unfortunately, reservoir water levels vary and thermocline depths can change based on weather conditions and water levels; therefore, management biologists should consider these possibilities when determining habitat structure installation sites.

The number of black bass we observed at each structure type generally varied throughout the summer and it varied differently between the two years (Figures 4.9, 4.12). Again, this is likely due to the differences in lake condition between 2010 and 2011. This further emphasizes the importance of gathering data throughout a summer and during multiple years. Monitoring structures once in a single summer would yield very different results depending on the year and date the observations were conducted. We did not monitor structures during autumn, winter, or spring; structure use by fish could have varied during these periods as well. Other work suggests that installed habitat structures are effective at attracting black bass throughout the year (Vogele and Rainwater 1975; Prince and Maughan 1979; Hoff 1991; Hunt and Annett 2002).

Unfortunately, we were unable to examine by summer season crappie use of installed structures

due to low numbers of crappie being observed. During these other seasons, fish could use deeper structures since the lake would not be stratified. It appears that several factors interact to influence fish use of a particular structure, and this use varies temporally. To better understand structure use by fish across all seasons and provide additional insight into the importance of installed habitat structures and their ability to attract fish year-round, Harris (2013) evaluated fish use of installed structures using bio-telemetry.

The locations and orientations of individual structures were factors that could not be accurately measured or analyzed for SCUBA surveys. Some structures attracted many more fish than others, as was evident in our crappie surveys. One cedar structure attracted crappie during each season. Counts at this single structure accounted for over 40percent of all crappie observed at cedar structures. Structures that were located in areas devoid of other natural habitat seemed to be occupied by more fish than structures adjacent or near to other structures or natural habitat, though we did not quantify this. Structures that are taller and extend higher into the water column may attract more black bass than structures that are shorter and spread along the bottom. Prince and Maughan (1979) found that black bass seemed to be attracted to high-profile artificial structures more so than others. Location within the lake could also influence fish use of certain structures. Although we did not examine structure location, structures that were on points versus those that were in coves might have differing levels of fish use at different times of the year.

### **Management Implications**

During the large-scale habitat improvement project on Table Rock Lake, five different habitat structure types were utilized. By installing cedar trees, hardwood trees, pine trees, stump fields, rock piles, and combinations of different habitat types, we provided fish with a variety of different habitat types allowing us to monitor these structures and develop recommendations for future habitat enhancement projects. The costs and benefits of utilizing various different habitat structure types should always be considered when planning habitat projects. The costs of each habitat structure type used in our evaluation varied substantially (Table 4.5). Pine structures were the least expensive to install, but dive surveys indicated minimal use by black bass and crappie during the summer season when our survey was conducted. The costs associated with placing hardwood and cedar brush structures were greater than placing pine structures due to

their size (Table 4.5). The hardwood and cedar trees used to create structures were much larger than the pine trees and required the use of large equipment to place these types of materials on our habitat barge. The final size of the installed habitat structures were generally the same, but the pine structures were composed of more trees with much smaller trunks and limbs, therefore, deterioration of these structures would likely occur faster. Hardwood or cedar habitat structures seem to attract both black bass and crappie and, based on our study, are some of the more cost effective habitat structures installed. Rocks and stumps also attract fish and could be more important during other times of the year or for other species of interest to anglers. These structures were utilized by bass and did provide habitat to locations devoid of habitat capable of attracting sport fishes, but were more costly to install. The area that can be covered by placing rock or stump structures should be considered when determining the proper materials and techniques to be used. Although some structures were not as effective on Table Rock Lake, they should not be discounted for other systems. For example, rock structures attracted no crappie and fewer black bass than some other structure types in Table Rock Lake. Substrate in Table Rock Lake is predominately a mixture of gravel, cobble, and boulder whereas other systems in different ecoregions may have mostly sand or silt substrates, making rock more attractive to fish. Rock is also permanent, and would provide long lasting benefits to fish when installed in these areas. Since black bass and crappie were attracted to most habitat types we evaluated, the decision of which habitat structure type to install in a particular reservoir will likely be determined by funding, personnel, existing habitat types, and habitat material availability.

Table 4.5: Estimated installation costs (in USD) associated with five different habitat structure types installed in Table Rock Lake as part of a large fish habitat improvement project. Habitat materials were donated, so no costs were associated with purchasing habitat materials. Supply costs include anchors and supplies utilized for sinking habitat materials. Installation times varied, and depended on the location of structures relative to access points where habitat was staged; costs and time associated with transporting the habitat material to the access point staging areas are not considered in these estimates. Installation times are estimated per structure type, and these will vary based on distance between staging areas and habitat installation sites.

Habitat Structure Type	Supply costs	Installation Time (hours × number of staff)	MDC staff hourly rate avg. (\$/hr)	Contractor Costs (\$/hr)	Total cost per structure
Cedar	50.00	2 × 2	15.00	78.00	\$266.00
Pine	50.00	1.5 × 5	15.00	NA	\$162.50
Hardwood	50.00	2 × 2	15.00	78.00	\$266.00
Stump	0	2 × 1	15.00	656.00	\$1,342.00
Rock	0	2.5 × 1	15.00	656.00	\$1,677.50

### Bio-telemetry

**Jason Harris**  
 Graduate Student  
 University of Missouri

Substantial research has been conducted on habitat selection of Largemouth Bass in systems lacking augmentation structure. In small impoundments (<250 ha) Largemouth Bass select for vegetated habitats and large woody debris (Schlagenhaft and Murphy 1985; Annett et al. 1996; Olson et al. 2003; Hasler et al. 2009). Largemouth Bass in large reservoirs (>2000 ha) are often associated with aquatic vegetation (Durocher et al. 1984; Karchesky and Bennett 2004; Slipke and Maceina 2007). Our study site is unique in that it is a meso-eutrophic system and relatively devoid of aquatic macrophytes, which provided us with an opportunity to document Largemouth Bass habitat selection in a relatively unstudied environment. In addition, we could not find any studies on Largemouth Bass diel or seasonal habitat selection over a 12- month period in large reservoirs. Therefore, our objective was to determine which variables best predict diel and seasonal habitat selection of Largemouth Bass following a habitat improvement project in a large, aging reservoir.

Augmentation structure in Table Rock Lake was placed proactively to determine if fish would use these areas while natural structure was still present and deteriorating. Our hypothesis was that if Largemouth Bass select for these structures at a similar rate to naturally occurring

structure, these augmentation structures may be used in the future to help restore decreasing natural habitat structure in many reservoirs across the country. We hypothesized Largemouth Bass will select near shore areas of intermediate depths with woody structure during both day and night. However, we hypothesize that Largemouth Bass will be located in areas closer to shore during night hours compared to day. Seasonally, we expect Largemouth Bass to utilize the littoral zone within intermediate depths throughout the year. During summer, fall, and winter we predict Largemouth Bass will use naturally occurring woody debris, and select complex augmentation structure at similar rates to naturally occurring woody structure. During spring we predict a shift to flat areas near complex structure for nesting opportunities and to provide recently hatched offspring adequate cover (Annett et al. 1996). The addition of augmentation structure in an aging reservoir may provide Largemouth Bass with a suitable alternative to natural habitat, which continues to deteriorate in many reservoirs.

### **Study Site**

A proactive approach was taken to enhance reservoir habitat before a complete loss of natural structure occurred. Within approximately 13 km (8 miles) from the confluence of the Kings River Arm there are 88 augmentation structures including: 25 hardwoods, 28 evergreens, 6 evergreen/hardwood mixes, 7 rock piles, 8 stump fields, and 14 rock/stump mixes (Figure 4.15). However, eventually all structure types were grouped into two broad categories: complex and coarse augmentation structure (see Analysis section below). Main lake structures were placed at depths of 3-7.5 m (10-25 ft.), at conservation pool, while cove structures were placed at 1-4 m depths (3-13 ft.) at conservation pool.

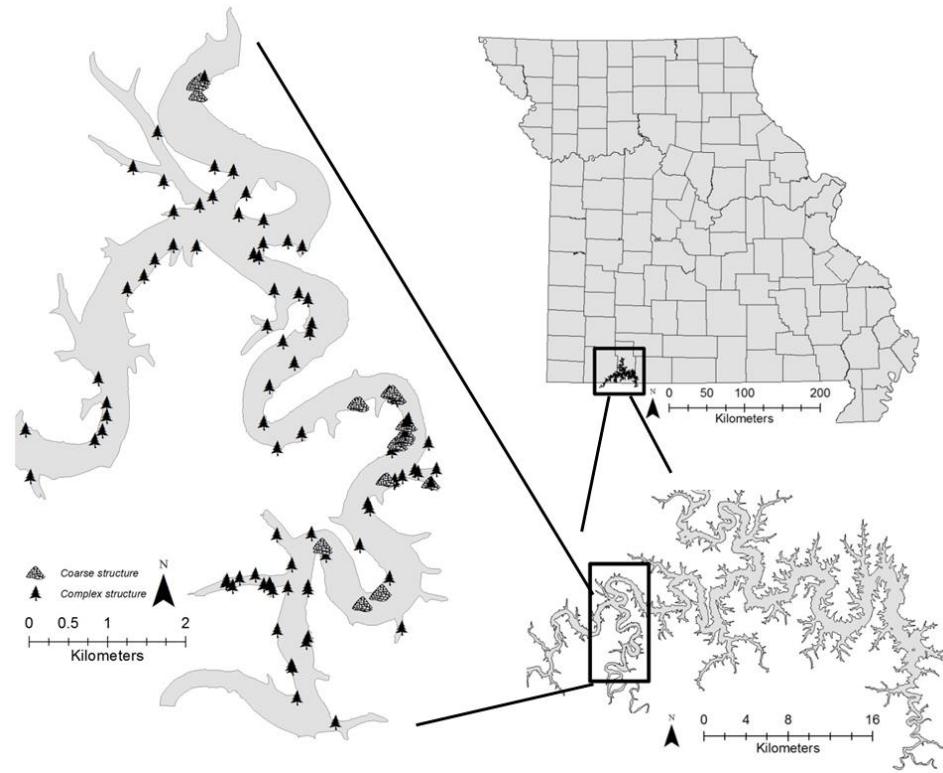


Figure 4.15: Study site location and distribution of coarse (stump and rock piles) and complex (evergreen and hardwood trees) augmentation structures within the Kings River Arm of Table Rock Lake, Missouri.

## Methods

### Largemouth Bass Collection and Tagging

During April 2011, 60 adult Largemouth Bass between 380 and 590 mm (15" and 23") total length (680-3383 g, 1.5-7.45 lbs) were collected for transmitter implantation with pulsed direct current boat electrofishing within an 8 km (5 mile) shoreline reach of the Kings River Arm of Table Rock Lake. Fish were held in a recirculating livewell, weighed, measured, and anesthetized prior to surgical implantation of the radio telemetry transmitters and insertion of t-bar anchor tags (so anglers could identify tagged fish). A mixture of 1 L seltzer to 45 L lake water (1:45) was used for anesthesia, which was combined in a 68.1 L plastic container, and was a sufficient quantity to anesthetize four to five fish. Dissolved oxygen levels were maintained above five mg/L. An additional ten adult Largemouth Bass between 380 and 546 mm (15" and 21") total length were collected in October 2011 to supplement the original tagged fish, for a total of 70 radio tagged bass within the reservoir.

Surgical procedures were similar to Hart and Summerfelt (1975). We implanted Largemouth Bass with ATS radio transmitters (model F1840B with a weight of 18g (.63 oz) in air, battery life of about 486 days, and a pulse rate of 35 per minute). Radio transmitter weight ranged from 0.5 to 2.6 percent of fish body weight, which fell slightly outside of the “2 percent rule” (Winter 1996). However, transmitters up to 12 percent of fish body weight have been shown to have little effect on swimming performance when implanted intraperitoneally (Brown et al. 1999).

Surgery began by placing the fish ventral side up on a piece of open-cell foam, with a mixture of lake and seltzer water constantly recirculating over the gills. The first 1 cm (0.4") incision was posterior to the pelvic fins and a 14 gauge needle was inserted to thread the transmitter antenna out of the body cavity posterior to the incision. After transmitter insertion, sutures (monofilament PDS 3-0 FS-1) occurred every two to six mm (.08"-.23") along the incision. After surgery, fish were held in the lake inside a floating holding pen until fully recovered, which was typically 15-30 minutes. If fish had difficulty recovering (>one hour upside down, little to no gill movement), the tag was removed and inserted into another fish. The entire surgery was completed within three to five minutes. Once fully recovered, fish were released near their collection site.

### **Radio Tracking and Collection of Habitat Variables**

Radio tracking began May 2011, which was >30 days post transmitter implantation to avoid issues related to erratic behavior known to occur the week following capture and surgery (Mesing and Wicker 1986). Monthly tracking was accomplished within two to three days each month from May 2011 through June 2012, when reduced battery life prohibited relocations.

We relocated fish by tracking paths 100-150 meters (328-492 ft) along the shore to cover the most area, following the river arm up and downstream alternating shorelines. We also randomized our sampling pattern (varied starting location, time, and direction) to minimize bias associated with relocating the same fish at approximately the same time of day each month. We used Lotek SRX 600 telemetry receivers coupled with a three or five element hand held yagi antenna. The scan cycle was set at three seconds so we could detect one to two pings before the cycle moved onto the next frequency. We used a combination of triangulation and direct pinpointing with the antenna to locate tagged fish. When a signal was found we would reduce gain and float over the top of fish until the signal was lost, repeating this process until an exact

location could be determined. Because of low Secchi depths boats rarely influenced fish locations. However, if fish were close to the boat, and a sudden change in location occurred (scared fish), we recorded the initial location before the move, rather than continue chasing the fish. Based on test tag trials we estimated an average error of five meters (16 ft) on fish locations.

Our goal was to relocate all 70 tagged fish once a month during the daytime (one hour after sunrise to one hour before sunset). If all 70 fish were not found we expanded our search  $\geq 10$  km in each direction of the last fish location each month. Because we were also interested if habitat selection differed by diel period, we randomly selected about 20 fish each month to track during the night (one hour after sunset to one hour before sunrise). A smaller sample size was used because of the small time window during night tracking.

Our final tracking event occurred June 2012 following Largemouth Bass spawning activities. During this time fish were likely nesting in shallow areas ( $<2.8$  m, 9 ft) (Hunt et al. 2002) and guarding their nests several weeks following hatching (Cooke et al. 2002), which made tagged Largemouth Bass easier to detect in shallow water. Since not all fish were relocated during the last tracking event, we performed expanded tracking the following day using two additional boats and telemetry receivers. After 60+ hours of additional tracking and over 80 percent of the reservoir searched, no other fish were located. Both our first tracking event (May 2011), and final expanded search (June 2012) were not included into the final analysis because available locations were not recorded.

When a tagged fish was relocated we recorded GPS coordinates using a GPS unit with sub-meter accuracy. Water depth was recorded using a portable depth finder. Distance from shore was also recorded using a Bushnell sport 450 laser rangefinder. Any visible structure (floating woody debris, boat docks, standing timber, and rock ledges) within 15 m (50 ft) of a fish location were also recorded. In addition to visible structure, fish were recorded as “using” an augmentation structure (Figure 4.15) if they were located within a 30 m radius of the GPS-stored augmentation structure coordinates. After recording of the used location variables, three random “available” locations were recorded immediately following, which was used to determine habitat selection (see Analysis section below). A random distance based on the previous months mean Largemouth Bass day or night movement rate (Harris 2013) and a random bearing (1-360°) were

used to determine the “available” locations. If an available point fell onto inaccessible areas (land), the distance was reflected back from the water’s edge until achieving the desired distance.

We were unable to measure aspect and bottom slope in the field, so we calculated these values using ArcMap 10.0 (ESRI 2011). All variables were derived from a depth profile map (Figure 4.16) using the geostatistical analyst kriging tool in ArcMap 10.0 (ESRI 2011), in which we used multiple 150 m (492 ft) transects ran parallel then perpendicular to the shoreline (unpublished data) collected in July 2011 and April 2012. Water levels were standardized by adding or subtracting depth measurements to match conservation water levels (full pool). The outline of the shore at conservation pool was broken into one meter (three feet) points; each assigned a depth of 0.01 meters to create an edge for our kriging analysis. Using these points in addition to all transects and fish depths (standardized to conservation pool), a total of 206,000 depth point locations were used in the final kriging analysis. From the kriging map of depth we were able to determine bottom slope (degrees) and aspect (north, 337.5-22.5°; northeast, 22.5-67.5°; east, 67.5-112.5°; southeast, 112.5-157.5°; south, 157.5-202.5°; southwest, 202.5-247.5°; west, 247.5-292.5°; northwest, 292.5-337.5°).

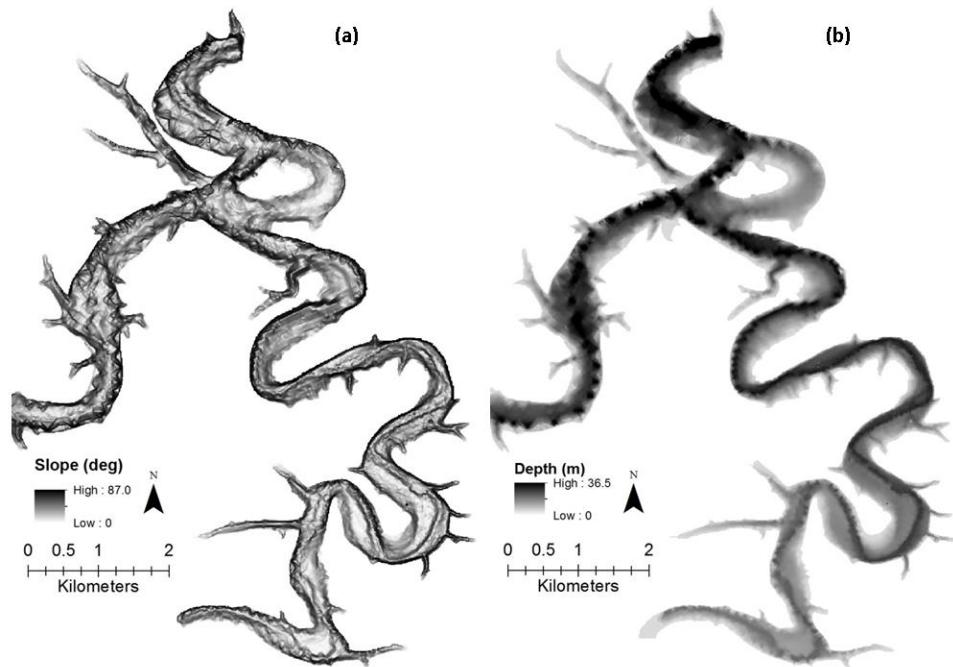


Figure 4.16: Kriging estimate of slope (degrees) (a) and depth at conservation pool (meters) (b) in the Kings River Arm of Table Rock Lake, Missouri.

Not all locations were included into our analysis. Because of the sedentary nature of Largemouth Bass (Mesing and Wicker 1986), two consecutive locations in the same coordinate were not sufficient evidence to assume the fish had died. Instead, we determined if fish were located in the same location over three consecutive months, and had been tracked during at least two 24-hour tracking events (Harris 2013) with no apparent movement they were presumed dead and removed from further analysis. However, we continued to record a used location on all fish presumed dead for the remainder of the study, in case the fish was alive and remained sedentary. No fish resumed movement after presumed dead.

## Analysis

Discrete choice models (Cooper and Millspaugh 1999) were used to determine habitat selection of tagged Largemouth Bass. Discrete choice models assume that individuals receive utility (e.g., increased foraging opportunities, increased growth, decreased probability of predation) from selecting specific habitats over less desirable areas (Cooper and Millspaugh 1999) and have seen increased application for terrestrial (Irwin et al. 2011) and aquatic systems (Bonnot et al. 2011). The utility  $U$  of resource  $i$  to the individual  $j$  takes the form:

$$U_{ij} = B'X_{ij} + e_{ij} = \beta_1 x_{1j} + \beta_2 x_{2j} \dots \beta_m x_{mj} + e_{ij}$$

where  $B'$  is a vector length of  $m$  estimable parameters and  $X$  is a vector of  $m$  measurable attributes of the resource, and  $e$  is the error term (Cooper and Millspaugh 1999). In its simplest form discrete choice is basically a mixed effects logistic model, where individual radio tag frequencies were used as random effects.

Discrete choice assumes that resource availability is not constant over time and that individuals do not have equal access to all resources considered available (Cooper and Millspaugh 2001). Many habitat selection studies record availability estimates once throughout the study period (Schlagenhaft and Murphy 1985) or not at all (Lyons 1993). This may be problematic when documenting habitat selection in variable environments such as reservoirs where available resources may change daily. Therefore, we created “choice sets” in which each used fish location

was paired with three corresponding available locations, recorded at the same time as the used location.

Availability in our study was defined using the previous months mean Largemouth Bass movement rate (Harris 2013). Largemouth Bass movement patterns can vary by water temperature and diel period (Warden and Lorio 1975; Sammons and Maceina 2005; Hanson et al. 2007). Therefore, we defined a new area of availability each month for both day and night habitat selection because of significant differences we observed between monthly and diel movement rates (Harris 2013). We assumed the entire reservoir arm is not available to the fish. Instead, availability was defined by the mean distance all fish traveled each month during the day or night, depending on when the fish was relocated. For example, when fish moved little in February during daylight hours (mean=11 meters/hour; Harris 2013), fish had 132 m of available day habitat to select from (11 m/h \*12 hours of daylight).

We developed 12 *a-priori* models based on our knowledge of how Largemouth Bass select habitats. Multiple continuous and categorical variables (Table 4.6) comprised the models, which were grouped into six candidate model sets: 1) day, 2) night and 3) summer, 4) fall, 5) winter, and 6) spring to examine differences observed between diel and among seasonal periods. Based on the distribution of our used habitat data we assumed non-linear distributions. Multiple distributions (e.g. exponential, square root, squared, etc.) were tested, with the best fit for the model (based on Akaike's information criteria (AIC) weight) being chosen for each variable. We fit a natural log (ln) form to the distance from shore variable and fit a quadratic form ( $\beta_1x_1 + \beta_2(x_2^2)$ ) centered around its mean ( $x_i + x_i^2$ ) to our depth and slope variables (Franklin et al. 2000). Categorical variables required a dummy variable be designated to compare to all other categorical variables. We designated open water as our dummy variable in habitat structure analysis. For our aspect analysis we combined southeast, south, and southwest aspects and used this as the dummy variable to compare with other aspects.

Table 4.6: Covariates used in resource selection models for Largemouth Bass habitat selection located in Table Rock Lake, Missouri 2011-2012.

Variable	Description	Range	Mean
D	Water depth (m)	0.5 - 30	9
DS	Distance from nearest shoreline (m)	2 - 285	50
S	Slope (degrees)	1 - 83.5	49
ASPECT <sub>N</sub>	Northern aspect (degrees)	337.5 - 22.5	N/A
ASPECT <sub>NE</sub>	Northeastern aspect (degrees)	22.5-67.5	N/A
ASPECT <sub>E</sub>	Eastern aspect (degrees)	67.5 - 112.5	N/A
ASPECT <sub>W</sub>	Western aspect (degrees)	247.5 - 292.5	N/A
ASPECT <sub>NW</sub>	Northwestern aspect (degrees)	292.5-337.5	N/A
WD	Woody debris (Presence/absence)	0 - 1	N/A
TMB	Standing timber (Presence/absence)	0 - 1	N/A
DOCK	Floating boat docks (Presence/absence)	0 - 1	N/A
LEDGE	Rock ledge (Presence/absence)	0 - 1	N/A
AUG <sub>Complex</sub>	Complex augmentation structure (Presence/absence)	0 - 1	N/A
AUG <sub>Coarse</sub>	Coarse augmentation structure (Presence/absence)	0 - 1	N/A

We used AIC corrected for small sample sizes (AIC<sub>c</sub>) to rank our candidate models and select the model(s) with the most support based on model weight (Burnham and Anderson 2002). If more than one model was supported ( $\Delta \text{AICc} < 2.0$ ) the parameter estimates were averaged across models using:

$$\widehat{\beta} = \sum_{i=1}^R w_i \widehat{\beta}_i$$

Where  $\widehat{\beta}$  is the model averaged estimate of the parameters,  $w_i$  is the Akaike weights from the most supported models, and  $\widehat{\beta}_i$  is the parameter estimate from model  $i$  (Burnham and Anderson 2002). Averaging models may help to reduce bias and increase precision (Burnham and

Anderson 2002). From our top model(s) we were able to calculate parameter estimates to determine the direction and magnitude of selection for individual variables. The relative probability of selection at different intervals of use can be calculated from the parameter estimates for each choice set using:

$$P_j(A|i) = \left( \frac{\exp(U_{Aj})}{\sum_{A \rightarrow i} \exp(U_{ij})} \right)$$

where  $j$  is the individual,  $A$  is the resource in question, and  $i$  is any other resources available to that individual (Cooper and Millspaugh 1999).

In order to validate our top model(s) we used a k-fold cross validation to assess model accuracy (Boyce et al. 2002). We randomly selected 80 percent of our data from each candidate set (e.g., day, night, summer, fall, winter, and spring) to be used as training data, while the remaining 20 percent were used as test data to validate our models. Training data were used to re-run the top ranked models. If there was support for more than one model ( $\Delta \text{AICc} < 2.0$ ), model averaging was performed. This was repeated five times for the top model in each candidate set. The training data parameter estimates were used with the test data set to calculate the utility of each value in the choice set (one used and three available). Correctly classified sets were those in which the relative probability of use was higher than the sum of the relative probability of available. Averaging the results among the five replicates gave us the model accuracy, which gave us the predictive ability of the top model from each candidate set.

## Results

### Mortality and Tag Detection

A total of 70 Largemouth Bass were tagged over the course of our study. Of those tagged, seven (10 percent) were never relocated after initial implantation. We could confirm an additional 23 (33 percent) of our fish died or expelled radio tags sometime throughout the 14 month tracking period. However, we were able to collect data on these fish until they were presumed dead, after which time they were removed from further analysis. Confirmed angler harvest occurred on an additional three (4 percent) fish; while catch and release was reported on ten (14 percent) other tagged individuals.

The number of fish relocated each month ranged from 13 to 42. We relocated an average of 31 fish between June and August 2011 and 16 fish per month from September 2011 through May 2012. The maximum number of times an individual Largemouth Bass was relocated was 12, with seven others being relocated at least 10 months out of the year.

## Habitat Selection

From June 2011 through May 2012, a total of 430 choice sets were used in our analysis. Diel habitat selection was determined using 256 choice sets for day (sunrise – sunset) and 174 choice sets for night (sunset – sunrise) over the 12-month study. We also collected 163 choice sets during summer (June – August 2011), 90 during fall (September – November 2011), 89 during winter (December 2011 – February 2012), and 88 during spring (March 2012 – May 2012).

Largemouth Bass diel habitat selection was a combination of all choice sets (June 2011 – May 2012). The diel habitat selection of Largemouth Bass was best described by model 10 (Table 4.7), which included depth, distance from shore, and structure for both day and night (Table 4.8) with Akaike weights of 0.89 (day) and 0.96 (night).

Table 4.7: *A-priori* models representing hypothesis illustrating habitat selection of Largemouth Bass in Table Rock Lake, Missouri, 2011-2012. See Table 1 for variable names and definitions.

Hypothesis	Model structure
1). Increased selection of structure	$=\beta_1(WD) + \beta_2(TMB) + \beta_3(DOCK) + \beta_4(LEDGE) + \beta_5(AUG_{Complex}) + \beta_6(AUG_{Coarse})$
2). Increased selection of a mid-range of depths	$=\beta_1(D) + \beta_2(D^2)$
3). Decreased selection of increasing distance to shore	$=\beta_1(DS)$
4). Increased selection of a mid-range of slopes	$=\beta_1(S) + \beta_2(S^2)$
5). Decreased selection of north facing slopes	$=\beta_1(ASPECT_N) + \beta_2(ASPECT_{NE}) + \beta_3(ASPECT_E) + \beta_3(ASPECT_W) + \beta_5(ASPECT_{NW})$
6). Increased selection of a mid-range of depths and decreased selection of increasing distance to shore	$=\beta_1(D) + \beta_2(D^2) + \beta_3(DS)$
7). Decreased selection of north facing slopes and Increased selection of mid-range of slope	$=\beta_1(ASPECT_N) + \beta_2(ASPECT_{NE}) + \beta_3(ASPECT_E) + \beta_3(ASPECT_W) + \beta_5(ASPECT_{NW}) + \beta_6(S) + \beta_7(S^2)$
8). Increased selection of structure and decreased selection of north facing slopes	$=\beta_1(WD) + \beta_2(TMB) + \beta_3(DOCK) + \beta_4(LEDGE) + \beta_5(AUG_{Complex}) + \beta_6(AUG_{Coarse}) + \beta_7(ASPECT_N) + \beta_8(ASPECT_{NE}) + \beta_9(ASPECT_E) + \beta_{10}(ASPECT_W) + \beta_{11}(ASPECT_{NW})$
9). Increased selection of a mid-range of depths and Increased selection of structure	$=\beta_1(D) + \beta_2(D^2) + \beta_3(WD) + \beta_4(TMB) + \beta_5(DOCK) + \beta_6(LEDGE) + \beta_7(AUG_{Complex}) + \beta_8(AUG_{Coarse}) + \beta_9(DS)$
10). Increased selection of a mid-range of depths and selection of structure with decreased selection of increasing distance to shore	$=\beta_1(D) + \beta_2(D^2) + \beta_3(WD) + \beta_4(TMB) + \beta_5(DOCK) + \beta_6(LEDGE) + \beta_7(AUG_{Complex}) + \beta_8(AUG_{Coarse}) + \beta_9(DS)$
11). Increased selection of a mid-range of slope and selection of	$=\beta_1(S) + \beta_2(S^2) + \beta_3(DS) + \beta_4(WD) + \beta_5(TMB) +$

structure with decreased selection of increasing distance to shore 12). Global model	$\beta_6(\text{DOCK}) + \beta_7(\text{LEDGE}) + \beta_8(\text{AUG}_{\text{Complex}}) + \beta_9(\text{AUG}_{\text{Coarse}})$ All Parameters
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Table 4.8: Akaike information criterion (AIC) output for top 5 diel models (see Table 2 for model number and variables) explaining habitat selection of Largemouth Bass in Table Rock Lake, Missouri from June 2011 to May 2012.

Diel period	Model #	Log likelihood	K	AICc	$\Delta$ AICc	Weight
<b>Day</b>	10	-164.97	10	350.85	0	0.89
	6	-173.65	4	355.45	4.61	0.09
	12	-161.22	17	359.02	8.17	0.01
	11	-169.59	10	360.08	9.23	0.01
	3	-182.76	2	369.57	18.72	0
<b>Night</b>	10	-95.48	10	212.31	0	0.96
	9	-100.21	9	219.52	7.21	0.03
	6	-107.01	4	222.26	9.95	0.01
	12	-92.79	17	223.51	11.2	0
	2	-110.66	3	227.47	15.16	0

Diel models accurately predicted use in 76 percent of cases during the day and 85 percent of cases during night. Habitat selection was consistent for both day and night periods with the exception of depth selection. Largemouth Bass selected for shallow depths (2-4 m, 6.5-13 ft) during night and deeper areas (4-7 m, 13-23 ft) during daylight (Figure 4.17), whereas selection of areas near shore (<25 m, 82 ft; Figure 4.17), and selection of structure was similar between both day and night periods (Figure 4.17). Largemouth Bass selected boat docks at twice the rate of natural woody debris, and three to four times more than all other structure types during both diel periods (Figure 4.17). Natural woody debris was selected more than all other structures types except boat docks during both diel periods. During day hours complex augmentation structures were selected 1.5 times as often as standing timber and three times more than rock ledges. However during night hours, selection of coarse augmentation structure was higher, with a selection 2.5 times higher than standing timber and 4.5 times more than rock ledges (Figure 4.17).

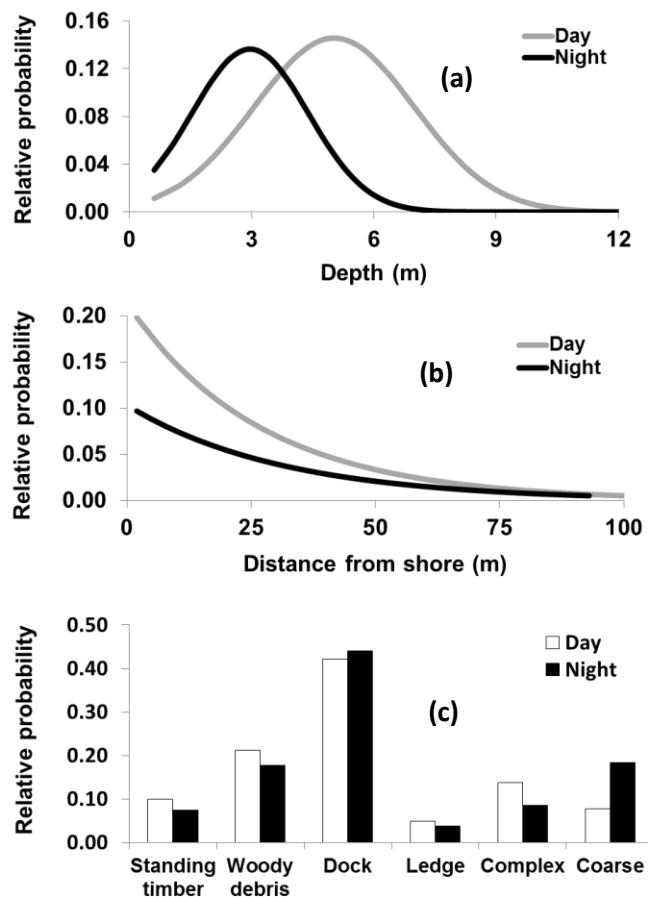


Figure 4.17 Results from our top model in the diel candidate set showing the relative probability (derived from parameter estimates and odds ratios) of Largemouth Bass selecting a specific depth (a), distance from shore (b), and structure (c), specifically standing timber, natural woody debris, boat docks, rock ledges, complex (evergreen and hardwood trees) and coarse (stump and rock piles) augmentation structure.

Seasonal habitat selection was determined from all diel choice sets pooled over the three month seasons. Habitat selection could not be determined by diel period for each season due to small sample sizes so all seasonal analysis combined diel periods. We combined three subsequent months into seasonal categories (summer: June, July, August, fall: September, October, November, winter: December, January, February, spring: March, April, May). Seasonal models accurately predicted 71 percent of cases during summer, 81 percent during fall, 90 percent during winter, and 81 percent during spring. Summer habitat selection was best described by model 10 (Table 4.9) with an Akaike weight of 0.96, where intermediate water depths (4-7 m, 13-23 ft) near shore (<25 m, 82 ft) with structure were positively selected (Figure 4.9). Fall selection was described by model 9 and 10 with Akaike weights of 0.53 and 0.39 respectively (Table 4.9). The model-averaged estimates found areas of high use in intermediate depths (3-4 m, 10-13 ft), locations near shore (<25m, 82 ft), with structure (Figure 4.18). Winter selection was best defined by model six with an Akaike weight of 0.82 (Table 4.9), and indicated Largemouth Bass selected shallower depths (2-3 m, 6.5-10 ft) near shore (<15 m, 50 ft; Figure 4.18). Spring selection was best explained by model six with an Akaike weight of 0.82 (Table 4), where Largemouth Bass selected intermediate depths (3-4 m, 10-13 ft) and locations near shore (<20 m, 65 ft; Figure 4). The presence of structure was important only for summer (model 10) and fall (model 9 and 10), during this time structure types selected were similar between seasons (Figure 4.18). Largemouth Bass selected boat docks at about 1.5 to 4.0 times more than any other structure type (depending on season). During both summer and fall complex augmentation structure was selected at the same rate as natural woody debris and more than any other structure type, except boat docks (Figure 4.18). Coarse augmentation structure was also selected more than standing timber or rock ledges but at only half the rate of natural woody debris and complex augmentation structure during both summer and fall (Figure 4.18).

Table 1.9: Akaike information criterion (AIC) output for top five seasonal models (summer: June, July, August, fall: September, October, November, winter: December, January, February, spring: March, April, May) explaining habitat selection of Largemouth Bass in Table Rock Lake, Missouri. See Table 2 for model number and variables.

Season	Model #	Log likelihood	K	AICc	$\Delta$ AICc	Weight
<b>Summer</b>	10	-146.01	10	313.48	0.00	0.96
	11	-149.87	10	321.18	7.71	0.02
	6	-156.64	4	321.54	8.06	0.02
	12	-144.43	17	327.09	13.61	0.00
	3	-162.24	2	328.56	15.08	0.00
<b>Fall</b>	9	-33.58	9	87.41	0.00	0.53
	10	-32.61	10	88.02	0.61	0.39
	12	-25.25	17	93.01	5.60	0.03
	2	-44.01	3	94.31	6.90	0.02
	11	-35.96	10	94.70	7.29	0.01
<b>Winter</b>	6	-19.42	4	47.32	0.00	0.82
	10	-14.24	10	51.31	3.99	0.11
	3	-24.95	2	54.04	6.72	0.03
	12	-5.78	17	54.19	6.87	0.03
	11	-17.51	10	57.85	10.53	0.00
<b>Spring</b>	6	-46.09	4	100.67	0.00	0.82
	10	-41.11	10	105.07	4.40	0.09
	3	-50.77	2	105.68	5.01	0.07
	2	-51.35	3	108.99	8.32	0.01
	9	-45.47	9	111.25	10.58	0.00

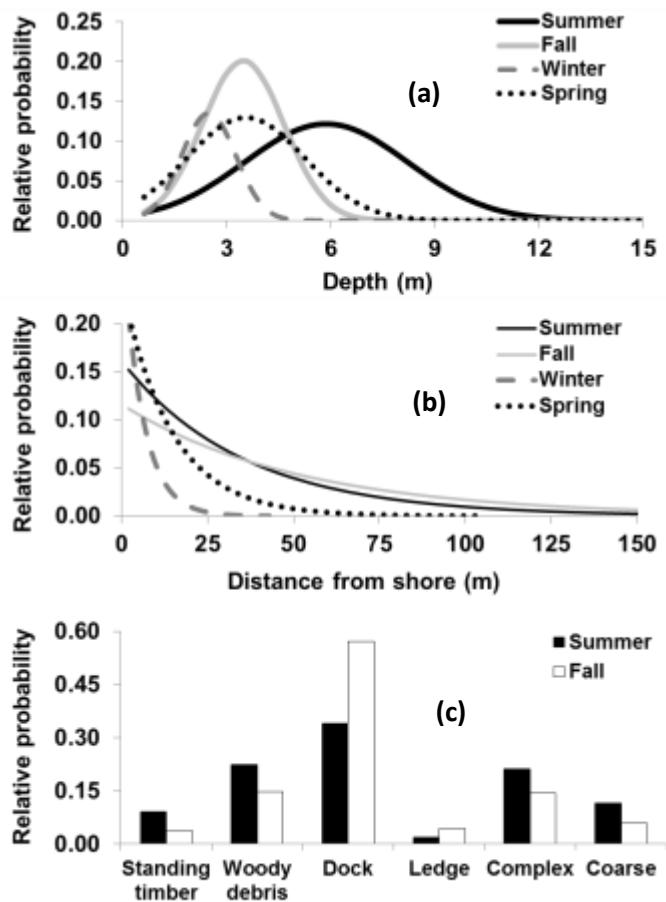


Figure 1.18: Results from our top models in the seasonal candidate set showing the relative probability (derived from parameter estimates and odds ratios) of Largemouth Bass selecting a specific depth (a), distance from shore (b), and structure (c), specifically standing timber, natural woody debris, boat docks, rock ledges, complex (evergreen and hardwood trees) and coarse (stump and rock piles) augmentation structure.

## Discussion

### Habitat Selection

Largemouth Bass habitat selection was generally consistent between day and night periods, with the only difference being Largemouth Bass preferred slightly shallower areas during the night. This is likely due to the visual cues required by many *Centrarchids spp.* to feed and therefore, may have reduced foraging success at low levels of light intensity (Howick and O'Brien 1983). Despite differences in depth selection, Largemouth Bass were using similar habitat structures during both day and night periods. While we did not find differences in habitat selection between

diel periods, our study determined both day and night habitat selection and therefore provides a broader view of Largemouth Bass habitat selection in reservoirs.

Habitat selection of Largemouth Bass did vary among seasons. Intermediate depths were selected across all seasons; however variability occurred in the range of depths selected. During fall, winter, and spring a narrow range of depths (2-4 m, 6-13 ft) were used almost exclusively; while during summer a wider range of depths (4-7 m, 13-23 ft) were selected. This selection of greater depth may have been attributed to high water levels during summer, in which water levels were up to 4.3 m (14 ft) above conservation pool, compared to  $\pm 0.3$  m (1 ft) the rest of the year. These high water levels in summer created greater depths throughout the reservoir, even though bass appeared to be using similar areas from shore among seasons. Areas close to shore were also selected at higher rates than those off shore, possibly relating to high concentrations of structure or forage species such as Bluegill (Paukert and Willis 2002). These areas may be suitable for Largemouth Bass feeding in which they spend time ambushing or searching for prey dependent on the type of habitat structure available within the littoral zone (Wanjala et al. 1986; Savino and Stein 1989).

Largemouth Bass selection of structure was important, but only during summer and fall. During summer and fall Largemouth Bass selected natural woody structure, which can provide cover for many invertebrate and fish species (Everett and Ruiz 1993), camouflage for predators (Angermeier and Karr 1984), and is consistent with other studies in Texas that found Largemouth Bass use of woody debris was high in small (Schlagenhaft and Murphy 1985) and large (Lyons 1993) impoundments. In addition, complex augmentation structures (supplemental evergreen or hardwood tree piles) were selected at similar rates to naturally occurring woody debris and standing timber, suggesting that supplemental habitat may provide the same benefits to Largemouth Bass as naturally occurring woody structures.

Largemouth Bass did not select for habitat structure in spring despite other studies demonstrating how Largemouth Bass may prefer nesting near complex structure (Hunt et al. 2002). During spring, water temperatures averaged  $19.3^{\circ}\text{C}$  ( $66.7^{\circ}\text{F}$ ) which coincides with nesting, spawning, and guarding activities in Largemouth Bass (Annett et al. 1996; Ludsin and DeVries 1997). However, close vicinity to structure also leads to increased brood predation in these areas (Hunt

et al. 2002). Radio-tagged Largemouth Bass in Table Rock Lake appear to prefer areas further from structure which may be related to an instinctive desire to better protect their young.

Largemouth Bass did not select for habitat structure during winter. This may be related to colder winter water temperatures which may reduce Largemouth Bass metabolism (Suski and Ridgway 2009), when they may be feeding less and likely not occupying ambush sites they would normally use to forage, such as areas of high structural complexity (Savino and Stein 1982). Shallow water depths were also used during winter in our study, which contrasts other studies that found very little use of shallow water during winter (Karchesky and Bennett 2004), with the greatest depths being used during the coldest months (Hanson et al. 2007). However, these studies had an abundance of ice cover during portions of their tracking, which may cause varying levels of dissolved oxygen throughout the lake (Hasler et al. 2009). During our study, ice cover never occurred and dissolved oxygen levels likely remained constant throughout the water column. Therefore Largemouth Bass were likely targeting shallow areas because of warmer surface temperatures (Gibbons et al. 1972).

Many studies have demonstrated the importance of woody structure for several life stages of Largemouth Bass (Vogele and Rainwater 1975; Schlagenhaft and Murphy 1985; Hunt and Annett 2002), but very few have documented such high selections of boat docks. Previous studies evaluating floating augmentation structures found higher numbers of Bluegill on these structures possibly because these structures provide overhead cover and shade which can be used to avoid predation (Helfman 1979). Another explanation of the high dock use could be the presence of artificial lights, which were found on all boat docks and have been shown to attract different fish (Floyd et al. 1984). Therefore, Largemouth Bass may be selecting boat docks due to their attraction of forage species such as Bluegill. Similar to our study, low abundances of Largemouth Bass in other reservoirs have been observed near steep natural rocky areas (Sammons and Bettoli 1999), which may demonstrate how other variables such as slope may play an important part in selecting overhead cover types. There was also little use of coarse augmentation structure by Largemouth Bass during fall and summer which was surprising given that Largemouth Bass in reservoirs have been found to utilize rocky shorelines and rip-rap areas throughout the year (Sammons and Bettoli 1999).

Largemouth Bass strongly selected for boat docks although they rarely occurred in Table Rock Lake. Groups of boat docks in the Kings River Arm of Table Rock Lake averaged 600 m (1,969 ft) to the next nearest dock (unpublished data), thus it was unlikely that a fish would select a boat dock and have another dock available to them which likely inflated our selection indices. In contrast, the opposite occurred with standing timber, which was readily selected, but had very high availability due to wooded shorelines and fluctuating water levels. The high availability of standing timber reduced the overall selection by Largemouth Bass. Therefore, it is important to consider that while a specific structure may not be selected at a high rate it can still play an important role in the animal's habitat requirements.

### **Mortality and Tag Detection**

Our estimates of tag loss, mortality, and catch-and-release are consistent with other studies. About 33 percent of tagged Largemouth Bass died or expelled their tag over the 14-month tracking period, which was similar to other Largemouth Bass tracking studies, (e.g., 32 percent mortality in an Alabama reservoir; Hunter and Maceina 2008) and was consistent with total annual mortality estimates in lakes and reservoirs (30-35 percent ; Beamesderfer and North 1995; Paukert and Willis 2004). We were unable to locate an additional 10 percent of our fish even with expanded tracking efforts. This loss of individuals may be attributed to tag failure, fish moving out of the system, or angler harvest. Exact numbers of fish harvested by anglers may be hard to determine because tag return rates vary between 55-65 percent (Green et al. 1983). However, previous studies found similar results with 11 percent of tagged individuals never being relocated after initial release (Hunter and Maceina 2008). Based on angler correspondence of our transmitter-tagged Largemouth Bass that were caught, 77 percent were released. An angler creel survey conducted between 2006-2007 on Table Rock Lake found an average of 77 percent of black bass caught were also released (Bush 2009). Our results follow closely with others who used creel surveys to estimate catch and release rates on black bass.

Our results may have been influenced by detection probability of our radio transmitters. Although we located 90 percent of our fish at least once throughout the 12 month tracking period, few locations were in depths greater than 4 m (13 ft). Radio telemetry signals often dissipate in deep water (Cooke et al. 2012), and a pilot study we conducted found the maximum detection range of the transmitter was over 1.5 km (.93 mile) when the transmitter was at a depth

of 2 m (6.5 ft) but was less than 100 m (328 ft) when the transmitter was at a depth of 12 m (39 ft). Certain areas of Table Rock Lake had depths over 30 m (98 ft). While these depths are likely unavailable to fish during certain times of the year due to thermal stratification, fish may be able to use depths over 12 m (39 ft) at times. However, all augmentation habitat structure was placed in depths less than 12 m (39 ft) so if a fish was in depths greater than 12 m (39 ft) (and we did not detect them) it was not using an augmentation structure. Because of these factors, our inferences on habitat selection should be for fish in 12 m (39 ft) depths or less.

### **Management Implications**

Largemouth Bass in Table Rock Lake selected for areas of intermediate depth (2-7 m, 6.5-23 ft), near shore (<25 m, 82 ft), in the presence of structure. Boat docks and woody debris were the most selected structures, but complex augmentation structures were used at similar rates to naturally occurring woody structure. This suggests these augmentation structures may be able to supplement the loss of habitat occurring in many reservoirs throughout the United States. While natural and augmentation woody structures were selected at similar rates, the high selection of boat docks warrants further research. In addition to sinking structure types, it may be important to diversify structure and implement a type of floating augmentation structure for future habitat enhancements. With these data we can provide recommendations to managers on placement of future augmentation structure to best target sport fish, such as Largemouth Bass.

Short-term studies on Table Rock Lake have demonstrated Largemouth Bass will use all augmentation structure types (Allen et al., 2014). Radio-telemetry allowed us to determine habitat selection of Largemouth Bass in an area unavailable to other methods of habitat selection. Tracking fish over a 12-month period during both day and night hours provided a unique view to Largemouth Bass habitat selection in a large reservoir, which may be applicable to other large reservoirs, especially where deteriorating fish habitat is problematic. Because large scale habitat improvement projects are costly and time consuming, managers need science based information to make informed decisions about the design and placement of these structures. Our results confirm the findings of Allen et al. (2014) which suggest the addition of augmentation structure may be able to supplement the habitat needs of adult Largemouth Bass, as well as other species that rely on woody or rocky habitat to meet their life history requirements.

## **Angler Surveys**

**Shane Bush**

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Angler surveys can provide biologists with useful information regarding angler and fish interactions. Stanovick and Haverland (1995) standardized creel surveys in Missouri and Table Rock Lake has a dataset from a roving-roving creel survey for four different years prior to habitat augmentation; 1995-1996 and 2006-2007.

Two types of surveys were implemented in March 2012 to assist in the evaluation of the NFHI project. A roving-roving creel survey was conducted in order to assess changes in angler catch rates and fishing pressure as a result of the installation of additional fish habitat. In addition, a web-based angler opinion survey was conducted to assess angler opinions regarding the habitat project as well as their angling success in Table Rock Lake.

### **Roving-Roving Creel Survey**

#### **Methods**

The roving-roving creel survey was conducted from March 15 to November 15, 2012 and March 15 to November 15, 2013. The objectives of the creel were to evaluate current fishing regulations, augment long term trend information, interact with anglers to assess angler attitudes and opinions, foster partner relationships with anglers, characterize fish populations that are not regularly sampled, assess angler catch rates, and assess changes in angler catch rates and fishing pressure as a result of habitat augmentation.

In order to prevent bias associated with overall lake changes, each of the two historical creel zones was divided into two sections and compared among sections versus the historical data. Section 1 of each zone was inundated with fish habitat in 2011 while Section 2 of each zone did not receive any habitat (Figures 4.19-4.20).

Two creel clerks conducted the surveys; one in the James River Arm and one in the Mid-White River Arm. Each arm was divided into two sections, Section 1 and Section 2. In the James River Arm, Section 1 included the 1,039 acres between the Highway 76 Bridge and Porter

Branch Cove. Section 2 in the James River Arm included the 887 acres between Porter Branch Cove and Piney Creek (Figure 4.19).

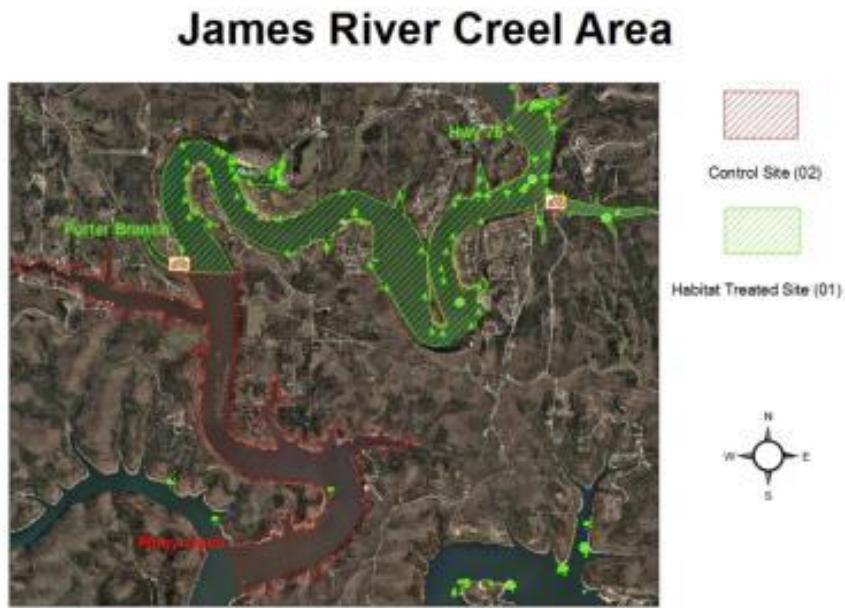


Figure 4.19: James River Creel Zones

In the Mid-White Arm, Section 1 included the 1,692 acres between Baxter Cove and Point 20. Section 2 in the Mid-White Arm included the 2,140 acres between Point 9 and Baxter Cove (Figure 4.20).

## Mid-White Creel Area



Figure 4.20: Mid-White River Creel Zones

During the months of March, April, May, September, October, and November, clerks worked seven hour work days that included one hour for preparation and/or equipment maintenance. During these months, nine days per month were worked in each of the four sections, which included five week days and four weekend days. One of two survey periods (7 am to 1 pm or 1 pm to 7 pm) was selected at random for each shift worked and creel data was collected during this time.

During the months of June, July, and August, clerks worked eight hour workdays, including one hour for preparation and/or equipment maintenance. During these months, eight days per month were worked in each of the four sections, which included five week days and three weekend days. One of two survey periods was selected at random for each shift worked and ran from either 6 am to 1 pm or 1 pm to 8 pm.

Each creel day consisted of two angler and boat counts at randomly selected start times and lasted for 30 minutes or until all anglers and boaters within the creel area were counted. Bank and boat anglers, as well as pleasure boats were counted. The remaining five to six hours of work time was spent interviewing and checking the lengths and numbers of fish in possession of the anglers. Anglers were interviewed individually and their responses to a standard series of

questions about their fishing effort, success, and preferences were recorded. Interviewed anglers also received a handout with information related to the NFHI project and how to access the fish habitat structure locations. Data sheets were collected from the creel clerk at the end of each month, error checked and forwarded to the MDC Resource Science Division in Columbia, Missouri to be analyzed. Computer data analysis revealed additional errors that were corrected before final analyses and summaries were generated.

In addition to the standard angler survey questions, six additional questions related to fishing on or adjacent to habitat structures were incorporated into the surveys. These questions were designed to assess the opinions and usage of MDC installed habitat by anglers in the creel areas. The six optional questions are listed below, with explanation:

1. Did you fish Table Rock Lake prior to 2007?

MDC began placing habitat utilizing NFHI funding in 2007. This information helped to inform biologists of improvements to angler catch rates and opinions of anglers who had fished the lake before the NFHI project began.

2. Are you aware of the fish habitat project MDC has been doing since 2007?

Information was gathered related to the efforts MDC and others have done to educate the public about the NFHI project.

3. Did you fish MDC installed fish habitat structures today?

This information helped biologists determine how many anglers fished MDC installed fish habitat structures. In addition it aided in answering questions concerning anglers' attitudes about fishing the structures.

4. Have the fish habitat improvements in Table Rock Lake improved your fishing?

This question gathered information related to the improvements, actual or perceived, to angling in the areas where habitat has been placed.

5. Do you support MDC placing fish habitat structures into Table Rock Lake?

This information helped to determine if anglers supported MDC efforts to place fish habitat in Table Rock Lake, as well as aiding other biologists in determining if habitat placement in aging reservoirs is something that anglers would support.

6. Have you already been interviewed this year?

If an angler had been interviewed before, some of the information could have been biased. For example, whether or not an angler had been interviewed before

he or she had gained information related to the habitat placement by MDC in Table Rock Lake. It also helped to determine if angler awareness of the project was improved by being contacted by a creel clerk.

## **Results**

A total of 4,793 anglers were interviewed during 2012 and 2013. Estimated angler effort was higher in Section 1 (treatment area) than Section 2 (control area) in each arm of the lake that was surveyed in each respective year. Estimated fishing hours, estimated fishing trips, and estimated catch for all species of fish combined were all higher in Section 1 than Section 2 in both areas in 2012 and 2013 (Table 4.10, Figure 4.21). Estimated fishing hours for individual species, such as black bass, crappie, and catfish, were also higher during both years in sections one versus two in both areas (Figure 4.22). However, catch rates for bass, crappie, and catfish were quite variable among the different sections and different arms during 2012 and 2013 (Figure 4.23). Table Rock Lake black bass and crappie populations are managed with minimum total length limits of 15" and 10", respectively. No significant differences were observed between sections one and two in the catch rates of legal vs. sublegal bass or crappie, or in the mean length of fish caught. Angler effort for catfish and sunfish was considerably higher in Section 1 versus Section 2 of the James River Arm, but similar among sections in the Mid-White Arm.

Table 4.10: Standard Roving Creel Survey Summary.

	James River Site 01		James River Site 02		Mid-White River Site 01		Mid-White River Site 02	
	2012	2013	2012	2013	2012	2013	2012	2013
<u>All Species</u>								
Estimated Fishing Hours	54,869 (4,629)	32,103 (4,200)	23,296 (2,428)	16,874 (1,669)	21,700 (3,247)	16,725 (1,890)	19,609 (3,003)	13,777 (1,665)
Estimated Fishing Trips	9,764 (765)	5,532 (634)	4,450 (424)	1,711 (220)	6,321 (1,326)	3,996 (458)	3,982 (838)	2,534 (311)
Estimated Catch	67,712 (7,730)	32,405 (5,357)	23,998 (2,786)	18,344 (2,302)	36,586 (6,064)	28,012 (3,258)	32,292 (5,630)	22,086 (3,362)
Catch Rate (Fish/Hour)	1.23 (0.13)	1.01 (0.14)	1.03 (0.10)	1.09 (0.10)	1.69 (0.11)	1.67 (0.13)	1.65 (0.15)	1.60 (0.13)
<u>Black Bass</u>								
Estimated Fishing Hours	23,482 (2,238)	17,626 (2,852)	15,685 (1,692)	11,095 (1,236)	14,504 (2,110)	13,649 (1,574)	14,067 (2,309)	11,179 (1,423)
Catch Rate Total Number/Hour	1.15 (0.22)	0.88 (0.17)	0.83 (0.13)	1.06 (0.14)	1.41 (0.15)	1.33 (0.14)	1.34 (0.17)	1.35 (0.11)
Catch Rate Legal Number/Hour	0.20 (0.04)	0.10 (0.03)	0.14 (0.03)	0.16 (0.03)	0.32 (0.04)	0.30 (0.02)	0.31 (0.07)	0.34 (0.04)
Catch Rate Sublegal Number/Hour	0.95 (0.19)	0.78 (0.14)	0.69 (0.12)	0.90 (0.12)	1.08 (0.12)	1.03 (0.11)	1.03 (0.12)	1.02 (0.09)
Mean Length Caught (inches)	13.6	13.9	13.4	13.6	13.1	13.7	12.9	13.7
<u>Crappie</u>								
Estimated Fishing Hours	22,540 (2,705)	12,334 (1,606)	6,129 (809)	4,948 (758)	1,170 (271)	689 (165)	715 (194)	626 (155)
Catch Rate Total Number/Hour	1.06 (0.26)	1.16 (0.41)	0.97 (0.33)	0.84 (0.27)	1.30 (3.34)	0.91 (2.35)	1.58 (6.75)	1.21 (3.66)
Catch Rate Legal Number/Hour	0.78 (0.17)	0.84 (0.30)	0.81 (0.27)	0.71 (0.25)	0.93 (2.41)	0.83 (2.13)	0.98 (4.21)	1.01 (3.04)
Catch Rate Sublegal Number/Hour	0.28 (0.13)	0.32 (0.14)	0.16 (0.09)	0.13 (0.06)	0.37 (0.94)	0.06 (0.17)	0.60 (2.54)	0.20 (0.63)
Mean Length Caught	10.9	10.4	11.1	10.7	11.0	12.2	10.9	12.3
<u>Catfish</u>								
Estimated Fishing Hours	4,474 (726)	1,608 (373)	420 (159)	667 (184)	598 (299)	427 (191)	692 (252)	262 (160)
Catch Rate Total Number/Hour	0.56 (0.60)	0.26 (0.68)	1.19 (6.69)	0.22 (0.55)	0.18 (0.10)	0.05 (0.25)	0.15 (0.63)	0.07 (0.48)
Mean Length Caught	18.3	19.7	18.6	19.7	19.3	20.1	19.8	19.5
<u>Sunfish</u>								
Estimated Fishing Hours	2,371 (530)	536 (178)	436 (224)	165 (67)	797 (186)	130 (54)	664 (181)	499 (163)
Catch Rate Total Number/Hour	2.46 (4.84)	1.89 (14.76)	1.84 (10.10)	3.53 (36.22)	4.49 (18.23)	15.6 (225.91)	6.20 (27.27)	5.54 (20.29)
Mean Length Caught	4.8	5.9	4.8	5.3	5.7	4.8	5.7	5.6
<u>Walleye</u>								
Estimated Fishing Hours	-	-	-	-	951 (364)	-	179 (74)	271 (118)
Catch Rate Total Number/Hour	-	-	-	-	0.02 (0.07)	-	0.05 (0.92)	0.09 (0.59)
Catch Rate Legal Number/Hour	-	-	-	-	0.02 (0.07)	-	0.05 (0.92)	0.09 (0.59)
Catch Rate Sublegal Number/Hour	-	-	-	-	-	-	-	-
Mean Length Caught (inches)	-	-	-	-	20.7	17.6	22.6	26.5

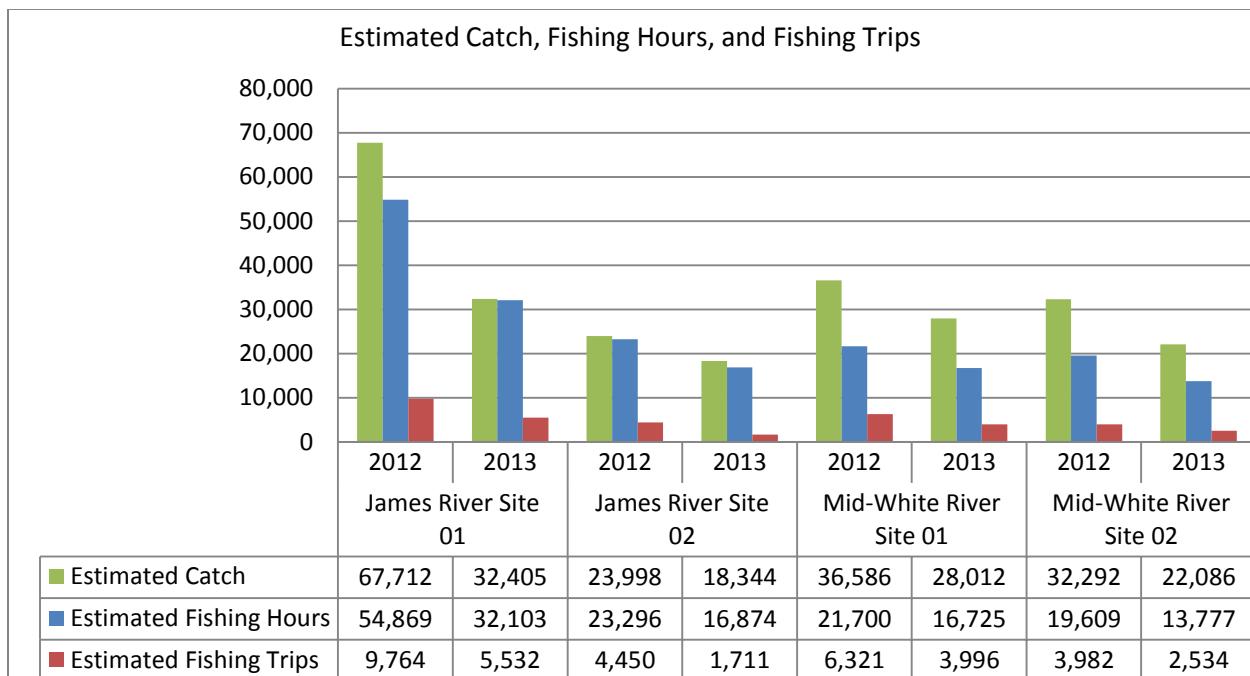


Figure 4.21: Estimated catch, fishing hours, and fishing trips from standard roving creel survey for all species.

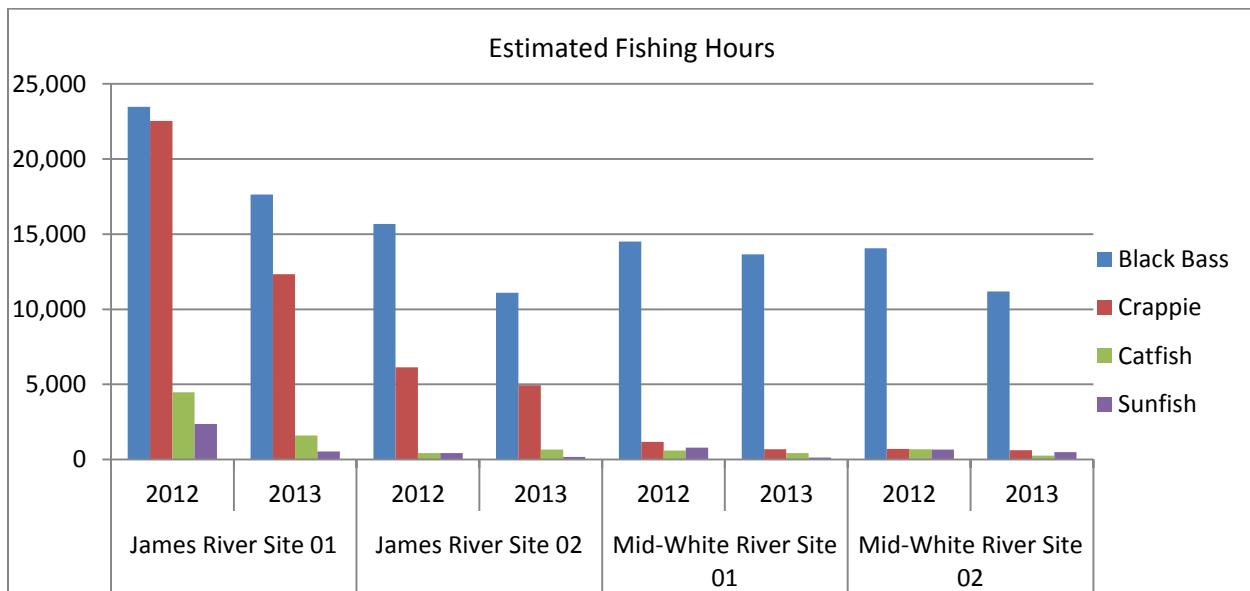


Figure 4.22: Estimated fishing hours from standard roving creel survey for selected species.

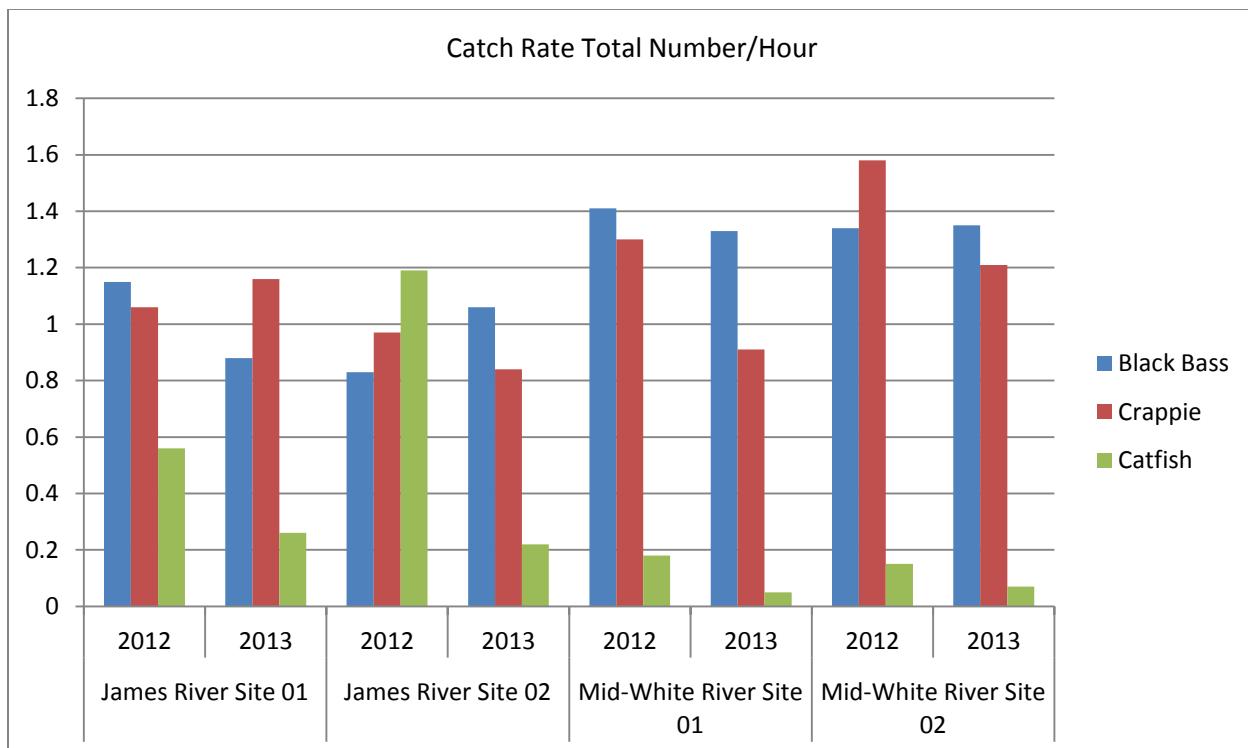


Figure 4.23: Catch rates from standard roving creel survey for selected species.

As expected, anglers fishing in Section 1 of the creel zones fished habitat structures more than those in Section 2 (Table 4.11). In 2012, 33 percent of anglers fishing in Section 1 of each zone fished habitat structures, and this number increased to 43 percent in 2013. Only 82 percent of anglers contacted during their first interview were aware of the habitat project. However, angler awareness of the NFHI project increased over time as anglers interacted with the creel clerks, especially in the James River Arm. Of the anglers who reported that they had already been interviewed, 99 percent were aware of the NFHI project. The number of anglers who were aware of the NFHI project increased from 2012 to 2013 as well. Angler opinions of the NFHI project varied among arms but improved over time. The percentage of anglers who reported that the NFHI project had improved their fishing increased from 64 to 80 percent from 2012 to 2013 with much of this increase being reported in the James River Arm. Nearly all of the respondents were in favor of the NFHI project as 99 percent of anglers reported that they supported MDC placing fish habitat structures into Table Rock Lake.

Table 4.11: Optional questions and angler responses on standard roving creel survey.

Did you fish Table Rock Lake prior to 2007?	James River Site 01				James River Site 02				White River Site 01				White River Site 02				All Sites			
	2012		2013		2012		2013		2012		2013		2012		2013		2012		2013	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Yes	962	86.4%	709	92.6%	684	86.7%	518	94.4%	656	81.1%	549	75.6%	640	83.8%	543	78.2%	2942	84.7%	2319	84.8%
No	151	13.6%	57	7.4%	105	13.3%	31	5.6%	153	18.9%	177	24.4%	124	16.2%	151	21.8%	533	15.3%	416	15.2%
Are you aware of the fish habitat project MDC has been doing since 2007?	879	79.0%	691	90.2%	614	77.8%	504	91.8%	683	84.4%	644	88.7%	644	84.1%	610	87.9%	2820	81.1%	2449	89.5%
Yes	234	21.0%	75	9.8%	175	22.2%	45	8.2%	126	15.6%	82	11.3%	122	15.9%	84	12.1%	657	18.9%	286	10.5%
Did you fish MDC installed fish habitat structures today?	303	27.2%	328	42.8%	80	10.1%	111	20.2%	321	39.7%	315	43.4%	83	10.8%	80	11.5%	787	22.6%	834	30.5%
Yes	809	72.8%	438	57.2%	709	89.9%	438	79.8%	488	60.3%	411	56.6%	683	89.2%	614	88.5%	2689	77.4%	1901	69.5%
Have the fish habitat improvements in Table Rock Lake improved your fishing?	564	50.7%	578	75.6%	368	46.6%	384	69.9%	667	82.4%	624	86.0%	619	80.8%	607	87.5%	2218	63.8%	2193	80.2%
Yes	177	15.9%	40	5.2%	150	19.0%	38	6.9%	10	1.2%	1	0.1%	6	0.8%	0	0.0%	343	9.9%	79	2.9%
I don't know	372	33.4%	147	19.2%	271	34.3%	127	23.1%	132	16.3%	101	13.9%	141	18.4%	87	12.5%	916	26.3%	462	16.9%
Do you support MDC placing fish habitat structures into Table Rock Lake?	1107	99.6%	763	99.7%	786	99.6%	547	99.6%	807	99.8%	720	99.2%	754	98.6%	693	99.9%	3454	99.4%	2723	99.6%
Yes	5	0.4%	2	0.3%	3	0.4%	2	0.4%	2	0.2%	6	0.8%	11	1.4%	1	0.1%	21	0.6%	11	0.4%
Have you already been interviewed this year?	380	34.2%	302	39.4%	288	36.5%	254	46.3%	321	39.7%	253	35.1%	251	32.8%	238	34.3%	1240	35.7%	1047	38.4%
Yes	732	65.8%	464	60.6%	501	63.5%	295	53.7%	487	60.3%	467	64.9%	515	67.2%	455	65.7%	2235	64.3%	1681	61.6%

Of the anglers who responded that they fished MDC installed fish habitat structures on the day that they were interviewed, Walleye anglers comprised the highest percentage in 2012 with 56 percent (10 of 18) of Walleye anglers reporting that they did fish habitat structures (Table 4.12). Crappie anglers comprised the highest percentage of anglers who fished habitat structures in 2013. Approximately 31 percent (147 of 480) of crappie anglers fished habitat structures in 2012 and this number increased to 53 percent (170 of 320) in 2013. On average during 2012 and 2013, 25 percent (111 of 438) of sunfish anglers fished habitat structures. While bass anglers comprised the majority of anglers interviewed during both years, only 27 percent (955 of 3527) reported that they fished MDC installed fish habitat structures on the day they were interviewed. Anglers fishing for catfish, White Bass, or other species did not frequently fish habitat structures.

Table 4.12 Percentage of angler response based on species preference to the question, “Did you fish MDC installed fish habitat structures today?”

Did you fish MDC installed fish habitat structures today?																
Angler Response Based on Species Preference																
2012	Bass		Crappie		Sunfish		Catfish		Walleye		White Bass		Other		TOTAL	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Yes	485	25%	147	31%	91	27%	29	19%	10	56%	21	19%	121	15%	905	24%
No	1451	75%	333	69%	251	73%	126	81%	8	44%	88	81%	684	85%	2941	76%
Total	1936		480		342		155		18		109		805		3846	
2013	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Yes	470	30%	170	53%	20	21%	8	14%	2	33%	6	12%	171	26%	847	31%
No	1121	70%	150	47%	76	79%	51	86%	4	67%	44	88%	475	74%	1921	69%
Total	1591		320		96		59		6		50		646		2768	

Responses to the optional questions from local anglers (<60 miles from Table Rock Lake) were compared to responses from non-local anglers (>60 miles from Table Rock Lake) to determine if the distance traveled to fish at Table Rock Lake had any bearing on their responses. Responses from local versus non-local anglers were similar to most of the questions with the exception that more local anglers had fished Table Rock Lake prior to 2007 and local anglers were generally more aware of the NFHI project (Table 4.13). The percentage of local anglers who felt that the fish habitat improvements had improved their fishing was lower than that of non-local anglers in 2012, but higher in 2013. No significant differences were discerned between sections one and two in the response rate of local or non-local anglers.

Table 4.13: Optional questions and angler responses from local and non-local anglers on standard roving-roving creel survey.

	All Local				All Non-Local			
	2012		2013		2012		2013	
	Number of responses	Percent of responses						
Did you fish Table Rock Lake prior to 2007?								
Yes	1999	89.0%	1624	90.0%	941	76.8%	692	74.3%
No	248	11.0%	174	10.0%	284	23.2%	239	25.7%
Are you aware of the fish habitat project MDC has been doing since 2007?								
Yes	1872	83.3%	1685	93.7%	946	77.1%	760	81.6%
No	375	16.7%	113	6.3%	281	22.9%	171	18.4%
Did you fish MDC installed fish habitat structures today?								
Yes	490	21.8%	595	33.1%	297	24.2%	236	25.3%
No	1756	78.2%	1203	66.9%	930	75.8%	695	74.7%
Have the fish habitat improvements in Table Rock Lake improved your fishing?								
Yes	1407	62.6%	1494	83.1%	810	66.0%	696	74.8%
No	255	11.3%	61	3.4%	88	7.2%	18	1.9%
I don't know	585	26.0%	242	13.5%	329	26.8%	217	23.3%
Do you support MDC placing fish habitat structures into Table Rock Lake?								
Yes	2234	99.5%	1789	99.5%	1217	99.2%	928	99.8%
No	11	0.5%	9	0.5%	10	0.8%	2	0.2%
Have you already been interviewed this year?								
Yes	861	38.3%	764	42.6%	378	30.8%	283	30.5%
No	1385	61.7%	1030	57.4%	848	69.2%	645	69.5%

## Discussion

Typically, increased angler catch rates are the objective of habitat installation projects, and concentrating sport fish near cover will likely increase angler catch rates (Wege and Anderson 1979). Estimated fishing hours, estimated fishing trips, estimated catch, and catch rate for all species of fish combined were all higher in Section 1 compared Section 2 in both areas and this could be a result of the addition of fish habitat structures. Estimated fishing hours, trips, and catch were generally highest in Section 1 of the James River Arm; however this area has been shown to have higher boating use than the other three creel areas (Cherokee 2010). The high amount of boating use in this area could have contributed to the increase in angling effort and trips.

Angler catch rates for black bass were very similar among Sections 1 and 2 during both years in the Mid-White Arm, but differed among years and sections in the James River Arm (Figure 4.23). Some of this could be attributed to the fact that relatively few bass anglers fished habitat structures. Crappie catch rates were higher in Section 1 than Section 2 in the James River Arm during both years and increased from 2012 to 2013 in Section 1 of the James River Arm. This increase was likely due to increased awareness of the habitat project from interviews conducted with crappie anglers in 2012, resulting in the increased number of crappie anglers fishing habitat structures in 2013 (Table 4.12). Crappie catch rates were higher in Section 2 versus Section 1 in

the Mid-White Arm, however the low number of fishing hours for crappie and low number of crappie caught in the Mid-White Arm resulted in a low sample size and high standard error values, making it difficult to draw conclusions from this data. Similarly, the low number of fishing hours and fish caught resulted in very high standard error values for both catfish and sunfish; therefore the differences in angling effort and catch for these species may not be significant (Table 4.10). Higher estimated fishing hours for catfish and crappie and the higher catch rates of catfish in the James River Arm versus the Mid-White Arm could likely be attributed to higher densities of these species in the James River Arm.

Our results support the continued installation of habitat structures as a means to potentially maintain or improve angler catch rates in large reservoirs like Table Rock Lake. However, in order to significantly increase angler catch rates, additional habitat would likely be necessary. In Table Rock Lake, both bass and crappie are highly mobile (Allen et al. 2014, Harris 2013). Because of this, it is likely that bass and crappie do not use fish habitat structures all of the time or during all times of the year. As a result, anglers may have difficulty catching these fish near habitat structures at times, thus reducing the fishing pressure and success near habitat structures. Increased awareness of the NFHI project might have resulted in an increase in angling near habitat structures, possibly improving catch rates. Our analysis did not allow us to look at catch rates of anglers solely fishing habitat structures. Future surveys could be directed at determining catch rates of anglers solely fishing habitat structures and those that do not fish any habitat structures to determine if catch rates do indeed differ.

More anglers fished the habitat structures in Section 1 than Section 2 in both the James River Arm and the White River Arm. This is likely a direct result of the increased availability of structures to fish in Section 1. The percentage of anglers who fished the habitat structures increased from 32 percent in 2012 to 43 percent in 2013, likely due to increased awareness of the NFHI project through interviews and handouts. Given that only 32 to 43 percent of anglers interviewed fished the habitat structures, it is difficult to conclude that fish habitat structures increased angling catch rates. However, the creel survey did provide an excellent opportunity to raise angler awareness of the NFHI project and the locations of the fish habitat structures to over 4,000 anglers. The number of anglers aware of the NFHI project increased throughout the survey and likely resulted in an increase of angling near habitat structures. Additionally, the

percentage of anglers who reported that the NFHI project improved their fishing increased by 16 percent from 2012 to 2013, indicating that anglers may have caught more fish near habitat structures as they became aware of them and improved their perception of fish habitat in Table Rock Lake. Overall, anglers are very supportive of the NFHI project and fish habitat installation in Table Rock Lake.

Although Walleye anglers comprised the highest percentage of anglers who fished habitat structures in 2012, the total number of Walleye anglers was very low making it difficult to conclude that Walleye anglers fished habitat more than other anglers (Table 4.12). Crappie anglers comprised the highest percentage of anglers who fished habitat structures in 2013 and increased substantially from 2012. This increase was likely a direct result of increased awareness of the habitat project and locations of the structures as a result of interviews conducted during 2012. In general, the number of “yes” responses to each of the six optional questions increased more with local anglers than non-local anglers from 2012 to 2013. Local anglers were generally more aware of the NFHI project and fished installed habitat structures more than non-local anglers in 2013. In addition, local anglers’ perceptions that the habitat improvements in Table Rock Lake had improved their fishing increased by 20 percent from 2012 to 2013 and only increased 10 percent with non-locals. It is likely that local anglers noticed more of a difference in their catch rates and overall lake changes, possibly resulting from the NFHI project, than non-local anglers did. Greater than 99 percent of both local and non-local anglers supported the NFHI project.

### **Web- Based Opinion Survey**

#### **Methods**

In addition to the creel survey questions regarding NFHI habitat placement in Table Rock Lake, a web-based survey was created to gain opinions and information from the general public. This survey was created using SurveyMonkey® and was available through a link placed on the MDC website between March 15, 2012 and November 15, 2013. This survey contained 15 questions that were similar to those included in the standard roving-roving creel survey. However, these questions were specifically designed to obtain angler attitudes and opinions and included more detailed questions about specific types of structures and orientations anglers preferred. The survey also allowed for anglers to voice their comments about improving fish habitat placement

in Table Rock Lake as well as other lake related concerns. The 15 questions that were asked were:

1. Is this the first time you have completed this survey?
2. What species do you fish for most at Table Rock Lake?
3. What is your second choice of fish to catch at Table Rock Lake?
4. What is your third choice of fish to catch at Table Rock Lake?
5. Approximately how many days did you fish Table Rock Lake in the last 12 months?
6. Did you fish Table Rock Lake prior to 2007?
7. Are you aware that MDC has been placing fish habitat structures in Table Rock Lake since 2007?
8. How often have you fished MDC installed habitat structures in Table Rock Lake in the last 12 months?
9. Considering the species you said you fished for most in question 2, how would you rate the effectiveness of MDC installed fish habitat structures at each of the following depths in Table Rock Lake?
10. Considering the species you said you fished for most in question 2, how would you rate the effectiveness of MDC installed fish habitat structures in Table Rock Lake for each of the following structure types?
11. Do you use a GPS for locating MDC installed habitat structures in Table Rock Lake?
12. How would you prefer MDC habitat structures to be marked in Table Rock Lake?
13. In your opinion, have the MDC fish habitat structures improved your fishing success?
14. To what extent do you support or oppose the MDC fish habitat structure placement in Table Rock Lake?
15. What suggestions do you have to help improve fish habitat in Table Rock Lake and other reservoirs?

## **Results**

A total of 436 anglers completed the web-based survey. Of the responses received, 412 were from anglers who were completing the survey for the first time (Figure 4.24). Of the 436 anglers surveyed, 55 percent said that Largemouth Bass was the species they fished for most at Table Rock Lake and 17 percent of anglers said that they fished for crappie the most (Figure 4.25).

Smallmouth Bass and Spotted Bass comprised the highest percentages of anglers' second and third choices of fish to catch, respectively (Figures 4.26-4.27). Survey respondents fished an average of 36 days per year in Table Rock Lake from 2012-2013 (Figure 4.28). Seventy-four percent of anglers fished Table Rock Lake prior to 2007 and 72 percent of anglers interviewed were aware of the NFHI project (Figures 4.29-4.30). When asked how often they had fished habitat structures during the past 12 months, 70 percent of anglers reported that they had fished habitat to some degree and 20 percent fished it regularly or exclusively (Figure 4.31).

Forty-four percent of people completing the web-based survey said that structures placed in 11-20 feet of water were effective (rated 4 or 5) and 40 percent said that structures placed in 21-30 feet were effective. Thirty-two percent of people completing the survey also indicated that structures placed in one to ten feet of water were effective (Figure 4.32). Forty-five percent of people who completed the survey indicated that hardwood and rock structures were effective, 43 percent indicated that stumps were effective, and 42 percent indicated cedar structures were effective (Figure 4.33). Only 25 percent of respondents felt that pines were effective. Only 45 percent of anglers reported that they used a GPS to locate habitat structures and 55 percent said they would prefer structures be marked with both GPS and signs (Figures 4.34-4.35). Forty-six percent of anglers reported that the MDC habitat structures had improved their fishing and 89 percent of anglers supported habitat structure placement (Figures 4.36-4.37).

Is this your first time completing this survey?		
Answer Options	Response Percent	Response Count
Yes	94.5%	412
No	5.5%	24
	<i>answered question</i>	<b>436</b>
	<i>skipped question</i>	<b>0</b>

Figure 4.24: Angler responses for the question, "Is this your first time completing this survey?"

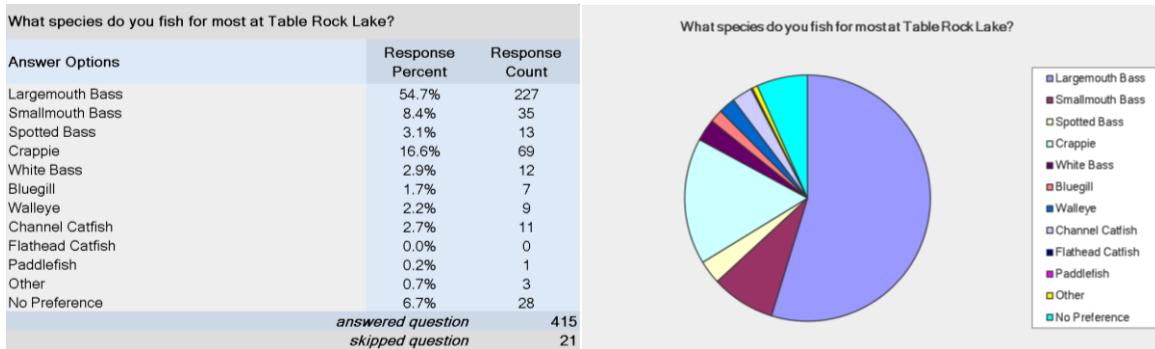


Figure 4.25: Angler responses to the question, “What species do you fish for most at Table Rock Lake?”

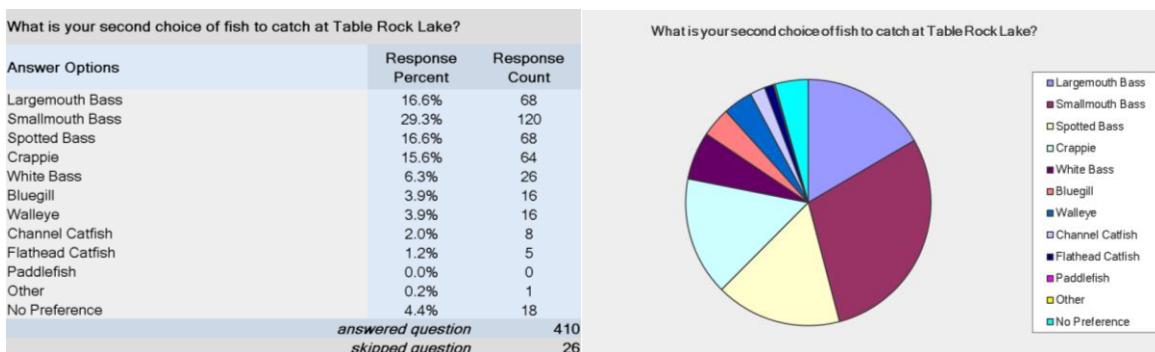


Figure 4.26: Angler responses to the question, “What is your second choice of fish to catch at Table Rock Lake?”

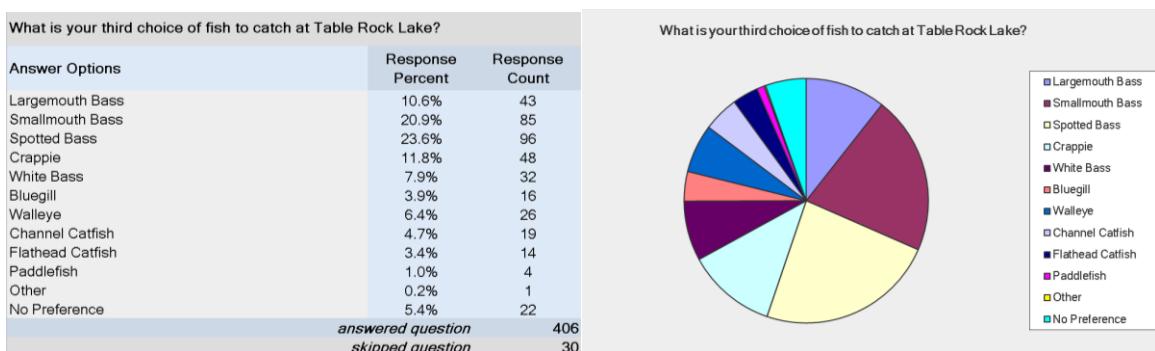


Figure 4.27: Angler responses to the question, “What is your third choice of fish to catch at Table Rock Lake?”



Figure 4.28: Angler responses to the question, “Approximately how many days did you fish Table Rock Lake in the last 12 months?”

Did you fish Table Rock Lake prior to 2007?			
Answer Options	Response Percent	Response Count	
Yes	74.0%	296	
No	26.0%	104	
<i>answered question</i>		400	
<i>skipped question</i>		36	

Figure 4.29: Angler responses to the question, “Did you fish Table Rock Lake prior to 2007?”

Are you aware that MDC has been placing fish habitat structures in Table Rock Lake since 2007?			
Answer Options	Response Percent	Response Count	
Yes	71.8%	287	
No	28.3%	113	
<i>answered question</i>		400	
<i>skipped question</i>		36	

Figure 4.30: Angler responses to the question, “Are you aware that MDC has been placing fish habitat structures in Table Rock Lake since 2007?”

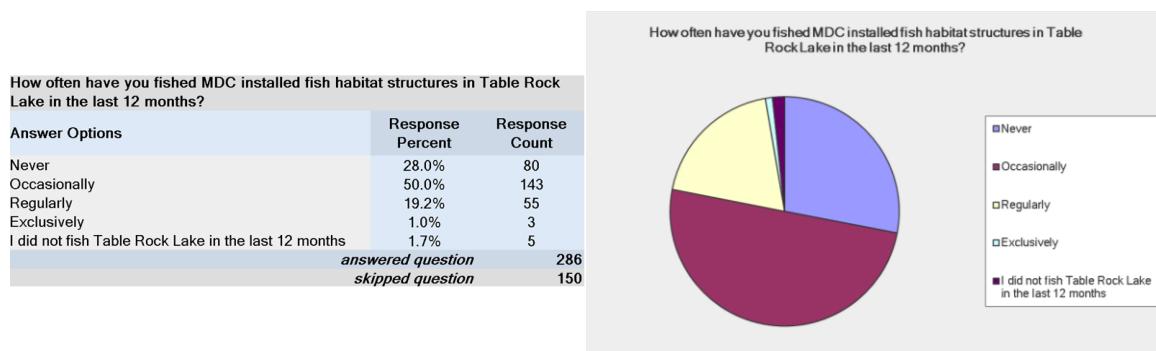


Figure 4.31: Angler responses to the question, “How often have you fished MDC installed fish habitat structures in Table Rock Lake in the last 12 months?”

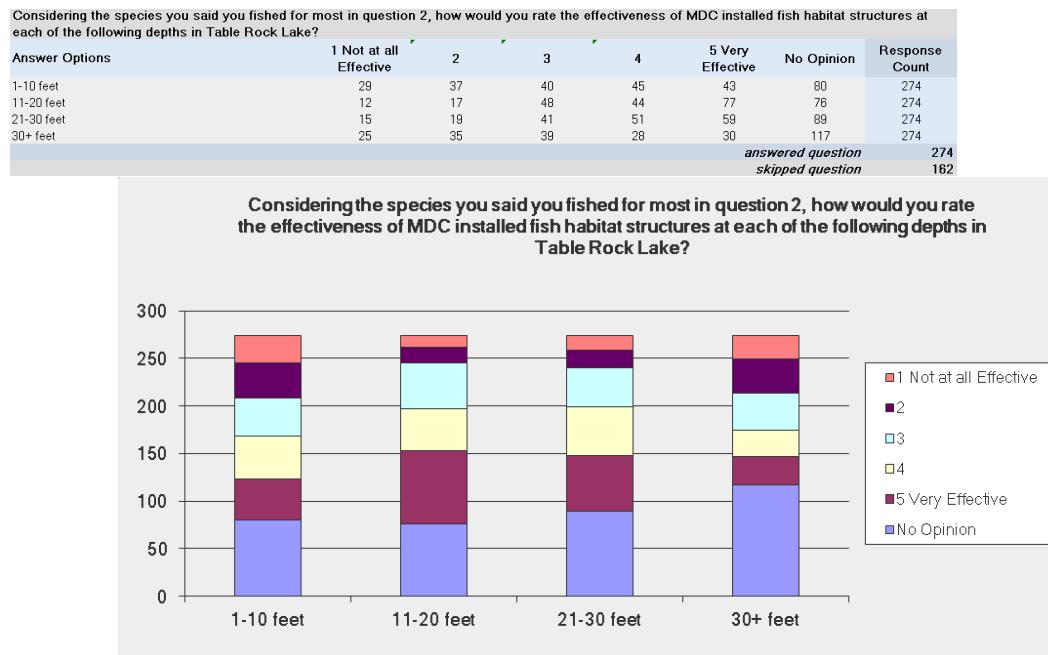


Figure 4.32: Angler responses to the question, “Considering the species you said you fished for most in question 2, how would you rate the effectiveness of MDC installed fish habitat structures at each of the following depths in Table Rock Lake?”

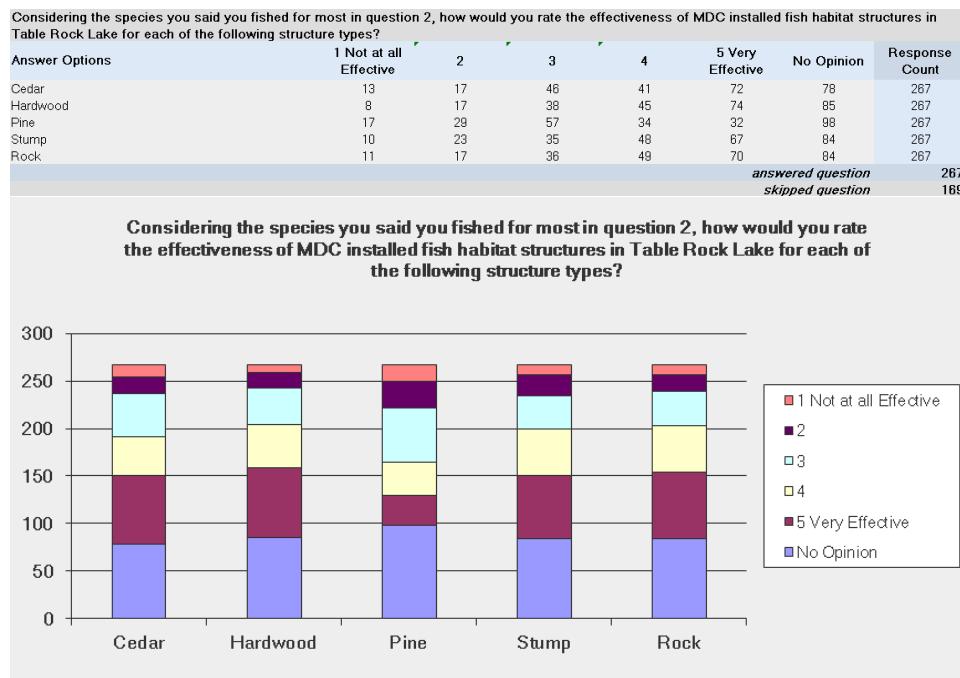


Figure 4.33: Angler responses to the question, “Considering the species you said you fished for most in question 2, how would you rate the effectiveness of MDC installed fish habitat structures in Table Rock Lake for each of the following structure types?”

Do you use a GPS for locating MDC installed fish habitat structures in Table Rock Lake?			
Answer Options	Response Percent	Response Count	
Yes	44.7%	119	
No	55.3%	147	
	<i>answered question</i>	266	
	<i>skipped question</i>	170	

Figure 4.34: Angler responses to the question, “Do you use a GPS for locating MDC installed fish habitat structures in Table Rock Lake?”

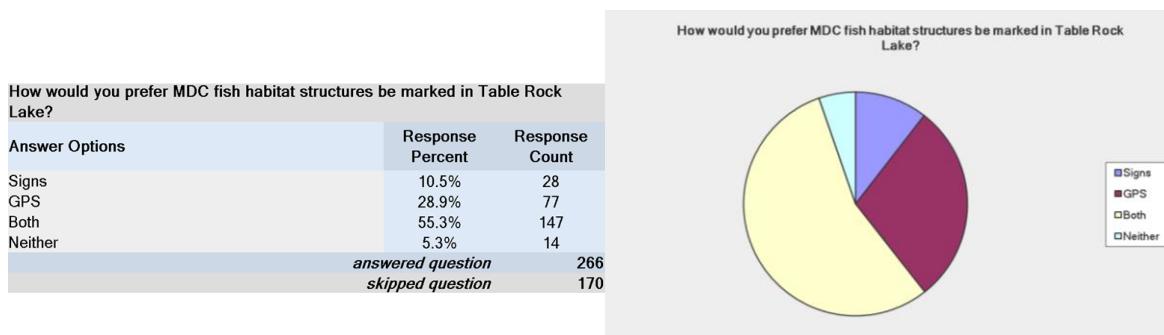


Figure 4.35: Angler responses to the question, “How would you prefer MDC fish habitat structures be marked in Table Rock Lake?”

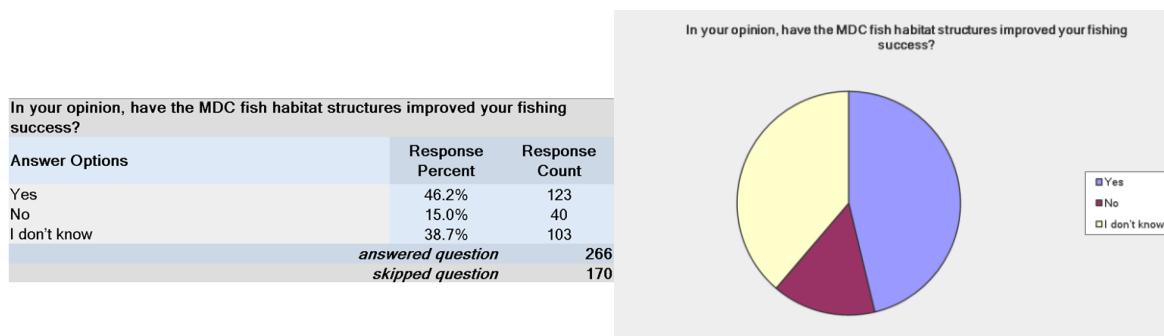


Figure 4.36: Angler responses to the question, “In your opinion, have the MDC fish habitat structures improved your fishing success?”

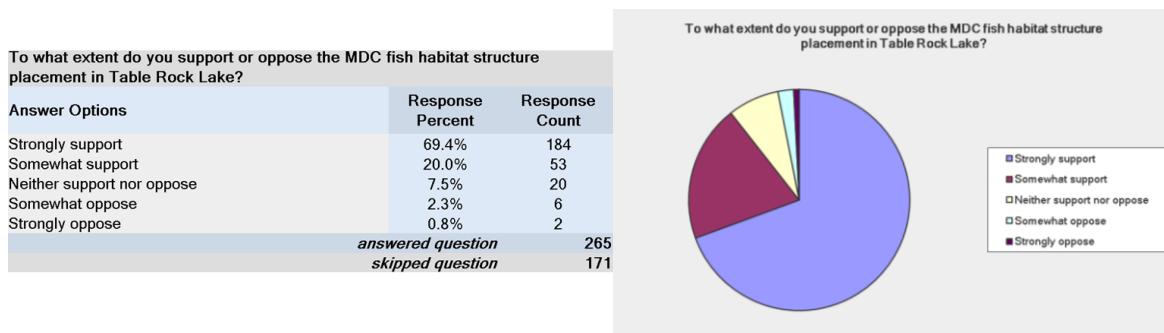


Figure 4.37: Angler responses to the question, “To what extent do you support or oppose the MDC fish habitat structure placement in Table Rock Lake?”

What suggestions do you have to help improve fish habitat in Table Rock Lake and other reservoirs?	
Answer Options	Response Count
<i>answered question</i>	148
<i>skipped question</i>	288

Figure 4.38: Number of angler responses to the question, “What suggestions do you have to help improve fish habitat in Table Rock Lake and other reservoirs?”

Selected angler responses:

- Continue with the information supplied online. The maps and GPS coordinates are very helpful and very useful.
- Great Program, hope this continues... Table Rock is becoming a better fishery every year.
- The brush that stands higher in the water holds fish better than flat trees
- Keep up what you’re doing and improving.
- Keep it up and keep dropping brush piles in the lake. Continue adding to the piles you currently have.
- More rock piles in 10 to 20 ft. range
- Put rock piles on gravel areas, brush in rocky areas, nothing in standing timber.
- I think the use of sycamore and willow trees would be advantageous. Cedars work well for crappie, but in my experience the first two listed are the best for bass. I can't tell you how much I support adding structure to older Ozark lakes. It REALLY helps the fishing especially with today's fishing pressure. I must say, I am impressed with placement of structure too. It's often located on tips of points, near channel breaks, etc. Somebody does their homework. GREAT JOB.
- Place more trees on gravel flats and points where there aren't any. Put some shallow, then put some more close to them, but deeper. 10-12 feet, then 18-25 feet.
- Thanks for what you are doing to improve the fishing.

## Discussion

Largemouth Bass were the most sought after species of fish to catch, followed by Smallmouth Bass, Spotted Bass, and crappie. Many of the anglers who responded were aware of the NFHI project, but this survey was accessed through the Table Rock Lake fish attractor websites. Therefore, those who responded likely had some previous knowledge of the NFHI project prior to filling out the survey.

Responses to similar questions in the roving-roving creel survey and the web-based opinion survey were slightly different. More respondents to the web-based survey fished habitat structures than respondents during the roving-roving survey (Table 4.11, Figure 4.31). However, more anglers in the roving-roving creel survey responded that the fish habitat improvements had improved their fishing than those in the web-based survey (Table 4.11, Figure 4.36). Overall, results from both surveys indicate that anglers are very supportive of the NFHI project and the fish habitat improvements in Table Rock Lake.

Angler preferences of locations for habitat structures for bass corroborated findings of the other evaluation methods used for the NFHI project on Table Rock Lake. SCUBA surveys conducted by Allen et al. (2014) showed that legal-sized bass were observed most often on hardwood structures and sub-legal bass and all sizes of crappie were observed most using cedar structures. Anglers reported that hardwood and cedar trees were effective habitat types, but also reported that rocks and stumps were effective. Pine trees were by far the least effective habitat type for anglers completing the web-based survey. Harris (2013) found that tagged Largemouth Bass in Table Rock Lake were typically found in depths ranging from two to seven meters (6 to 22 feet). Anglers reported that the most effective depth range for installing fish habitat structures was 11 to 20 feet. This agreement in results from differing evaluation techniques could suggest that the fish habitat structures placed in Table Rock Lake are utilizing the best materials and placement to attract fish and improve angler success in the reservoir.

**Objective 5: Develop framework for broader national program focused on habitat protection/restoration in reservoirs and their watersheds**

The NFHI project was the result of many companies, agencies, organizations and individuals working together to produce the best results for improving fish habitat and water quality in reservoirs. With each objective of this project, new techniques and ideas emerged to improve angling opportunities and reservoir health. Working with as many partners as possible to complete objectives is vital to the success of such a large scale project. Most agencies have only enough resources to include a single biologist or manager for a reservoir. This can be problematic as one person typically may not be able to complete all aspects of a project of this magnitude. Installation of habitat structures in the lakes was the primary task of the lead

biologist on the project and required the most attention and effort. During the fall and winter months, the biologist and temporary employees spent up to 95 percent of their time coordinating habitat projects with contractors and partners, locating sources of materials, installing habitat structures, managing GPS data, and maintaining vehicles. The spring and summer months were focused on evaluation of the structures and promoting the project.

Partners on the NFHI project focused on a watershed approach to reservoir habitat enhancement. The MDC fisheries biologists focused the majority of the “on the ground” efforts to in-reservoir habitat and solicited help from other divisions within MDC as well as other agencies with different resources to help manage watershed influences. TRLWQ and JRPB were already in the process of trying to maintain watershed health by informing the public in the James River and Table Rock Lake watersheds about the effects that poor water quality can have on the lake. With the additional funding through the NFHI project, these organizations were able to work with the residents of the watershed and educate them about the techniques that can be used to improve water quality and watershed health. These organizations could also work with other businesses to perform the work needed, without requiring contracts for specific work. This increased the efficiency of the work done in the watershed. While these organizations were focused on reducing nutrient inputs to the watershed, MDC used the NFHI funding to perform work on riparian and in-stream improvements. The funding directed towards streambank stabilization projects allowed for MDC personnel to complete projects using MDC equipment. This not only reduced the costs of the projects, but ensured they were completed by operators experienced in this kind of work. Involving personnel from many MDC divisions, as well as other agencies, allowed for focused efforts on watershed health, reservoir habitat, and proper monitoring of all projects in place. This also allowed for all of the objectives of the project to be completed by experienced and knowledgeable staff in the specific aspects of the project.

Expertise on habitat placement and improving water quality was gained many ways, but one of the most helpful methods was meeting with anglers, focus groups, and stakeholders. Many meetings were held to raise awareness of the project, promote project publicity, and obtain input from the public on how work within the reservoir should be completed. Many of the habitat structure installation projects on Table Rock Lake were completed using information provided to biologists by angling guides and avid anglers in the specific areas where projects were taking

place. Each project meeting helped to inform biologists about the angling pressure, fish behavior, and general use of structures within that area of the lake. This improved habitat placement in other areas of the lake that were similar to each other and improved the knowledge of existing structures and natural habitat within the lake. Many of the types of habitat structures used were determined as a result of these meetings. For example, the rock structures and rock fence structures were developed based on information obtained from angling guides about similar structures that already existed within Table Rock Lake and other reservoirs.

The NFHI project utilized many different methods to improve the fish and aquatic resources in Table Rock Lake and each objective could be used individually to assist other agencies with reservoir management. Different eco-regions have specific management goals related to reservoir health and aquatic resources and this project addressed many of the management goals for Table Rock Lake. These techniques can be adapted for use in other eco-regions and reservoirs throughout the United States. Some of the techniques developed through the NFHI project have already been used in different regions and reservoirs in Missouri. The MDC biologists have attended and presented information at numerous conferences and been involved with discussions related to habitat augmentation and methods for installation. Information learned from the NFHI project has been shared with multiple state, federal, and private entities. Many of these entities have requested information from the NFHI project to develop methods for habitat improvements in reservoirs and their watersheds. As with any new project or management technique, funding will be a concern. The determination of the types of materials and installation techniques used on a reservoir should be based on the types of structures that best attract fish, the most cost effective structures (Table 4.5) and, the longevity of materials used.

This report represents the culmination of information gathered from the NFHI project on Table Rock Lake. Many different ideas regarding habitat placement, watershed health improvements and recreational fishing improvements are included in this document. As a result of the habitat enhancements and evaluation techniques performed and carried out with this project, new techniques have been developed. The information shared in this report could potentially be used by multiple state, federal, non-government and private entities to help determine the proper techniques to improve angling opportunities, fishery health, and watershed conditions as an

initial plan for habitat restoration in large reservoirs. It contains the necessary information to complete projects for improving habitat and water quality in large reservoirs.

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## Literature Cited

Allen, M., S. Bush, I. Vining, and M. J. Siepker. 2014. Black bass and crappie use of installed habitat structures in Table Rock Lake, Missouri. *North American Journal of Fisheries Management*, 34:2, 223-231

Angermeier, P. L. and J. R. Karr. 1984. Relationships between woody debris and fish habitat in a small warmwater stream. *Transactions of the American Fisheries Society* 113:716-726.

Annett, C., J. Hunt, and E. D. Dibble. 1996. The compleat bass: habitat use patterns of all stages of the life cycle of Largemouth Bass. Pages 306-314 *in* L. E. Miranda, and D. R. DeVries, editors. *Multidimensional approaches to reservoir fisheries management*. American Fisheries Society, Symposium 16, Bethesda, Maryland.

Bassett, C. E. 1994. Use and evaluation of fish habitat structures in lakes of the eastern United States by the USDA Forest Service. *Bulletin of Marine Science* 55:1137-1148.

Beamesderfer, R. C. P., and J. A. North. 1995. Growth, natural mortality, and predicted response to fishing for Largemouth Bass and Smallmouth Bass populations in North America. *North American Journal of Fisheries Management* 15:688-704.

Bohnsack, J. A., and S. P. Bannerot. 1986. A stationary visual census technique for quantitatively assessing community structure of coral reef fishes. NOAA (National Oceanic and Atmospheric Administration) Technical Report NMFS (National Marine Fisheries Service) 41. U.S. Department of Commerce, Washington, D.C.

Bonnot, T., M. Wildhaber, J. Millspaugh, A. DeLonay, R. Jacobson, and J. Bryan. 2011. Discrete choice modeling of Shovelnose Sturgeon habitat selection in the Lower Missouri River. *Journal of Applied Ichthyology* 27:291-300.

Boyce, M. S., P. R. Vernier, S. E. Nielsen, and F. K. A. Schmiegelow. 2002. Evaluating resource selection functions. *Ecological Modelling* 157:281-300.

Bretz, F., T. Hothorn, and P. Westfall. 2010. *Multiple Comparisons Using R*, CRC Press, Boca Raton.

Brown, R. S., S. J. Cooke, W. G. Anderson, and R. S. McKinley. 1999. Evidence to challenge the “2% rule” for biotelemetry. *North American Journal of Fisheries Management* 19:867-871.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Springer Science, New York.

Bush, S. 2009. Table Rock Lake 2006-2007 angler creel survey summary. Missouri Department of Conservation, Branson, Missouri.

Cherokee CRC, LLC. Recreational Boating Use Study, Table Rock Lake, Missouri. April 2010.

Cooke, S., S. Hinch, M. Lutcavage, and M. Lucas. 2012. Biotelemetry and biologging. Pages 819-881 *in* A. V. Zale, D. L. Parrish, and T. M. Sutton, editors. Fisheries techniques, third edition. American Fisheries Society, Bethesda, Maryland.

Cooke, S. J., D. P. Philipp, and P. J. Weatherhead. 2002. Parental care patterns and energetics of Smallmouth Bass (*Micropterus dolomieu*) and Largemouth Bass (*Micropterus salmoides*) monitored with activity transmitters. Canadian Journal of Zoology 80:756-770.

Cooper, A. B., and J. J. Millspaugh. 1999. The application of discrete choice models to wildlife resource selection studies. Ecology 80:566-575.

Cooper, A., and J. Millspaugh. 2001. Accounting for variation in resource availability and animal behavior in resource selection studies. Pages 243-273 *in* Radio tracking and animal populations. Academic Press, San Diego, California.

Crowder, L. B., and W.E. Cooper. 1979. Structural complexity and fish-prey interactions in ponds: a point of view. Pages 2-10 *in* D. L. Johnson and R. A. Stein, editors. Response of fish to habitat structure in standing water. North Central Division, American Fisheries Society, Special Publication 6. Bethesda, Maryland.

Dibble, E. D. 1991. A comparison of diving and rotenone methods for determining relative abundance of fish. Transactions of the American Fisheries Society 120:663-666.

Dolloff, A., J. Kershner, and R. Thurow. 1996. Underwater observation. Pages 533-554 *in* B. R. Murphy and D. W. Willis, editors. Fisheries Techniques, 2<sup>nd</sup> edition. American Fisheries Society, Bethesda, Maryland.

Durocher, P. P., W. C. Provine, and J. E. Kraai. 1984. Relationship between abundance of Largemouth Bass and submerged vegetation in Texas reservoirs. North American Journal of Fisheries Management 4:84-88.

ESRI. 2011. ArcGIS Desktop: Release 10. Environmental Systems Research Institute, Redlands, CA.

Everett, R. A., and G. M. Ruiz. 1993. Coarse woody debris as a refuge from predation in aquatic communities. *Oecologia* 93:475-486.

Floyd, K. B., W. H. Courtenay, and R. D. Hoyt. 1984. A new larval fish light trap: the quatrefoil trap. *The Progressive Fish-Culturist* 46:216-219.

Franklin, A. B., D. R. Anderson, R. Gutiérrez, and K. P. Burnham. 2000. Climate, habitat quality, and fitness in northern spotted owl populations in northwestern California. *Ecological Monographs* 70:539-590.

Gibbons, J. W., J. T. Hook, and D. L. Forney. 1972. Winter responses of Largemouth Bass to heated effluent from a nuclear reactor. *The Progressive Fish-Culturist* 34:88-90.

Graham, R. J. 1992. Visually estimating fish density at artificial structures in Lake Anna, Virginia. *North American Journal of Fisheries Management* 12:204-212.

Green, A. W., G. C. Matlock, and J. E. Weaver. 1983. A method for directly estimating the tag-reporting rate of anglers. *Transactions of the American Fisheries Society* 112:412-415.

Hanson, K., S. Cooke, C. Suski, G. Niezgoda, F. Phelan, R. Tinline, and D. Philipp. 2007. Assessment of Largemouth Bass (*Micropterus salmoides*) behaviour and activity at multiple spatial and temporal scales utilizing a whole-lake telemetry array. *Hydrobiologia* 582:243-256.

Harris, J. 2013. Habitat selection, movement, and home range of Largemouth Bass (*Micropterus salmoides*) following a habitat enhancement project in Table Rock Lake, Missouri. Master's thesis. University of Missouri, Columbia, Missouri.

Hart, L. G., and R. C. Summerfelt. 1975. Surgical procedures for implanting ultrasonic transmitters into Flathead Catfish (*Pylodictis olivaris*). *Transactions of the American Fisheries Society* 104:56-59.

Hasler, C., C. Suski, K. Hanson, S. Cooke, and B. Tufts. 2009. The influence of dissolved oxygen on winter habitat selection by Largemouth Bass: an integration of field biotelemetry studies and laboratory experiments. *Physiological and Biochemical Zoology* 82:143-152.

Halfman, G. S. 1979. Fish attraction to floating objects in lakes. Pages 49-57 in D. L. Johnson, and R. A. Stein, editors. *Response of Fish to Habitat Structure in Standing Water*. North Central Division, American Fisheries Society, Special Publication 6, Bethesda, Maryland.

Hoff, M. J. 1991. Effects of increased nesting cover on nesting and reproduction of Smallmouth Bass in northern Wisconsin lakes. Pages 39-43 in D. C. Jackson, editor. The first international Smallmouth Bass symposium. American Fisheries Society, Bethesda, Maryland.

Howick, G. L., and W. J. O'Brien. 1983. Piscivorous feeding behavior of Largemouth Bass: an experimental analysis. *Transactions of the American Fisheries Society* 112:508-516.

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

Hunt, J., N. Bachelier, D. Wilson, E. Videan, and C. Annett. 2002. Enhancing Largemouth Bass spawning: behavioral and habitat considerations. Pages 277-290 in D. P. Philipp, and M. S. Ridgway, editors. *Black Bass: Ecology, Conservation, and Management*. American Fisheries Society, Symposium 31, Bethesda, Maryland.

Hunt, R. L. 1971. Response of a Brook Trout population to habitat development in Lawrence Creek. *Wisconsin Department of Natural Resources Technical Bulletin* 48.

Hunt, R. L. 1988. A compendium of 45 trout stream habitat development evaluations in Wisconsin during 1953-1985. *Wisconsin Department of Natural Resources, Technical Bulletin* 162, Madison

Hunter, R. W., and M. J. Maceina. 2008. Movements and home ranges of Largemouth Bass and Alabama Spotted Bass in Lake Martin, Alabama. *Journal of Freshwater Ecology* 23:599-606.

Irwin, L. L., D. F. Rock, and S. C. Rock. 2011. Habitat selection by northern spotted owls in mixed-coniferous forests. *Journal of Wildlife Management* 76:200-213.

Jennings, D. 1987. Standardization. Missouri Department of Conservation memo. Jefferson City.

Karchesky, C. M., and D. H. Bennett. 2004. Winter habitat use by adult Largemouth Bass in the Pend Oreille River, Idaho. *North American Journal of Fisheries Management* 24:577-585.

Kruse, M. 2003. Sport Fish Restoration Project F-1-R-51: Study I-35: Job 3: Management of Lake Taneycomo, Missouri: Job 3: Management Evaluation. Missouri Department of Conservation Final Report.

Kruse, M., B. Anderson, A. Austin, J. Civiello, A. Daniels, Q. Fronterhouse, C. Fuller, W. Hutton, G. Kromrey, D. Mayers, K. Meneau, M. Miller, K. Richards, T. Roberson, B. Stimson, C. Vitello, N. Stucky, D. Steward, D. Humburg, D. Erickson. 2003. A Plan for Missouri Trout Fishing. Missouri Department of Conservation.

Ludsin, S. A., and D. R. DeVries. 1997. First-year recruitment of Largemouth Bass: the interdependency of early life stages. *Ecological Applications* 7:1024-1038.

Lyons, B. W. 1993. Distribution and habitat selection of Florida and northern Largemouth Bass in Lake Tawakoni, Texas. *Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies* 47:633-641.

Magnelia, S. J., M. J. De Jesus, J. W. Schlechte, G. C. Cummings, and J. L. Duty. 2008. Comparison of plastic pipe and juniper tree fish attractors in a central Texas reservoir. *Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies* 62:183-188.

Mesing, C. L., and A. M. Wicker. 1986. Home range, spawning migrations, and homing of radio-tagged Florida Largemouth Bass in two central Florida lakes. *Transactions of the American Fisheries Society* 115:286-295.

Moyle, P.B., and R. A. Leidy. 1992. Loss of biodiversity in aquatic ecosystems: Evidence from fish faunas. *Conservation Biology* II:127-169.

Neumann, R. M., C. S. Guy, and D. W. Willis. 2012. Length, weight, and associated indices. Pages 637-676 in A. V. Zale, D. L. Parrish, and T. M. Sutton, editors. *Fisheries techniques*, 3<sup>rd</sup> edition. American Fisheries Society, Bethesda, Maryland.

Olson, M. H., B. P. Young, and K. D. Blinkoff. 2003. Mechanisms underlying habitat use of juvenile Largemouth Bass and Smallmouth Bass. *Transactions of the American Fisheries Society* 132:398-405.

Patrick, K. A. 1996. Utilization of half-log structures as spawning sites for Smallmouth Bass in Norris Reservoir, Tennessee. Master's thesis. University of Tennessee, Knoxville.

Paukert, C. P., and D. W. Willis. 2002. Seasonal and diel habitat selection by Bluegills in a shallow natural lake. *Transactions of the American Fisheries Society* 131:1131-1139.

Paukert, C., and D. Willis. 2004. Environmental influences on Largemouth Bass *Micropterus salmoides* populations in shallow Nebraska lakes. *Fisheries Management and Ecology* 11:345-352.

Perry, N. 2009. Table Rock project forebay oxygen diffuser system report update. Draft report. Tennessee Valley Authority, Office of Environment & Research, Environmental Resources & Services. TVA contract no. 64870; Military Interdepartmental Purchase Request number W38XGR72437084. 25 pp.

Ploskey, G. R., J. M. Nestler, and W. M. Bivin. 1996. Predicting black bass reproductive success from Bull Shoals Reservoir hydrology. Pages 422-441 in L. E. Miranda and D. R. DeVries, editors. Multidimensional approaches to reservoir fisheries management. American Fisheries Society Symposium 16. Bethesda, Maryland.

Prince, E. D., and O. E. Maughan. 1979. Attraction of fishes to tire reefs in Smith Mountain Lake, Virginia. Pages 19-25 in D. L. Johnson, and R. A. Stein, editors. Response of fish to habitat structure in standing water. North Central Division, American Fisheries Society, Special Publication 6, Bethesda, Maryland.

Prince, E. D., and O. E. Maughan. 1979. Telemetric observations of Largemouth Bass near underwater structures in Smith Mountain Lake, Virginia. Pages 26-32 in D. L. Johnson and R. A. Stein, editors. Response of fish to habitat structures in standing water. North Central Division American Fisheries Society Special Publication 6.

Proctor, W.D., H.D. Harshbarger, M.H. Mobley and J.C. Carter, Jr. April, 1999. Table Rock project aeration options. Tennessee Valley Authority, River System Operations & Environment. WR97-2-760-107. 69 pp.

Quinn, J. W. and T. J. Kwak. 2000. Use of rehabilitated habitat by Brown Trout and Rainbow Trout in an Ozark tailwater river. North American Journal of Fisheries Management 20:737-751.

Rold, R. E., T. S. McComish, and D. E. Van Meter. 1996. A comparison of cedar trees and fabricated polypropylene modules as fish attractors in a strip mine impoundment. North American Journal of Fisheries Management 16:223-227.

Sammons, S. M., and P. W. Bettoli. 1999. Spatial and temporal variation in electrofishing catch rates of three species of black bass (*Micropterus spp.*) from Normandy Reservoir, Tennessee. North American Journal of Fisheries Management 19:454-461.

Sammons, S., and M. Maceina. 2005. Activity patterns of Largemouth Bass in a subtropical US reservoir. Fisheries Management and Ecology 12:331-339.

Savino, J. F., and R. A. Stein. 1982. Predator-prey interaction between Largemouth Bass and Bluegills as influenced by simulated, submersed vegetation. *Transactions of the American Fisheries Society* 111:255-266.

Savino, J. F., and R. A. Stein. 1989. Behavior of fish predators and their prey: habitat choice between open water and dense vegetation. *Environmental Biology of Fishes* 24:287-293.

Schlagenhaft, T. W., and B. R. Murphy. 1985. Habitat use and overlap between adult Largemouth Bass and Walleye in a west Texas reservoir. *North American Journal of Fisheries Management* 5:465-470.

Shuler, S. W., R. B. Nehring, and K. Fausch. 1994. Diel habitat selection by Brown Trout in the Rio Grande River, Colorado, after placement of boulder structures. *North American Journal of Fisheries Management* 14:99-111.

Siepker, M. J., A. J. Pratt, and S. Gao. 2013. Effect of eastern red cedar brush on nest abundance and survival of age-0 black bass in Bull Shoals Lake, Missouri. *Science and Management Technical Series. Number 4. Missouri Department of Conservation.* Jefferson City, Missouri.

Siepker, M. J., and P. H. Michaletz. 2013. Exploring the influence of stock-recruitment relationships and environmental variables on black bass and crappie recruitment dynamics in Missouri reservoirs. *Transactions of the American Fisheries Society* 142:119-129.

Slipke, J. W., and M. J. Maceina. 2007. Movement and use of backwater habitats by Largemouth Bass and White Crappie in Demopolis Reservoir, Alabama. *Journal of Freshwater Ecology* 22:393-401.

Stanovick, J. S. and P. Haverland. 1995. Standardization of Missouri Angler Surveys. *Proceedings of the Annual Conference of Southeastern Fish and Wildlife Agencies* 49:69-77.

Suski, C., and M. S. Ridgway. 2009. Winter biology of centrarchid fishes. Pages 264-292 in S. J. Cooke, and D. P. Philipp, editors. *Centrarchid fishes: diversity, biology, and conservation.* Wiley-Blackwell, West Sussex.

Van Zyll De Jong, M. C., I. G. Cowx, and D. Scruton. 1997. An evaluation of instream habitat restoration techniques on salmonid populations in a Newfoundland stream. *Regulated Rivers: Research and Management* 13:603-614.

Vitello, C. 2002. White River minimum flows. Missouri Department of Conservation memo. Jefferson City.

Vitello, C. B., and M. L. Armstrong. 2008. The White River fisheries partnership: a template for cooperative fisheries management in Arkansas and Missouri. Pages 135-146 in M. S. Allen, S. Sammons, and M. J. Maceina, editors. Balancing fisheries management and water uses for impounded river systems. American Fisheries Society, Symposium 62, Bethesda, Maryland.

Vogege, L. E., and W. C. Rainwater. 1975. Use of brush shelters as cover by spawning black basses (*Micropterus*) in Bull Shoals Reservoir. Transactions of the American Fisheries Society 104:264-269.

Wanjala, B. S., J. C. Tash, W. J. Matter, and C. D. Ziebell. 1986. Food and habitat use by different sizes of Largemouth Bass (*Micropterus salmoides*) in Alamo Lake, Arizona. Journal of Freshwater Ecology 3:359-369.

Warden, R. L., and W. J. Lorio. 1975. Movements of Largemouth Bass (*Micropterus salmoides*) in impounded waters as determined by underwater telemetry. Transactions of the American Fisheries Society 104:696-702.

Wege, G. J., and R. O. Anderson. 1979. Influence of artificial structures on Largemouth Bass and Bluegills in small ponds. Pages 59-69 in D. L. Johnson, and R. A. Stein, editors. Response of Fish to Habitat Structure in Standing Water. North Central Division, American Fisheries Society, Special Publication 6, Bethesda, Maryland.

Wills, T. C., M. T. Bremigan, and D. B. Hayes. 2004. Variable effects of habitat enhancement structures across species and habitats in Michigan reservoirs. Transactions of the American Fisheries Society 133:399 - 411.

Winter, J. D. 1996. Advances in underwater biotelemetry. Pages 555-590 in B. R. Murphy, and D. W. Willis, editors. Fisheries Techniques, second edition. American Fisheries Society, Bethesda, Maryland.