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Examination of experimentally engineered larval fish habitat in the Marmet Pool, Kanawha River, West Virginia

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Examination of experimentally engineered larval fish habitat
in the Marmet Pool, Kanawha River, West Virginia

Jonathan M. Niles

A Thesis

Submitted to
The Davis College of Agriculture, Forestry, and Consumer Sciences
at
West Virginia University

in partial fulfillment of the requirements
for the degree of

Master of Science
In
Wildlife and Fisheries Resources

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Morgantown, WV
2004

Keywords: Kanawha River, Larval fish, Finger dikes, River restoration

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Abstract

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Jonathan M. Niles

In rivers, velocity shelters are thought to serve as limiting factors in the retention and recruitment of young fish. Such shelters are formed in backwaters and tributaries, however these areas are limited in the Marmet Pool of the Kanawha River, West Virginia. In response to this concern, several structures that are thought to serve as low velocity zones were placed within the Marmet Pool. This study was conducted to evaluate the experimental rock structures (Finger and Zipper Dikes) as potential mitigation for navigational impact and to determine which sampling gears are best to sample these shallow, structurally diverse areas. The study was conducted over the course of two years. For each rock structure (treatment), we had two reference areas (high and low quality) that reflected typical river habitat. During the first year we sought to evaluate the effectiveness of three larval sampling devices (light traps, benthic sleds, and activity traps) to sample the rock structures and their associated reference areas. Larval fish were sampled for eight weeks from June 17 through August 3, 2002. Larval abundances peaked in the river during late June 2002. The light trap was the most effective gear to sample larval fish within these rock structures, collecting significantly more larval fish than both the benthic sled and activity trap. The light trap also collected more taxonomic groups than the benthic sled and activity trap. During 2003, we sought to evaluate the overall effectiveness of the rock structures as larval fish habitat. Larval abundances peaked during early July 2003. Throughout both years of the study, larval fish were captured at significantly higher rates ($p < 0.0001$) at rock structures than in high and low quality reference areas. Taxonomic richness within artificial structures was greater than or equal to both high and low quality natural reference sites in both 2002 and 2003. *Percidae* species distribution appears to be most influenced by the introduction of artificial structures in comparison to other abundant fish groups. Water velocities were significantly lower at rock structures (mean 0.03 m/s) than at reference areas (mean 0.16 m/s) suggesting that differences in use may be attributed to velocity shelters, which the structures provide to larval fish. This study suggests that experimental rock structures can serve as velocity shelters and retention areas for larval fish in navigationally impacted rivers.

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Dedication

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Chapter 1: *A review of existing literature and study site descriptions*

Introduction

The Kanawha River is a sixth order tributary of the Ohio River that is formed by the confluence of the Gauley and New Rivers at Gauley Bridge, West Virginia. The river flows northwest for 188 km to its confluence with the Ohio River at Point Pleasant, WV. The Kanawha River is commercially navigable for 153 km of its length.

Mountains extend nearly to the river's banks leaving little opportunity for the formation of backwater areas and floodplains (Scott and Nielson 1989). The Kanawha River, or as it once was referred, "The Great Kanawha" began as a free flowing river with sand bars and large shoals which provided excellent fish habitat. The first settlers of the lower Kanawha arrived in 1774 and were followed shortly after by industries utilizing the rivers' capacity for shipping goods (Sutphin and Andre 1991).

Navigation needs fueled changes along the Kanawha River and thus led to the demise of its aquatic life. The need to transport goods began with the salt industry in the early 1800s followed by shipments of coal and timber. Like most of the East coast, the surrounding landscape was stripped of trees, and the timber was used as fuel or shipped to growing cities. Industrial growth increased the demand for river "improvements." Changes to the river first came in the 1820s when wing dams were constructed to establish a 1-m deep navigation channel (Sheehan and Rasmussen 1993). River regulation began in 1875 with the construction of 10 wicket dams (Kemp 2000). This construction increased the rivers' depth to 2-m for 142 km upstream from its confluence with the Ohio River (Sheehan and Rasmussen 1993). In the 1920s, the wicket dams began to deteriorate, navigation pressure continued to increase, and again the

Kanawha River prepared for additional changes (Kemp 2000). In the 1930's the ten wicket dams were removed in exchange for four roller gate lock and dams (London, Marmet, and Winfield lock and dams on the Kanawha River and Gallipolis on the Ohio River). River depth was increased to nine feet and the capacity to regulate flow was improved (Kemp 2000). The full volume of the river's flow is now confined within a relatively narrow channel of uniform width, with a strong, swift current. Power generation plants were incorporated with the London, Marmet, and Winfield lock and dams (Kemp 2000). The result was a completely altered physical habitat for fish with reduced habitat complexity, higher flows, and decreased river bank area.

The Kanawha River valley and the development of its waterway attracted industrial development. Coal companies found high quality coal seams with much less expensive acquisition costs in comparison to the Monongahela coals just to the north (Great Kanawha Navigation Company 1868). With navigational improvements, lower costs, and access to nearby large cities, industrialization along the Kanawha River continued. Coal companies flocked to the valley and coal shipments on the river grew nearly exponentially (Kemp 2000). Chemical industries moved in during the turn of the century, utilizing the river for shipments and the area's abundance of natural resources (Hubacher and Wintz 2003).

The first official reports of declining fish populations occurred in 1907. The U.S. Bureau of Fisheries cited declines due to mining development, timbering, chemical industry, and occasional use of dynamite for fishing (Addair 1944). Chemical pollution became a major problem for the decades to follow. Fish populations decreased in the lower reaches of the Kanawha River as chemical factories poured waste into the river (Kemp 2000). In addition, housing development along the river banks had direct sewage inputs. Forest removal throughout

the entire valley caused high sediment loads into the Kanawha River mainstem and tributaries. Addair (1944) collected few fish in the mainstem in 1942. Those fish captured were located near tributaries where chemical concentrations were diluted. Addair (1944) pointed to several factors in the demise of Kanawha River aquatic populations. The greatest issues were related to its lack of vegetation and pollution problems. In addition, channelization, and the removal of shoals, sand bars, and debris decreased available habitat. These problems, in combination with the newly altered flow regime, gave the original fish community little opportunity to survive. Chemical pollution continued through the 1970s. In the early 1980s, chemical inputs began to decrease enough for the river to recover (Kuntz 2003).

The Kanawha River is currently recovering from a century long fight with human induced alterations. In the late 1980s fish populations began to rise with game species doing extremely well (Scott 1988). Today, chemical pollution is reduced, surrounding lands are reforested, and mining continues, but with better regulation. Navigation continues with coal and chemicals being the most prominent goods shipped.

Once again the Kanawha River is undergoing alterations to allow for increased navigation. Increased traffic through the Winfield locks grew dramatically as demand has increased for low-sulfur coal. Commercial traffic increased 140% on the Kanawha River between 1950 and 1980 (USACE 1983). Between 1985 and 1992, lockages increased from 16,000 to 22,000 annually (Spoor, 2002). As a result of increased use, barges had to wait in turn for up to 24 hours to pass through the locks which increased costs for producers, the navigation industry, and consumers. In response, the U.S. Army Corp of Engineers (USACE) is conducting a series of lock and dam expansions. The Winfield lock expansion was completed in 1997, the Marmet lock expansion is underway and the London lock expansion is pending. Every change

made to the river has inevitably had an impact on fish populations. However, this time the USACE is attempting to mitigate impacts to aquatic life as part of the lock expansion plan.

Importance of low velocity zones and habitat heterogeneity to larval fish

The expansion of the Marmet Lock to accommodate larger tows will significantly increase the amount of barge traffic on the Kanawha. This increased navigational traffic could adversely affect fish of all age classes in the Marmet Pool. Of particular concern are larval fish as they are extremely delicate organisms, they are passively moved in river currents, and are unable to avoid approaching vessels (ANSP 1980). Larval fish may be directly affected by collision with barges, displacement from waves, and de-watering due to lock and dam drawdown (Holland 1987). Previous studies have shown that larval stage fish are susceptible to navigational impacts (Morgan et al. 1976). High velocity zones are created in the main channel during the travel of barges. Studies have shown that commercial barge traffic causes physical damage of larvae from waves, increased shoreline erosion, increased turbidity, and re-suspension of particulate matter (UMRBC 1982). Investigations of larval fish densities before and after barge passage showed reductions associated with downbound loaded barges (Holland 1986).

As navigation traffic continues to increase, the need for shelter from waves and turbulence will be essential for the recruitment of young fish. The main channel often has swift flows and its homogeneity offers few areas of cover or low flow within its entire length. High flows within the main channel cause fish to be washed downstream (Cowx 2002). The survival of early life stage fish is significantly reduced during periods of higher flow versus low flow (Freeman 2001, Humphries et al. 2002). Higher flows also increase the energy that fish need to maintain position, therefore reducing growth during high flow events (Nunn et al 2003).

Areas of low velocity such as backwaters, tributaries, and main channel borders are ideal habitat for young fish. Lower velocity zones such as back channels, tributaries, and near-shore areas have been shown to have high densities of larval fish (Odom 1987 and Scott and Nielsen 1989). These low velocity areas are typically shallow and therefore sensitive to the effects of passing barges (Bhowmik et al. 1982, Holland and Sylvester 1983). Key attributes that distinguish backwater habitats from main-channel habitats are reduced current velocity, shallower depth, and greater autochthonous production (Eckblad et al. 1974).

Decreased abundance of many fish species in large rivers has been associated with the loss of backwaters (Funk and Robinson 1974). Ellis et al. (1979) found that fish diversity in side channels of the upper Mississippi River is positively associated with habitat diversity. Backwater areas of large river systems provide important habitat for many fish species at spawning, larval, and juvenile stages (Kallenmeyn and Novotny 1977, Holland and Sylvester 1983, Sheaffer and Nickum 1986, Copp and Penaz 1988, Kwak 1988, Scott and Nielsen 1989). Densities of larval fishes in the Lower Mississippi River are highest in backwaters, and contain a larval fish assemblage different from the main-stem river (Beckett and Pennington 1986). The shoreline, backwater and tributary mouth habitats have been identified as crucial to the survival of larval fish in the Kanawha River (Odom 1987, Scott 1988, Scott and Nielsen 1989, Rider 1991). These areas have been shown to serve as nursery areas and are important to young fish survival and overall recruitment. However, channelization and maintenance dredging has reduced the availability of quality fish habitat in the lower Kanawha River. It seems that the Kanawha River fish populations, although recovering, are probably limited by the amount of available habitat (Titus 2004). The little habitat that does exist is provided within the few islands, logs and snags along the river edge, and flooded tributary mouths. Areas of low velocity

in the Marmet Pool of the Kanawha River are limited to two back channels and seven small tributaries, Lens Creek, Witchers Creek, Cabin Creek, Kelly Creek, Paint Creek, Slaughter Creek, and Fields Creek.

A loss of heterogeneous habitats has been found to negatively affect fish populations in both diversity and abundance (Madejczyk et al. 1998, Langler and Smith 2001, Pretty et al. 2003). There are two major benefits that heterogeneous habitats provide. First, they may afford fish refugia from predation and environmental variables such as water flow. Prey cover decreases the ability of predators to both see and catch prey (Savino and Stein 1989, Walters et al. 1991, Lehtinen et al. 1997, Takemon and Nakanishi 1998). Second, heterogeneity tends to create higher productivity and concentrates food sources for many different species.

Heterogeneous habitats are crucial for larval fish (Pretty et al. 2003). Cover and increased forage opportunity aids in the survival of young fish. Larval fish prefer habitats with increased forage, plentiful cover, and littoral zones or backwater areas (Aggus and Elliott 1975, Scott 1988, Lobb and Orth 1991, Rountree and Able 1992, Skov and Berg 1999). Young fish are highly susceptible to predation, and cover allows them to increase their survival rate. The easiest way to compensate for the impacts of human alterations on fish abundance may be to increase young fish survival (Letcher et al. 1997). An increase in heterogeneity, targeted to benefit young fish, could potentially create an increase in localized fish production due to more fish reaching maturity (Letcher et al. 1997, Walters and Kitchell 2001, Pretty et al. 2003). Heterogeneous habitats are crucial for fish populations because they provide cover from predation and river flows, increase forage availability, and improve juvenile fish survival. The use of habitat types can vary by species, river conditions, or light levels. Heterogeneity may exist through vegetation, woody debris, cobbles, or artificial structures. Artificial habitats, such as dykes or

groins, offer a source of heterogeneity in large river that have few forms of habitat diversity (Nicholas and Pont 1995, Poizat and Pont 1996). Artificial structures have been placed in both marine and freshwater systems in an effort to support and enhance the early life stages of fish (Bassett 1994, Hernandez et al. 2001). Habitat enhancement structures are typically added to aquatic systems when the natural habitat is perceived to be lacking (Prince et al. 1977).

Mitigation and habitat enhancement techniques

Riverine systems throughout North America have been impacted by a wide variety of human activity. Large rivers changed world-wide with the growth of industry, agriculture, and urban development, and may be regulated by dams for navigation, flood control, water supply, recreation, or power generation (Sheehan and Rasmussen 1993). Large rivers have been subjected to physical alterations of the natural riverine habitat. These alterations include dredging of channels, installation of locks and dams, and straightening of channels. These alterations have reduced both habitat heterogeneity and nursery areas for young fish. River channelization and channel clearing for efficient navigation and regulating flow creates an unnatural homogeneous habitat compared to pre-impoundment conditions. World-wide, through human alterations, rivers have been changed from their original wide, shallow, meandering morphology to deep, narrow, straight systems to fulfill the needs of development (Aarts *et al.* 2004). As a result, many river systems struggle with poor or declining populations of aquatic fauna (Stanford et al. 1996, Cowx 2002, Pretty et al. 2003). Restoration of large rivers to a pristine or virgin state is incompatible with present human population levels (Welcomme 1989). Instead, the goal is the rehabilitation of developed river systems, towards, the recovery of some of their ecological functions and values (Gore and Shields 1995).

Riverine structures used for rehabilitation include spur dikes (or deflectors), weirs, boulders, logs, or other woody debris. These structures foster formation of low-flow pool areas, which provide protection from high velocities and cover from predators (Gore and Shields 1995). Many large rivers have used rock structures as artificial habitats. Rocks are piled to form dikes or groins. The interstitial spaces within these structures are used as cover for small fish and other organisms. Structures made of a wide range of stone sizes create more diverse habitat (Gore and Shields 1995). The low velocity waters between structures provide protection from the main channel flows. Structures may also provide areas of higher temperatures than the main channel. Assessment of these structures shows some success (Moring and Nicholson 1994, Nicholas and Pont 1995, Poizat and Pont 1996). These structures may provide bank stability, as well as a more diverse habitat for fish of all life stages (Gore and Shields 1995). Dike fields in the Lower Mississippi River often contain many fish species (Pennington et al. 1983b). Previous work by Li et al. (1984) on the Willamette River, Oregon has shown that the density and number of larval fish species in spur dike habitat was intermediate in quality between natural banks and continuous rip-rap revetments. Likewise, Shields (1995) found that spur dikes are better for fish habitat than continuous protection like rip-rap. Li et al. (1984) suggest that rip-rap revetments were not good larval fish habitat due to their proximity to faster water velocities. Pennington et al. (1983a) found that species composition was similar in both rip-rap and natural banks, but abundances were higher in rip-rap habitat for some species. Species of sport or commercial value were found to be more abundant by weight on rip-rap banks (Pennington et al 1983a). Li et al. (1984) further suggest that over time woody debris and riparian vegetation will accumulate between the spur dikes and create even more diverse habitat for larval fish.

In a study of rock structures in the Missouri River, Burress et al. (1982) found that dike fields had the most diverse fish community. Bischoff and Wolter (2001) found that the riverward end of groins were an important habitat for juvenile fish in the River Oder, Germany. However, both of these studies primarily sampled for juvenile fishes and used gears that were not appropriate to capture larval fish.

A review of the literature found very few studies involving larval fish use of rock structures like those placed in the Marmet Pool of the Kanawha River. Li et al. (1984) sampled larval fish that were associated with spur dikes, rip-rap, and natural banks in the Willamette River, Oregon. While larval fish were sampled with several methods, the study was only conducted between early April and mid-June, thus missing a significant portion of the spawning season. In a study of rock structures in the Missouri River, Burress et al. (1982) found that dike fields had the most diverse fish community. This study had serious flaws, as larval fish were collected during the day with 0.5-m conical plankton nets. In addition, this study sampled fish only in late summer and early fall and because of this only 63 larval fish were encountered. The U.S. Army Corp of Engineers: Waterways Experiment Station has conducted one of the most thorough studies of fish use of artificial habitats. In a series of studies they found that dike fields were important to riverine fish (Conner et al. 1983, Beckett and Pennington 1986, Baker et al. 1991). The study by Baker et al. (1991) focused on adult fish with little effort given toward juvenile or larval sampling. The study conducted by Conner et al. (1983) did not consider changes in the larval community and sampled infrequently. Beckett and Pennington (1986) found that dike fields in the Lower Mississippi River had different larval fish assemblages than main channel sites, but the study collected fish during the day with gears that were inefficient to sample such habitats.

We aim to examine the use of artificial structure areas in comparison to natural reference areas by larval fish in a regulated river system. The artificial rock structures the USACE constructed in 2000 within the littoral zone of the Marmet Pool are designed to increase habitat heterogeneity and attain the benefits associated with greater habitat diversity. These structures were designed to provide habitat for young and small fish that are adversely affected by the existing and expected navigation and river habitat conditions. In fact, these structures may help offset losses of the shoals and sand bars that existed previous to the river's harnessing. The USACE hopes that these structures will mitigate the effects of the river expansion and allow increased recruitment by fish populations in the future. This study is designed to examine larval fish use of artificial structures in comparison to natural reference areas in 2002 and 2003.

My objectives are to :

1. Compare three different gear types to sample larval fish in shallow water habitats.
2. Determine larval fish use of the five sets of artificial structures constructed in the Marmet Pool, Kanawha River.
3. Compare larval fish use of artificial structures to high and low quality natural reference areas.

Study Site Description

This study was conducted in the Marmet Pool of the Kanawha River, West Virginia. The Marmet Pool is just upriver from the city of Charleston, West Virginia (Figure 1). Sections near the city of Charleston are highly industrialized. The banks are steep with a relatively short submerged bench width. Fine sediments dominate the substrate and there are few backwater areas or places that would provide cover for fish beyond flooded tributary mouths (Scott and Nielsen 1989). The USACE, Huntington District, is conducting a project to renovate its locks and dams to allow for greater barge traffic. The increased barge traffic could negatively impact fish populations, especially larval and juvenile stages (Scott 1988, Rider and Margraf 1997). Artificial structures were constructed in the Kanawha River by the USACE in 2000 as mitigation to offset the effects of the expansion project.

Artificial Structure Characteristics

Five sets of artificial structures were constructed. Four finger dikes (FD1 - FD4) and one set of zipper dikes (ZD) (Figures 2 & 3). Each set varied in size and length but was made of similar material. Structure designs were somewhat different (number of dikes, angle from riverbank, distance between individual dikes, and length of dikes) (Figures 4 & 5); however, each achieved a goal of increasing habitat heterogeneity. Artificial structures were dominated by the rocks used for construction, but also had some low hanging vegetation and woody debris (Titus 2004). Two reference areas were selected to compare with each structure: one of high quality natural composition and one of low quality natural composition. The reference sites were determined to be of high or low quality based upon velocity characteristics (Figure 6) and the amount of potential cover available to larval fish.

The artificial structure sites each consisted of a series of dike structures. All dikes were constructed of rock/rubble material positioned along the shoreline and extending into the river along the bench (Titus 2004). The finger dikes were angled from shore in an upstream direction, while the zipper dikes were positioned parallel to shore. Each structure, although different, did at minimum provide a greater habitat heterogeneity and higher amount of cover within each of them than what was available naturally and most of the time dikes performed similarly (Titus 2004). However, since each artificial structure type was slightly different in design (Figure 4 and 5), (size of dikes, density of dike structures) each varied in their attraction to fish and thus it may be important to examine differences among structures if we are to learn how to best design artificial structures in the future. The artificial structure construction design varied between sites (Table 1). The shoreline length of each artificial structure site was 400 to 700 feet (Titus 2004). The greatest density of structure material within a site occurred within finger dike 2 (37 feet of

shoreline / dike and 1.6 feet between dikes / average dike length). The zipper dike was the next densest followed by finger dike 1, and lastly finger dike 4 and finger dike 3 (75 feet of shoreline / dike and 1.0 feet between dikes / average dyke length). Although finger dike 4 appears similar to finger dike 3 in the amount of habitat provided, little of finger dike 4 was submerged during normal flows thus the habitat available within that site was less (Titus 2004). Although the zipper dike structure had the shortest shoreline length, the design created the highest dike length / distance between dike value, and the site provided a large amount of heterogeneous habitat as a result.

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Table 1 : Structure characteristics for each set of artificial structures. (a.) Measurements within each structure type (feet) and structure density values. See Figure 4 and Figure 5 for the maps from which this data originated. Numbers after each title correspond to the diagram labels below. Density measures are as follows : “Shoreline ft / dike” = length of shoreline / number of dikes, “Dike length : distance between dikes” = distance between dikes / average dike length. (b.) Diagram describes how measurements within table were calculated for each artificial structure site.

(a.)

Artificial Structure	Total Length of Site (1)	Number of Dikes (2)	Average Length of Dikes (3)	Average Distance Between Dikes (4)	<u>Density</u>	<u>Measures</u>
					shoreline ft / dike	dike length : distance between dikes
Finger dike 1	465	10	30	45	46	1.5
Finger dike 2	600	16	36	60	37	1.6
Finger dike 3	600	8	36	36	75	1
Finger dike 4	705	13	39	53	54	1.3
Zipper dike	390	8 (4 small, 4 large)	24 & 60	15	48	3

(b.)

Study Sites: Marmet Pool, Kanawha River, West Virginia

Zipper Dikes and Finger Dikes 1 - 4

● = 20" iron stake (set)

		Map of Plan View 104 U.S. ARMY CORPS OF ENGINEERS	
Project: MAINTENANCE Location: Eastman Middle School, 201 Station: 1042.1		MAINTENANCE CO., & SUPPLY CO., INC. 101 S. 1st Street Louisville, KY 40202	
Station: 1042.1 Date: 10/1/81 Drawn by: W.M. Check: 1/1/82 Scale: 1"=50'		Project: CENTRAL SURVEYING 101 S. 1st Street Louisville, KY 40202 Phone: (502) 582-1111	

Sample Site Velocity Profiles

Figure 6 : Average velocity (meters/second) within each site and its associated high and low quality natural reference areas for finger dike 1 (FD1), finger dike 2 (FD2), finger dike 3 (FD3), finger dike 4 (FD4), and zipper dike (ZD). Measurements begin near shore (1 meter) and move linearly away from shore (6 meters).

Chapter 2: *Comparison of the effectiveness of three larval fish gears to sample shallow water sites.*

Abstract

Sampling within a shallow, structurally diverse area can create numerous sampling complications. We sought to evaluate the ability of three larval sampling devices (light traps, benthic sleds, and activity traps) to sample a shallow, structurally diverse area in a navigable inland river. Larval fish were sampled for eight weeks from June 17 through August 3, 2002. Results indicate that larval abundances peaked in the river during late June. The light trap collected more larvae (9221 individuals) than the benthic sled (396 individuals) and activity trap (65 individuals). The light trap also collected more taxonomic groups than the benthic sled and activity trap (11 groups vs. 7 and 5, respectively). Light trap catch per unit of effort was significantly higher than both benthic sleds and activity traps for the four most common taxonomic groups (*Cyprinidae- Notropis* type larvae, *Cyprinidae- Pimephales* type larvae, *Atherinidae*, and *Lepomis*). Coefficient of variation was lowest for the light trap (214%) when compared to both the benthic sled (966%) and activity trap (279%). While light traps may be limited in determining associated larval fish densities, they can be an effective means of determining species relative abundance, and or presence/ absence. Of the gears evaluated, light traps are the most effective sampling gear to collect larval fish in shallow structurally diverse areas in large navigable rivers.

Introduction

Methods are well developed for sampling larval fish populations in the open waters of lentic, lotic, and oceanic environments, and common sampling methods include various plankton nets, trawls, and traps (Ahlstrom et al 1958, Smith et al. 1964, Noble 1970, Brown and Langford 1975). In addition, manuals describing standard methods and equipment have been published (e.g. Kramer et al. 1972). However, open water ichthyoplankton sampling methods may be poorly suited to sample shallow water and structurally complex locations, because submerged rocks, logs, and other debris can pose a hazard to sampling gears and research vessels.

A variety of methods are available for sampling larval fish around complex ocean reef type environments. Methods that have been used include plankton pumps (Taggart and Leggett 1984, Powlik et al. 1991), larval purse seine (Kingsford and Choat 1985), diver pushed nets (Smith et al 1987), free fall nets (Kobayashi 1989), and light traps (Doherty 1987).

Effective research planning, execution, and valid interpretation of field data requires that the potential biases and limitations of sampling techniques be considered (Jacobsen and Kushlan 1987, Bain and Finn 1991, Magnan 1991). A high, stable catch efficiency should be the most important characteristic when selecting a sample device for larval fish (Rozas and Minello 1997). Rozas and Minello (1997) found that passive larval fish sampling devices are species selective, and have low and variable catch efficiencies. Finally, the total area that is sampled by these techniques is unknown, thereby making quantitative density estimates impossible.

Sampling within a shallow, structurally diverse area can create numerous sampling complications (e.g. dense vegetation on banks, submerged logs, and non-uniform bottoms), which preclude traditional approaches to fish sampling. Traditional sampling techniques for larval fish such as seine netting, electroshocking, and underwater observation do not provide

reliable estimates of fish densities in vegetated habitats (Freeman et al. 1984, Dewey et al. 1989). In contrast, enclosure traps that quickly surround a well-defined area of habitat have proven quite useful for sampling fishes (Rozas and Minello 1997). Little guidance is available for developing fish sampling protocols and selecting effective gears, and no thorough gear evaluations have been reported for sampling shallow, structurally diverse areas.

A lack of data exists for activity traps as sampling gear for fish. Breder (1960) constructed a box trap of clear plexiglass that had removable wings, which directed fish to a slot and to the interior of the trap. Activity traps have been commonly used to sample aquatic invertebrates in structurally diverse areas such as wetlands (Hanson et al. 2000). Activity traps are light, portable, and inexpensive to construct. In addition, they are easy to build, are highly adaptable to various sampling conditions, and the size of the entrance slots can be adjusted to capture small larvae or larger juveniles (Kelso and Rutherford 1996). Activity traps may be deployed horizontally or vertically and at various depths, depending on the specific study objectives. Activity traps have been shown to perform well in terms of number and diversity of invertebrates captured (Hanson et al. 2000). Activity traps gather clean samples containing little organic material, sediment, plant fragments, etc. Clean samples result in shorter sample processing times and often allow more intensive sampling (Hanson et al. 2000).

The need to sample eggs and larvae on or just above the substrate led to the development of benthic larval sleds. Frolander and Pratt (1962) developed a benthic sled that mounted a cylindrical net on a benthic skimmer to sample demersal larvae in a lake. Dovel (1964) used a larger net that was mounted on an aluminum sled to sample estuarine ichthyoplankton. Yocum and Tessar (1980) mounted a 0.5-m plankton net in a rectangular sled frame to sample within 5

cm of the bottom. Madenjian and Jude (1985) found that this type of gear provided better abundance estimates for fish larvae than the standard plankton net.

Larvae and juveniles of many fishes are positively phototactic, and using artificial light sources in nocturnally fished traps is an effective method of collecting larvae of certain species (Kelso and Rutherford 1996). Light traps were shown to be the most efficient and taxacomprehensive sampling technique for larval fish in forested floodplain wetlands and captured the vast majority of pooled larval fish catch, including six of seven families recorded at all sites (Knight and Bain 1996). Floyd et al. (1984) developed a trap with a central light-distributing rod that was surrounded by four plexiglass cylinders. In a study of a small Kentucky stream, the Quatrefoil light trap collected 25 of the 28 total species and was particularly effective for cyprinid larvae (Floyd et al. 1984). Secor et al. (1992) modified the trap to include a floatation device, a chemical light source, and a collection bucket. Light traps are relatively expensive to construct and maintain (Rozas and Minello 1997) and light traps are suggested as best suited for determining species presence or absence due to differences in movement patterns, microhabitat preferences, and phototactic behavior among species (Kelso and Rutherford 1996). Light traps have been shown to be useful for investigating intraspecific patterns of temporal or spatial abundance through time (Doherty 1987). Light traps are less likely to damage specimens and larvae are captured in excellent condition if checked at frequent (e.g. 1-h) intervals (Faber 1982). Gregory and Powles (1988) found that light traps were effective at collecting darter (*Percidae*), yellow perch (*Perca flavescens*), and pumpkinseed (*Lepomis gibbosus*) larvae. Wallus et al. (unpublished data) found that light traps were successful in collecting a variety of larval species in the Ohio and Tennessee Rivers. For the purpose of this project we sought to evaluate the effectiveness of both passive and active quantitative larval sampling devices to sample a shallow,

structurally diverse area in a navigable inland river. We chose Quatrefoil light traps, and activity traps for our passive sampling devices and a benthic larval sled for our active collecting method.

Materials and Methods

Field collections

As part of an ongoing study aimed at evaluating larval fish use of artificial structures in a large navigable river (Marmet Pool, Kanawha River, West Virginia), we sampled larval fish weekly, when weather conditions and river flows permitted, from mid-June – early-August 2002. Sampling stations were located in artificial structure sites (Finger and zipper dikes) and at high quality natural and low quality natural reference sites, which were located in the vicinity of the structure sites.

Larval fishes were sampled with three gears to identify the best method for monitoring these shallow water habitats. Each gear provided an estimate of relative abundance and species composition. Gears were selected for their use in sampling shallow water habitats from a literature review (Copp 1990; Kelso and Rutherford 1996; Rozas and Minello, 1997, Secor et al. 1992, and Turner et al. 1994). Larval gears used included: benthic sled sampler, larval activity trap, and larval light trap. For each sampling effort a total of six benthic sled samples, three larval activity traps, and three larval light traps were fished at 15 sites. Thus, for each sampling effort a total of 90 benthic sled samples, 45 larval activity traps, and 45 larval light traps were fished. Over the course of the study a total of 720 benthic sled samples, 360 activity traps, and 360 light traps were included in the gear comparison.

A benthic sled was constructed to sample along the bottom of the river. Yocum and Tesar (1980) showed that a benthic sled alleviates the near bottom sampling problems associated

with conical plankton nets. This method was also shown to capture less common shallow water fish larvae (Madenjian and Jude 1985). The sled consisted of two skids and a roller along the bottom with a rectangular plankton net mounted above this. In order to determine total volume sampled, a General Oceanics © flowmeter was mounted inside the mouth of the plankton net. Both the skids and the net frame were constructed of ¾ inch PVC pipe with lead providing ballast for the skids. A PVC roll bar was attached along the bottom of the sled so that the sled could roll over obstructions in the water. The plankton net was 50 cm x 40 cm and consisted of 500-micron nitex netting with a 250 micron sampling cup attached at the end. The benthic sled was deployed from a boat during the daytime and pulled parallel to the shoreline in near-shore areas (e.g. within dikes) at randomly determined locations at each site. The sled was towed upriver into the current at $\leq 2\text{m/s}$ to prevent specimen damage (Kelso and Rutherford 1996). Sample cups for the benthic sled were constructed of 500-micron mesh. At the completion of a tow, specimens were rinsed from the cup into sample jars, labeled and preserved in 10% buffered formalin (Kelso and Rutherford 1996). Tucker and Chester (1984) showed that this method was best for long-term storage of larval fish as it resulted in little length shrinkage and good pigment retention. This method is preferred, as storage in ethanol can cause shrinkage of specimens and therefore make species identification harder. In sampling the reference sites, the sled was towed the same average distance as it was towed in the treatment sites.

Two types of passive capture techniques were employed to sample larval fish in the shallow water habitats: quatrefoil light traps and activity traps. Light traps are best suited for determining species abundance (Turner et al. 1994). The light trap used was a floating 30 cm x 30 cm x 50 cm Plexiglass trap. Each trap had four 15 mm entrance slots and used a Cyalume green chemical light stick, which originated from a central light tube in each trap (Floyd et al.

1984). Previous research by Gerhke (1994) showed that green light sticks glowed brighter during the first hour of sampling than other colored light sticks and produced sufficient light to attract fish larvae. Chemical light traps can sample larval fish as efficiently as electric light traps (Gerhke 1994, and Kissick 1993). The light traps were randomly placed throughout the sample sites, with the sampling location being chosen randomly. These light traps were placed and anchored within the habitat starting approximately ½ h after dusk and were left for 1 h. Deployment and retrieval times were recorded to the nearest minute. Traps were retrieved by raising the trap slowly to allow the chamber contents to filter through the 500-micron mesh net. All samples were washed into sample jars, labeled, and preserved in 10% buffered formalin.

Larval fish activity traps were the second passive method of larval fish capture used in the study. A review of existing literature found no previous research using these types of traps for larval fish. These traps were constructed of plexiglass and epoxy. The traps were approximately 10cm in height, with a length of 30 cm and width of 15 cm. Two plexiglass leads of 50cm in length extended outward from the trap box. The slot opening to the trap box was approximately 15 mm in width. The activity traps were fished for a period of 24-h, as there is no literature that exists on the capture efficiency of this method. The activity trap was anchored at the site, and suspended between the water surface and 0.25m in depth. The placement of the activity traps was randomly chosen during each sampling period. All samples were washed into sample jars, labeled, and preserved in 10% buffered formalin.

Laboratory processing of samples

In the laboratory, the contents of each sample were washed through a 500-micron mesh sieve. The contents were then transferred to a dissecting tray where the larvae were removed and

counted. Samples were checked to ensure that all larvae had been removed from the sample. Larval fish collected in all study gears were treated similarly in processing and identification in the laboratory. All larval fish collected were identified to the lowest possible taxon using a variety of references (Auer 1982, Holland-Bartels et al. 1990, Wallus et al. 1990, Kay et al. 1994, B. Wallus personal communication). Larvae that could not be identified because of extensive damage ($\leq 0.5\%$ of total) were classified as “unidentified larvae”. Larvae that could not be identified at or below the family level were also classified as “unidentified larvae” ($\leq 0.5\%$ of total). Larvae were identified using a Leica MZ6© microscope, that was retrofitted with a Cole-Parmer© light ring and polarizing lens. All larval fish collected were assigned to a developmental stage according to Snyder (1976). Total lengths (TL) were measured to the nearest mm with an ocular micrometer mounted in a stereo dissecting scope.

A taxonomic guide for larvae collected was created for the project. This guide (Appendix 1) was developed with Bob Wallus (formerly of Tennessee Valley Authority), a regional larval fish expert. Mr. Wallus, who gave Jon Niles significant larval fish identification training, also helped to create a voucher specimen collection, and conducted Quality Assurance/ Quality Control on identifications. This guide helped to determine the lowest possible taxonomic level that our samples could be identified to; given our equipment, high number of samples and time constraints. We believe that this guide helped us get an accurate description of larval fish species in the Kanawha River, while keeping within the time constraints of the project. Overall, around 10% of the samples underwent QA/QC checks.

Taxonomic determination

Larvae were classified to 22 taxonomic groups (Appendix 1). Paddlefish (*Polyodon spathula*) were not found, but could have easily been identified to species level (Wallus et al. 1990). Longnose gar (*Lepisosteus osseus*), the only member of its family in the Kanawha River, was easily identified to the species level (Wallus et al. 1990). *Clupeidae* were easily identified to family level (Holland-Bartels et al. 1990), based on the position of the anal vent, and were assumed to be gizzard shad (*Dorosoma cepedianum*) based on juvenile and adult abundance (Titus 2004). Mooneyes (*Hiodon tergisus*) were not found, but can easily be identified to species level (Wallus 1986; Wallus et al. 1990). Pikes (*Esocidae*) were not found, but can easily be identified to species level (Wallus et al. 1990).

There are numerous *Cyprinidae* species found in the Kanawha River (Stauffer et al. 1995), which complicated the identification process. *Cyprinidae* were identified to four taxa: *Cyprinidae* Pimephales-type (*Erimystax* spp., *Macrhybopsis* spp., *Hybopsis* spp., *Phenacobius* spp., and *Pimephales* spp.), *Cyprinidae* Nocomis-type (*Camptostoma* spp., *Nocomis* spp., *Rhinichthys* spp., and *Semotilus* spp.), *Cyprinidae* Notropis-type (*Clinostomus* spp., *Ericymba* spp., *Exoglossum* spp., *Notemigonus* spp., *Margariscus* spp., *Cyprinella* spp., *Luxilus* spp., *Lythrurus* spp. and *Notropis* spp.), and common carp (*Cyprinus carpio*). *Cyprinidae* were identified using a variety of sources (Auer 1982, Holland-Bartels et al. 1990, B. Wallus personal communication). Suckers (*Catostomidae*) were identified to two taxa: *Catostomidae*- Ictioben-type (*Ictiobus* spp., *Carpionodes* spp.) and *Catostomidae*- Catostomini-type (*Moxostoma* spp., *Hypentelium* spp., and *Catostomus* spp.). Buffalo (*Ictiobus* spp.) and carpsuckers (*Carpionodes* spp.) were identified based upon pigmentation patterns and myomere counts (Kay et al. 1994, B. Wallus personal communication).

Perches (*Percidae*) were not identified below the family level because of overlapping characteristics and a lack of larval descriptions. Only 8 of the 13 *Percidae* species in the Kanawha River have larval descriptions in the literature (Auer 1982 and Holland-Bartels et al. 1990, B. Wallus personal communication). Sunfishes (*Centrarchidae*) were identified to four taxonomic groups: *Lepomis* spp. (sunfish), *Ambloplites rupestris* (rock bass), *Micropterus* spp. (black bass), and *Pomoxis* spp. (crappie) (Auer 1982, B. Wallus personal communication). Catfishes (*Ictaluridae*) were identified to four groups: *Ameiurus* spp. (bullheads), *Noturus* spp. (Madtoms), *Ictalurus punctatus* (channel catfish), and *Pylodictis olivaris* (flathead catfish) (Simon and B. Wallus personal communication). *Moronidae* were identified to the family level based on vent position and myomere counts (B. Wallus personal communication). Freshwater drum (*Aplodinotus grunniens*) were easily identified to the species level (Auer 1982, and B. Wallus personal communication). Brook silversides (*Labidesthes sicculus*) were easily identified by pigment patterns and location of the vent (Auer 1982 and B. Wallus personal communication).

Overall 8 % (35) of the collected samples with fish underwent a Quality Assurance/Quality Control check by our regional, larval fish expert, Mr. Bob Wallus (formerly of Tennessee Valley Authority). An additional 1.5 % (6) of the collected samples were independently identified by Mr. Wallus, with these samples serving as a voucher collection for the project. During the course of the QA/QC checks only one individual (*Micropterus*) was found to be misidentified (*Ambloplites*).

Catch per unit effort data was analyzed using the ANOVA/GLM model in SAS. All alphas were set at 0.05 and for each analysis we tested for normality using skewness and Kurtosis. Data not found to be normal were transformed using a log base 10 transformation.

Chi-square analysis was used to compare taxonomic compositions among the gear types. In order to estimate variation among the gears in collecting larval fish, we calculated variances using the coefficient of variation. The coefficient of variation measures variability in relation to the mean (or average) and is used to compare the relative dispersion in one type of data with the relative dispersion in another type of data (Zar 1996). The data to be compared may be in the same units, in different units, with the same mean, or with different means. The coefficient of variation is a calculation built on other calculations -- the standard deviation (s) and the mean ($\bar{x}$) as follows:

$$C.V. = \frac{s}{\bar{x}} * 100$$

In order to determine the variability we analyzed data from the June 30, 2002 sample. This date was selected because the captures were high on this date. In order to eliminate any bias of habitat selection in the variation estimate, we calculated the coefficient of variation based only on data collected from artificial structure sites, due to higher overall catches at those sites. The average catch per unit of effort was analyzed to determine significant difference among the ability of gears to sample the habitats.

Results

Light traps appeared superior to the other gears in all measures, including number's caught, taxonomic richness, and sampling variability. Overall, the 1440 samples (all gears combined) contained 9681 larvae from 12 taxonomic groupings (Table 2). The light trap collected more larvae (9221 individuals) than the benthic sled (395 individuals) and activity trap (65 individuals). The light trap also collected more taxonomic groups than the benthic sled and

activity trap (11 groups vs. 7 and 5, respectively). Four taxonomic groups (*Cyprinidae* Nocomis-type, *Cyprinus carpio*, *Ictaluridae*-*Ictalurus*, and *Sciaenidae*) were collected only in the light trap, while one taxonomic group (*Lepisosteus osseus*) was collected only in activity traps. The benthic sled contained no unique taxonomic group. Four groups were collected by all three methods. Average catch per unit of effort (CPUE) was significantly higher (ANOVA, $p < 0.001$) for light traps (25.61) than for both benthic sleds (1.10) and activity traps (0.18) (Figures 7 - 9). Light trap CPUE was significantly higher than both benthic sleds and activity traps for the four most common taxonomic groups (*Cyprinidae* Notropis-type larvae, *Cyprinidae* Pimephales-type larvae, *Atherinidae*, and *Lepomis*) (Figures 10 – 13). Both the benthic sled and light trap showed a decline in overall CPUE over time, while the activity trap catch rate remained constant. Benthic sleds captured no fish in the last three weeks of sampling, while light traps and activity traps averaged a CPUE of 5.48 and 0.14 fish respectively. Mean taxonomic richness was significantly higher in light trap samples (7.25) than in benthic sled (2.13) and activity trap (3.25) samples. The taxonomic richness was highest for light traps in all eight weeks of sampling (Figure 14). Catches of *Centrarchidae* were significantly different ($p < 0.01$) among the gear types, with a higher percentage captured in benthic sleds than in light traps and activity traps on June 30th (Figure 15). However, there were no significant differences among gear types in the overall taxonomic composition.

In terms of CPUE, light traps were the least variable of the larval gears used, but differences were noted in size ranges of fish captured among gears. Variance among gear types was high. The coefficient of variation for light traps was 214.34%, while the variation for benthic sleds was 966.16% and activity traps was 279.25% (Table 2). Light traps captured a wide size range of larvae, with the average minimum length being 7.38mm and the average

maximum length being 31.05mm (Table 3). Benthic sleds captured larvae of similar size, while the activity trap captured significantly longer ($p < 0.01$) larvae (minimum 13.00, maximum 38.07).

Discussion

Conducting larval sampling in large navigable rivers is a difficult task, but sampling shoreline microhabitats within large rivers is especially difficult given the need to maneuver into shallow habitats that contain a large amount of woody debris and rocks. The quatrefoil light trap was clearly the best method to sample shallow structurally diverse habitats. Light traps provided stable catch rates over the course of the study and showed overall temporal trends in the study sites.

Light traps, benthic sleds, and activity traps operate on very different principles. Light traps depend on the ability of larvae to see a light, along with their ability and willingness to enter an illuminated enclosure. Factors such as water clarity, current speed, behavioral response to light, and swimming ability can potentially affect this process (Doherty 1987, Milicich et al. 1992, Thorrold 1992). Even under optimal conditions, some taxa may not be attracted to light traps. The benthic sled actively samples along the substrate and strains larvae from the water column. Net characteristics such as mouth diameter, towing speed, and mesh size can interact with larval fish escape responses to effect the quantity, size structure, and taxonomic composition of samples (Clutter and Anraku 1968, Colton et al. 1980, Brander and Thompson 1989, Morse 1989, Suthers and Frank 1989). Activity traps function like light traps in that they are passive methods of capture, relying on drifting or swimming larvae to encounter the trap.

Unfortunately, light traps, activity traps and benthic sleds cannot be compared directly because the volume that light and activity traps sample is unknown. As an alternative, we compared the mean number of larvae per sample for all three methods (CPUE), taxonomic richness, and coefficient of variation. We felt that these methods would allow for valid comparisons between the gears.

Catch numbers decreased for both the light trap and benthic sled through time. Previous studies have shown that daytime tows with plankton nets suffer from avoidance, particularly by larger, faster swimming larvae (Clutter and Anraku 1968, Barkley 1972, Suthers and Frank 1989, and Leis 1991). No larvae were captured in the benthic sled in the last three weeks of sampling, probably due to the larval size structure at this point in time. Length analysis shows that larvae became much larger after the 4th week of sampling (July 8th) and were likely free swimming at this point and able to actively move away from the benthic sled. The activity trap captured much larger larvae/ small juvenile fish than the benthic sled and light trap. This is probably because these traps relied on the low chance encounter of fish swimming into the trap leads.

The taxonomic groups of larvae collected by the various methods were similar, but the light trap was statistically better at capturing most species. Although it should be noted; that the activity trap did collect the only *Lepisosteidae* species. These were juveniles ($n:2$) not larvae and were likely captured as they attempted to chase a smaller prey species into the trap. Species composition of larval fish captured in the Kanawha River study site was typical of river bank habitat in the Kanawha River system (Odom 1987, Scott and Nielsen 1989, Rider and Margraf 1997).

Except for our study, we are unaware of any other studies using activity traps to capture larval fish. While well suited for capturing benthic macroinvertebrates (Hanson et al. 2000,)

they were less effective than both light traps and benthic sleds at capturing larval fish. Activity traps captured a greater proportion of *Micropterus* species than either the benthic sled or light trap. On several occasions juvenile bass were found to have small *Cyprinidae* species in their mouths or guts. Perhaps baiting these traps with some type of food would prove effective to capture larvae, as it has been done with similar minnow traps (Layman and Smith 2001).

The benthic sleds, while a more effective capture method than activity traps in this study, are not recommended for sampling shallow structurally diverse areas. Frequently during sampling, the sled would become caught on submerged logs, branches, or other debris, requiring us to stop sampling, maneuver the research vessel so that we could remove the sled from the obstruction, and free the sled from the debris. In addition, the benthic sled captured a large amount of sand, sediment, leaves, sticks and other detritus in the net.

Direct observations of the light traps suggested that behavioral responses to light traps may vary, even among individuals of the same species. On several occasions schools of larvae were found to be congregating around the outside of the light trap, but were not entering the chamber itself. Brogan (1994) found similar results with marine fish in the Gulf of California. It is difficult to determine the depth from which the light trap attracted larvae, but observations suggest that the illuminated area extended from the surface at least 1 m and probably to 1.5 m depth.

Species captured in the light trap were similar to previous studies in freshwater systems. Kissick (1993) found that larval bluegill (*Lepomis macrochirus*) comprised 91% of the total light trap catch, while brook silverside and *Clupeidae* also comprised part of the catch. Floyd et al. (1984) found that *Micropterus* were the most commonly caught species in a study that employed light traps in a small Kentucky stream. In addition, light traps captured high numbers of

Cyprinidae and *Percidae* larvae, while no *Ictaluridae* were captured in any light trap samples.

Wallus et al. (unpublished data) found similar results in the Tennessee River, with *Centrarchidae* species being the most abundant in samples.

Although variability can be high in light traps, they appear to be the best gear for sampling fish larvae in shallow areas of complex habitat. The coefficient of variation was lowest for the light trap in comparison to the other two gears. The light traps captured significantly more numbers than any other gear and had higher taxonomic richness than both benthic sleds and activity traps. Light traps are well suited to sampling in structurally diverse shallow areas, that otherwise might not be sampled due to research vessels restrictions, and safety issues. Light traps are beginning to gain more popularity as a sampling tool, especially along riverbanks or in wetlands (Kilgore and Baker 1996, Knight and Bain 1996, Wallus unpublished data). While light traps may be limited in determining associated larval fish densities, they can be an effective means of determining species relative abundance, and or presence/ absence. They can be easily deployed and retrieved from a small boat, and can be placed under overhanging trees, bushes, and limbs. Kilgore and Baker (1996) found that light traps collected a substantially greater number of fish in forested wetlands, than in channel habitat. A team of two can effectively sample 50 to 60 sites in a night, with traps being deployed for 1-h, thus making them an excellent sampling gear for use in shallow structurally diverse areas and large navigable rivers. In similar large navigable rivers, light traps alone may provide as good or better estimates of relative abundance, and species composition and spatial/ temporal aspects of larval fish communities than study designs that employ a more complex combination of sampling methodologies.

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Table 2: Number of fish larvae, and percent gear accounted for by each taxon in 360 light trap, 360 activity trap, and 720 benthic sled samples taken in the Marmet Pool, Kanawha River, West Virginia.

Taxon	Light Trap		Benthic Sled		Activity Trap	
	<i>n</i>	(%)	<i>n</i>	(%)	<i>n</i>	(%)
Percidae	60	0.651	10	2.532	0	0
Cyprinidae						
Pimephales	337	3.655	9	2.278	0	0
Nocomis	4	0.043	0	0	0	0
Cyprinus	7	0.076	0	0	0	0
Notropis	7793	84.514	204	51.646	24	36.923
Ictaluridae						
Ictalurus	2	0.022	0	0	0	0
Atherinidae	243	2.635	3	0.759	6	9.231
Centrarchidae						
Lepomis	613	6.648	146	36.962	13	20.000
Micropterus	49	0.531	4	1.013	20	30.769
Sciaenidae	8	0.087	0	0	0	0
Lepisosteidae	0	0	0	0	2	3.077
Clupeidae	58	0.629	18	4.557	0	0
Unidentified	47	0.510	1	0.253	0	0
Totals	9221		395		65	
Mean CPUE		25.61		1.10		0.18
Coefficient of variation (%)		214.34		966.16		279.25

Table 3. Average minimum and maximum length (mm) of fish larvae for each gear type collected in the Marmet Pool, Kanawha River, West Virginia.

Sample Date	Light Trap		Benthic Sled		Activity Trap	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
6/17/2002	7.38	10.59	7.97	9.19	13.00	13.00
6/25/2002	6.79	8.93	6.63	6.88	30.43	31.14
6/30/2002	7.92	13.67	8.15	9.26	42.75	43.00
7/8/2002	13.37	20.85	20.00	22.50	42.67	43.83
7/15/2002	15.72	24.60	11.00	11.00	29.22	31.78
7/23/2002	23.88	28.98	-	-	50.00	50.00
7/29/2002	21.23	28.65	-	-	50.00	50.00
8/1/2002	21.68	31.05	-	-	41.80	41.80
Overall Average	13.75	19.47	10.75	11.77	37.48	38.07

- Denotes no catch.

Figure 7 : Catch per unit effort ((total catch per site/ effort) among 5 sites combined) for light traps on each sample date within each of the artificial structures, high quality reference and low quality natural reference sites for 2002. Error bars represent 95% confidence interval. Catch per unit effort is based on number / 1-h for light traps.

Figure 8 : Catch per unit effort ((total catch per site/ effort) among 5 sites combined) for benthic sled sampler on each sample date within each of the artificial structures, high quality reference and low quality natural reference sites for 2002. Error bars represent 95% confidence interval. Catch per unit effort is based on number / 3 m³ for benthic sled sampler.

Figure 9 : Catch per unit effort ((total catch per site/ effort) among 5 sites combined) for activity traps on each sample date within each of the artificial structures, high quality reference and low quality natural reference sites for 2002. Error bars represent 95% confidence interval. Catch per unit effort is based upon number / 24-h for activity trap.

Figure 10 : Average *Cyprinidae*- *Notropis* type (total/ effort) for each gear type among 5 sites combined) for each sample date within each of artificial structure, high quality natural and low quality natural reference sites in 2002. Error bars represent 95% confidence intervals. Notice change of y-axis scale between each gear.

Figure 11 : Average *Cyprinidae*- *Pimephales* type (total/ effort) for each gear type among 5 sites combined) for each sample date within each of artificial structure, high quality natural and low quality natural reference sites in 2002. Error bars represent 95% confidence intervals. Notice change of y-axis scale between each gear.

Figure 12 : Average *Atherinidae* (Average *Atherinidae* catch (total/ effort) for each gear type among 5 sites combined) for each sample date within each of artificial structure, high quality natural and low quality natural reference sites in 2002. Error bars represent 95% confidence intervals. Notice change of y-axis scale between each gear.

Figure 13 : Average *Lepomis* (Average *Lepomis* catch (total/ effort) for each gear type among 5 sites combined) for each sample date within each of artificial structure, high quality natural and low quality natural reference sites in 2002. Error bars represent 95% confidence intervals. Notice change of y-axis scale between each gear.

Figure 14 : Overall taxonomic richness (taxonomic richness among sites combined) for each sample date in 2002.

Figure 15 : Taxonomic composition for each gear type over the 8 sampling weeks (June 17, 2002 to August 1, 2002)

Chapter 3: *Larval fish use of experimental rock structures in a large, navigable river.*

Abstract

In rivers, velocity shelters are thought to serve as limiting factors in the retention and recruitment of young fish. Such shelters are formed in backwaters and tributaries, however these areas are limited in the Marmet Pool of the Kanawha River. In response to this concern, several structures that are thought to serve as low velocity zones were placed within the Marmet Pool. This study was conducted to evaluate the experimental rock structures (Finger and Zipper Dikes) as potential mitigation for navigational impacts in large rivers. For each rock structure (treatment), we had two reference areas (high and low quality) that reflected typical river habitat. Larval fish were sampled during 2002 and 2003, using larval light traps. Results show larval abundances peaked during late June 2002 and early July 2003. Throughout the study, larval fish were captured at significantly higher rates ($p < 0.0001$) at rock structures than in high and low quality reference areas. Taxonomic richness within artificial structures was greater than or equal to both high and low quality natural reference sites in both 2002 and 2003. *Percidae* species distribution in 2003, appears to be most influenced by the introduction of artificial structures in comparison to other abundant fish groups. Water velocities were significantly lower at rock structures (mean 0.03 m/s) than at reference areas (mean 0.16 m/s) suggesting that differences in use may be attributed to velocity shelters, which the structures provide to larval fish. This study suggests that experimental rock structures can serve as velocity shelters and retention areas for larval fish in navigationally impacted rivers.

Introduction

The human development of major rivers has tended to decrease spatial and temporal heterogeneity of aquatic habitats by eliminating multiple channels and backwater habitats (Brookes 1988, and Dister et al. 1990). Heterogeneous habitats are crucial for larval fish (Pretty et al. 2003), providing cover and increased forage opportunity that aids in the survival of young fish. Larval fish prefer habitats with increased forage, plentiful cover, and littoral zones or backwater areas (Aggus and Elliott 1975, Scott 1988, Lobb and Orth 1991, Rountree and Able 1992, Skov and Berg 1999). Young fish are highly susceptible to predation, and cover allows them to increase their survival rate. The most effective way to compensate for the impacts of human alterations on major rivers may be to increase young fish survival (Letcher et al. 1997).

The addition of habitat enhancement structures to aquatic systems is a common practice by fisheries managers hoping to increase production, spawning success, and angler catch rates of important game fishes. Habitat enhancement structures are added to aquatic systems when natural habitat is perceived to be lacking or insufficient (Prince et al. 1977), with the goal of providing additional cover and concentrating fish and so increasing some combination of recruitment, survival, growth, and angler catch rates (Johnson and Stein 1979). Habitat enhancement structures can produce these positive effects through a variety of mechanisms. For example, habitat enhancement structures have been proposed to increase recruitment by providing cover for spawning (Vogele and Rainwater 1975, Hoff 1991, Hunt et al. 2002), thereby increasing nest density. Nest success may also increase if structures provide habitat that allow adults to more effectively protect their young (Hoff 1991). Structures can also offer refuge from predation and alter survival by increasing cover (Bohnsack and Sutherland 1985, Johnson et al. 1988, Moring and Nicholson 1994), providing shade (Johnson and Lynch 1992), and

providing sites for orientation and schooling (Klima and Wickham 1971, Bohnsack and Sutherland 1985). Accordingly, prey abundance in the vicinity of structures may be enhanced (Wege and Anderson 1979, Aadland 1982), in turn increasing the abundance, feeding efficiency, and growth of nearby predators (Wege and Anderson 1979, Bohnsack 1989).

Dike fields are regions of high heterogeneity, containing a mix of rock structure, woody debris, lentic and lotic sandbars, eddies, plunge pools, scour holes and other habitats (Beckett and Pennington 1986). The placement of these structures as part of a mitigation program or restoration project can help to increase the habitat available to all life cycles of fish. Spur dikes have been recognized as riparian structures that slow velocity near the riverbank and as environmental structures that can provide plentiful ecological surroundings by creating diverse flow fields (Shields 1995). A spur dike can be defined as an elongated structure having one end on the bank of a stream and other end projecting towards the river. Spur dikes, finger dikes, wing dikes, groynes, hard points and other similar structures have been placed in a variety of large rivers for mitigation and restoration purposes (Li et al, 1984, Shields 1995, Beckett and Pennington 1986). These structures typically extend from shore into the stream or river, usually used in series, with the first structure at the greatest downstream angle and the latter ones more perpendicular to the bank. Spur dikes extend further into the stream and deflect flows well away from the bank. Hard points extend only a short distance and slow velocities along the banks. River engineers originally designed dikes for shoreline stabilization so that the low velocity zones near them would fill with sediment (Anding et al. 1968). However, these low velocity zones adjacent to and between dikes have been shown to provide valuable habitats for fishes (Pennington and Shields 1993, Shields 1995, and Pitlo 1998).

About 440 dikes have been designed and constructed on the Lower Mississippi River. These dikes have been constructed in about 125 groups (dike fields) of 2-12 structures per group (Baker et al. 1991). These structures and the regions of reduced velocity near them have been shown to be important habitats for fishes within the Lower Mississippi River. The biotic community of these dike fields is similar to main channel communities during high flows and lentic habitats during lower flows. Burress et al. (1982) conducted a study on nine riverine habitats in the Missouri River, of all habitats sampled, dike fields had the most diverse fish community, which was attributable to the presence of more sheltered and diverse habitats.

Several studies have examined larval fish use of dike structures, but no replicated comprehensive evaluations have been conducted. In the Mississippi River, Burress et al. (1982) failed to adequately sample for larval fish as only 63 total larval fish were encountered in the study. Previous work by Li et al. (1984) determined that spur dike habitat was intermediate in quality between natural banks and continuous rip-rap revetments. However, the study failed to consider changes in the community over time as sampling was conducted only for one year from mid-April thru mid-June. Beckett and Pennington (1986) found that larval fish assemblages within dike fields had distinctive species compositions, supporting high densities of centrarchids and atherinids. This study however, failed to adequately address the spatial and temporal aspects of larval fish ecology.

Given the importance that larval fish survival and recruitment have in structuring the juvenile and adult fish community (Houde 1989) along with the potential for artificial structures to be used on the thousands of kilometers of navigable rivers in the United States, a thorough evaluation of these artificial structures is needed. Therefore, in this study we sought to evaluate the utility of artificial habitats for larval fishes at five dike fields within the Marmet Pool of the

Kanawha River, West Virginia. Our hypothesis was that larval fish density and composition was the same at structures as nearby reference areas (null) versus densities and composition being higher or more diverse than reference areas (alternate).

Materials and Methods

Field collections

Five sets of artificial structures were constructed in the Marmet Pool during 2000. These dike sets consisted of four finger dikes (FD1 - FD4) and one set of zipper dikes (ZD) (Figures 2 & 3). Each set varied in size and length but was made of similar material. Structure designs were somewhat different (number of dikes, angle from riverbank, distance between individual dikes, and length of dikes) (Figures 4 & 5); however, each achieved a goal of increasing heterogeneity. Artificial structures were dominated by the rocks used for construction, but also had some low hanging vegetation and woody debris (Titus 2004). Two reference areas were selected to compare with each structure: one of high quality natural composition and one of low quality natural composition. The reference sites were determined to be of high or low quality based upon velocity characteristics (Figure 6) and the amount of potential cover available to larval fish. High quality natural reference areas had a large bench width (similar to the artificial structure sites) and typically had snags, woody debris, low hanging vegetation, and lower water velocity in comparison to low quality reference sites. Low quality natural reference areas had a smaller bench width, fewer snags and woody debris, vegetation was not as low hanging to the water, and water velocity was higher than in high quality natural reference sites.

The artificial structure sites each consisted of a series of dike structures. All dikes were constructed of rock/rubble material positioned along the shoreline and extending into the river

along the bench (Titus 2004). The finger dikes were angled from shore in an upstream direction, while the zipper dikes were positioned parallel to shore. Each structure, although different, did at minimum provide a greater habitat heterogeneity and higher amount of cover within each of them than what was available naturally and most of the time dikes performed similarly (Titus 2004). However, since each artificial structure type was slightly different in design (Figure 4 and 5), (size of dikes, density of dike structures) each varied in their attraction to fish and thus it may be important to examine differences among structures if we are to learn how to best design artificial structures in the future. The artificial structure construction design varied between sites (Table 1). The shoreline length of each artificial structure site was 400 to 700 feet (Titus 2004). The greatest density of structure material within a site occurred within finger dike 2 (37 feet of shoreline / dike and 1.6 feet between dikes / average dike length). The zipper dike was the next densest followed by finger dike 1, and lastly finger dike 4 and finger dike 3 (75 feet of shoreline / dike and 1.0 feet between dikes / average dike length). Although finger dike 4 appears similar to finger dike 3 in the amount of habitat provided, little of finger dike 4 was submerged during normal flows thus the habitat available within that site was less (Titus 2004). Although the zipper dike structure had the shortest shoreline length, the design created the highest dike length / distance between dike value, and the site provided a large amount of heterogeneous habitat as a result.

Sampling was conducted weekly at each site, when weather conditions and river flows permitted, from June-August 2002 and April – August 2003. Sampling stations were located in the structure sites, and at reference sites positioned at shoreline river left and shoreline river right. Sites were assessed using quatrefoil light traps that were placed randomly throughout each of the five sets of treatment and high and low quality reference areas. In 2002, three light traps

were set per site, while in 2003 a total of five traps were set per site on each date. The light trap used was a floating 30 cm x 30 cm x 50 cm Quatrefoil type- Plexiglass ® trap. Each trap had four 15 mm entrance slots and used a 12-h Cyalume ® green chemical light stick, which originated from a central light tube in each trap (Floyd et al. 1984). We selected this light source because previous research by Gerhke (1994) showed that green light sticks glowed brighter during the first hour of sampling than other colored light sticks. The light traps were placed and anchored within the habitat starting approximately ½ hour after dusk and were left for a period of 1 hour. All samples were washed into sample jars, labeled, and preserved in 10% buffered formalin.

Water quality

Water quality was measured with a YSI meter (Computer module: 650 MDS, Sonde: 6820) at each of the sites (artificial structures and reference areas) on each sample date. Measurements were taken within each site at the surface and at 1 m in depth. Water quality measurements included temperature (Celsius), specific conductivity ($\mu\text{S}/\text{cm}$), conductivity (mS/cm), pH, turbidity (NTU), dissolved oxygen (mg/L), and salinity (ppt). Dissolved oxygen was calibrated before use on each sample date and all other variables were calibrated at the start and middle of the sampling year.

In addition, to water quality information, we deployed temperature loggers Model: HOBO Water Temp Pro [H20-001] at each site (artificial structures and reference areas for a total of 15 loggers), which recorded the water temperature every two hours. The loggers were set in place after the 2002 sampling season. Temperature was collected from October 2002 through the latest download date of 17 March 2004.

Velocity profile

Water velocity measurements were taken in 2002 and 2003 using a Marsh McBirney Flo-Mate (Model:2000). In 2002, one velocity measure was taken at each sample site on each sample date. The velocity was taken in the middle of each sample site, at a distance of 5 meters perpendicular from the riverbank, near the outermost edge of the dikes. Water velocity was measured facing upstream at the thalweg depth (0.6 of bottom depth) using a staff gauge. A more thorough water velocity profile was conducted during 2003. During each sample date, water velocity measures were taken at 6 equidistant points (1, 2, 3, 4, 5, and 6 m) along three different fixed transects (perpendicular to shore) within each site. This occurred on 12 dates from May to August 2003.

Laboratory processing of samples

In the laboratory, the contents of each light trap sample were washed through a 250-micron mesh sieve. The contents were then transferred to trays where the larvae were removed and counted. Samples were re-checked to ensure that all larvae had been removed from the sample. All larval fish collected were identified to the lowest possible taxon using a variety of references (Auer 1982, Holland-Bartels et al. 1990, Wallus et al. 1990, Kay et al. 1994, B. Wallus personal communication). Larvae that could not be identified because of extensive damage (<0.5% of all larvae) or larvae that could not be identified at or below the family level were classified as “unidentified larvae” (<0.5% of all larvae). Larvae were identified using a Leica MZ6 microscope, that was retrofitted with a Cole-Parmer light ring and polarizing lens. All larval fish collected were assigned to a developmental stage according to Snyder (1976). Total lengths (TL) were measured to the nearest mm with an ocular micrometer mounted in a

stereo dissecting scope. In each sample the minimum and maximum length for each taxonomic group and developmental stage was recorded.

A taxonomic guide for larvae collected was created for the project. This guide was developed with Bob Wallus (formerly of Tennessee Valley Authority), a larval fish expert. Mr. Wallus, who gave the senior author significant larval fish identification training, also helped to create a voucher specimen collection, and conducted Quality Assurance/ Quality Control on identifications. This guide helped to determine the lowest possible taxonomic level that our samples could be identified to; given our equipment, high number of samples and time constraints. We believe that this guide helped us get an accurate description of larval fish species in the Kanawha River. Overall, 10% of the samples underwent QA/QC checks. Only one larval specimen was found to be misidentified during the QA/QC program, giving us confidence in the taxonomic identity of specimens in this study (B. Wallus personal communication).

Taxonomic determination

Larvae were classified to 22 taxonomic groups (Appendix 1). Paddlefish (*Polyodon spathula*) were not found, but could have been easily been identified to species level (Wallus et al. 1990). Longnose gar (*Lepisosteus osseus*), the only member of its family in the Kanawha River, was easily identified to the species level (Wallus et al. 1990). *Clupeidae* were easily identified to family level (Holland-Bartels et al. 1990), based on the position of the anal vent, and were assumed to be gizzard shad (*Dorosoma cepedianum*) based on juvenile and adult abundance (Titus 2004). Mooneyes (*Hiodon tergisus*) have not currently been found yet, but can easily be identified to species level (Wallus 1986; Wallus et al. 1990). Pikes (*Esocidae*) were not

found, but can easily be identified to species level (Wallus et al. 1990). There are numerous *Cyprinidae* species found in the Kanawha River (Stauffer et al. 1995), which complicated the identification process. *Cyprinidae* were identified to four taxa: *Cyprinidae* Pimephales-type (*Erimystax* spp., *Macrhybopsis* spp., *Hybopsis* spp., *Phenacobius* spp., and *Pimephales* spp.), *Cyprinidae* Nocomis-type (*Campostoma* spp., *Nocomis* spp., *Rhinichthys* spp., and *Semotilus* spp.), *Cyprinidae* Notropis-type (*Clinostomus* spp., *Ericymba* spp., *Exoglossum* spp., *Notemigonus* spp., *Margariscus* spp., *Cyprinella* spp., *Luxilus* spp., *Lythrurus* spp. and *Notropis* spp.), and common carp (*Cyprinus carpio*). *Cyprinidae* were identified using a variety of resources (Auer 1982, Holland-Bartels et al. 1990, B. Wallus personal communication). Suckers (*Catostomidae*) were identified to two taxa: *Catostomidae* Ictioben-type (buffalo and carpsuckers) and *Catostomidae* Catostomini-type (suckers). Buffalo and carpsuckers were identified based upon pigmentation patterns and myomere counts (Kay et al. 1994, B. Wallus personal communication). The rest of the suckers (*Moxostoma* spp., *Hypentelium* spp., and *Catostomus* spp.) were identified based on myomere counts and other meristics (Kay et al. 1994, B. Wallus personal communication).

Perches (*Percidae*) were not identified below the family level because of overlapping characteristics and a lack of larval descriptions. Only 8 of the 13 *Percidae* species in the Kanawha River have larval descriptions in the literature (Auer 1982 and Holland-Bartels et al. 1990, Wallus 2004). Sunfishes (*Centrarchidae*) were identified to four taxonomic groups: *Lepomis* spp. (sunfish), *Ambloplites rupestris* (rock bass), *Micropterus* spp. (black bass), and *Pomoxis* spp. (crappie) (Auer 1982, B. Wallus personal communication). Catfishes (*Ictaluridae*) were identified to four groups: *Ameiurus* spp. (bullheads), *Noturus* spp. (Madtoms), *Ictalurus punctatus* (channel catfish), and *Pylodictis olivaris* (flathead catfish) (Simon and B. Wallus

personal communication). *Moronidae* were identified to the family level based on vent position and myomere counts (B. Wallus personal communication). Freshwater drum (*Aplodinotus grunniens*) were easily identified to the species level (Auer 1982, and B. Wallus personal communication). Brook silversides (*Labidesthes sicculus*) were easily identified by pigment patterns and location of the vent (Auer 1982 and B. Wallus personal communication).

Site specific data was analyzed using the ANOVA/GLM model in SAS. All alphas were set at 0.05 and for each analysis we tested for normality using skewness and Kurtosis. Data not found to be normal were transformed using a log base 10 transformation.

Results

Fish use of artificial structures

Larval fish catches were higher on the artificial dike structures than on high and low quality reference areas. Larval fish used the artificial structures as a source of habitat (Figures 16 & 17). A total of 65,964 larval fish were collected in the two sampling years (2002 and 2003)(Table 4). Collections made over the two years indicate that 59.4% (39,212) of the total catch (sum of total catch for all sample dates) were associated with artificial structures in comparison to the two nearby natural reference habitats. Catch per unit of effort for larval fish was significantly higher in artificial structures than in low quality natural sites and high quality natural sites ($p < 0.001$) in both 2002 and 2003 (Figures 18 & 19)(Table 5). Overall, high quality natural sites, contained 27.2% (16, 985) of the total catch, and had significantly more fish ($p < 0.001$) than low quality natural sites 13.3% (8,767). Within years, the high quality natural sites contained significantly more larval fish than low quality natural sites in 2003 ($p < 0.001$), but there was no statistical difference among these sites in 2002. Significantly more fish were

collected in 2003 than in 2002 within all treatments (artificial structure vs. references) ($p < 0.001$) (Figure 18).

Temporal composition patterns

Temporal patterns in taxonomic composition differed between 2002 and 2003 (Figures 20 & 21). In 2002 sampling began in mid-June with *Lepomis* (i.e. sunfish), *Cyprinidae*-*Pimephales* type, and *Cyprinidae*-*Notropis* type being the dominant taxonomic groups. *Cyprinidae*-*Notropis* type were the dominant taxa throughout the 2002 sampling season (Figure 20). *Lepomis* were the 2nd most dominant species in 2002, with a peak in late June. *Percidae* (i.e. perches), *Clupeidae* (i.e. shad), and *Micropterus* were found throughout 2002 with no peaks in distribution.

Sampling for 2003 commenced earlier than 2002. The first taxa to appear were *Percidae* in mid-April. *Percidae* were prevalent throughout all of the samples identified in 2003 and peaked in early July (Figure 21). *Catostomidae* (suckers) began to appear and peak in mid-May, with *Catostomini* type (suckers) being more prevalent than *Ictioben* types (buffalo and carpsuckers). Overall, *Catostomidae* are found through early July 2003 samples. Several taxa also begin to appear in Mid-May including *Pimephales*-type cyprinids, *Nocomis*-type cyprinids, *Notropis*-type cyprinids, and *Clupeidae*. *Pimephales* type cyprinids are the dominant *Cyprinidae* taxa throughout June. In early July, *Notropis*-type cyprinids begin to peak and become the dominant cyprinid type. Common carp began to appear in late June, and peak in early July. *Lepomis* and *Micropterus* (black basses) did not appear until late June and steadily increased through July, with numbers peaking at the beginning of August. Brook silversides began to appear in late June but exhibited no clear peak in abundance.

Taxonomic groups and artificial structure

Larval fishes collected were typical of large river systems with individuals from the families Cyprinidae, Percidae, and Centrarchidae being the most abundant. Other taxa, yet not part of those families, include Catostomidae, Atherinidae, freshwater drum, and clupeidae (gizzard shad).

Taxonomic composition did not differ overall between dike structures and high and low quality reference areas (Figure 22). However, taxonomic composition differences were noted within various different sample weeks in both 2002 and 2003 (Figures 23 and 24). Key larval fish taxa were captured at significantly higher rates in the artificial structures, while no taxa were captured in higher rates at the reference sites.

Percidae use of artificial structures

Percidae taxa distribution appears to be most influenced by the introduction of artificial structures in comparison to other abundant fish groups. *Percidae*, many of them larger larvae, were found to have highest abundance on artificial structures versus natural high and low quality reference areas in comparison to other taxonomic groups. *Percidae* were collected in significantly higher numbers ($p < 0.001$) on artificial structures in comparison to high quality and low quality natural habitats during 2003 (Figure 25). *Percidae* were collected in low quality natural sites significantly less than in high quality natural reference sites during the 2003 sampling season ($p < 0.001$). Overall, very low *Percidae* numbers precluded meaningful comparisons between structures and reference sites in 2002.

Cyprinidae use of artificial structures

Cyprinidae (*Pimphales*-type, *Notropis*-type, *Nocomis*-type, and *Cyprinus carpio*) as an overall group were collected significantly more on artificial structures, followed by high quality natural habitats and lastly, low quality natural habitats ($p < 0.001$) during both 2002 and 2003 (Figures 26 & 27). The *Pimephales*-type, were collected significantly more ($p < 0.001$) in artificial structures than in high quality natural and low quality natural reference sites during both the 2002 and 2003 sampling seasons (Figure 26). In 2003, high quality natural habitats supported significantly ($p < 0.01$) more *Pimphales*-type, than low quality natural habitat. However, there was no difference in *Pimphales*-type use between high quality natural habitats and low quality natural habitats in 2002.

Notropis-type were collected significantly ($p < 0.001$) more on artificial structures than in high quality natural and low quality natural reference sites during both the 2002 and 2003 sampling seasons (Figure 27). In 2003, high quality natural habitats supported significantly ($p < 0.01$) more *Notropis*-type, than low quality natural habitat. However, in 2002, low quality natural habitats supported higher numbers of *Notropis*-type than high quality natural habitat but the difference was not significant.

Lepomis use of artificial structures

Lepomis (i.e. sunfish) were collected significantly more ($p < 0.001$) in artificial structures than in high quality natural, and low quality natural reference sites during both the 2002 and 2003 sampling season (Figure 28). However, *Lepomis* catches were much lower in 2003 than in 2002. In 2002, high quality natural habitats and low quality natural habitats contained similar numbers of larval fish. However, in 2003, high quality natural habitats had significantly higher numbers ($p < 0.01$) than low quality natural habitats.

Atherinidae use of artificial structures

Atherinidae were collected significantly more ($p < 0.001$) in artificial structures than in high quality natural and low quality natural reference sites during the 2002 sampling season (Figure 29). In 2002, high quality natural habitats had significantly higher numbers ($p < 0.01$) than low quality natural habitats. In 2003, very low *Atherinidae* numbers precluded meaningful comparisons between structures and reference sites.

Catostomidae use of artificial structures

Catostomidae- Catostomini type abundance on artificial structures was not significantly different from high quality and low quality natural sites (Figure 30). In 2003, low quality natural habitats contained more *Catostomidae*- Catostomini type larval fish than high quality natural sites, but the difference was not significant. We were unable to evaluate *Catostomidae*- Ictioben type numbers, as captures were too low to evaluate differences among sites. No *Catostomidae* of either type were collected in 2002.

Taxonomic richness

Taxonomic richness within artificial structures was greater than or equal to both high and low quality natural reference sites in both 2002 and 2003 (Figure 31). In 2002, taxonomic richness was significantly greater on artificial structures than in both high and low quality natural habitats ($p < 0.001$) averaging 5.47 taxonomic groups per sample week on artificial structures versus 2.50 taxa in high quality natural sites and 2.30 taxa in low quality natural sites. The 2003 sampling season consisted of an overall higher yield of fish and was correlated with a decrease in

taxonomic richness at the artificial structures and an increase at both the high quality natural and low quality natural sites. Taxonomic richness in 2003 was not statistically different between the artificial structures and the high quality natural sites, but richness did differ between low quality natural sites and artificial structures ($p < 0.05$). Taxonomic richness during 2003 averaged 4.65 taxonomic groups on artificial structures, 4.13 taxa in high quality natural sites, and 3.74 taxa in low quality natural sites (Figure 31).

Larval community size structure

There was little difference between sites in regards to the minimum and maximum lengths of larvae captured. In 2002, there were significant differences ($p < 0.05$) in the minimum larvae length on one occasion, June 17 (Figure 32). The minimum average length for high quality natural sites (8.67mm) was significantly higher than the minimum average length for artificial structure sites (5.83mm). There were no significant differences between sites for maximum larval length in 2002. In addition, there were no significant differences between sites for minimum and maximum larval length in 2003 (Figure 33). In 2002, larval fish captured at all sites became increasingly large over time, however in 2003 the larval fish size structure did not become increasingly large over time.

Water quality

There was no significant difference within each sample date in any of the water quality measurements between sites (artificial structure versus high and low quality natural reference sites and between structure types). Water quality among sites did not differ significantly within any measure (temperature, dissolved oxygen, salinity, conductivity, specific conductivity,

turbidity). Temperature was different on each date between 2002 and 2003, with 2002 having warmer temperatures (Figure 34).

Artificial structures provide low velocity zones

Artificial structures in place within the littoral zone provide areas of lower velocity in comparison to similar areas without artificial structures. In order to quantify this, we measured water velocity at each site. The three different categories of sites: artificial structures, and high and low quality natural reference areas had significantly different velocities within them ($p < 0.001$). Results show artificial structures have the lowest average velocities associated with them (Figure 6). For all artificial structures, velocities remain extremely low (less than 0.05 m/s) for most of their length. Velocities begin to increase at five meters from shore, which for most sites corresponds to the end of the structure and velocities measured at six meters have the highest velocities and are closest to the main channel flow.

Natural reference areas had significantly higher velocities than artificial structures ($p < 0.01$). High quality natural sites begin with velocities greater than the artificial structure sites and gently increase in velocities in a linear fashion until six meters from shore. The sixth meter velocities in high quality natural sites have a much higher velocity than the sixth meter measure on artificial structures indicating that structures are probably influencing velocity patterns after the end point.

The greatest velocities were measured in the low quality natural sites. Velocities began higher than in high quality natural sites or artificial structures and increased nearly exponentially with distance away from shore. Measured points furthest from shore had extremely high velocities with some highest measures often from 0.45 to 0.55 m/s. Artificial structures

maximum velocities (at the furthest point from shore) were between 0.04 and 0.14 m/s and high quality natural sites maximum velocities were between 0.21 and 0.36 m/s.

Individual artificial structures

Each of the five sets of structure varied some in their performance as indexed by the capture rates of larval fish. Each artificial structure differed from 2002 to 2003 in regards to total catch and CPUE, although some of this was related to greater effort (longer season and increased replication) between 2002 and 2003 (Figures 16 & 18)(Tables 4, 6-10). In 2002, the two most important structures for larval fish were finger dike 4 and finger dike 1. The two most important structures in 2003 were zipper dike and finger dike 4. In 2002, finger dike 2 supported the lowest number of larval fish. In 2003, finger dike 3 supported the lowest number of larval fish and was similar in number to the high quality reference site for finger dike 4 (Figure 16).

River discharge and habitat use

River discharges in 2002 were lower and 2003 discharges were higher than the 125 year average for the Kanawha River (Figure 35). The flows can be considered to be two extremes with the 2002 discharges being extremely low during a dry year and conversely the 2003 season characterized by high discharges with major spikes that on occasion pushed the Kanawha River to flood stage. The 2002 sampling season had lower flows and fish did not respond to the river flow significantly during the entire sampling season (Figure 36). Conversely, in 2003 the average catch was low during the first seven weeks of sampling. Larval catch numbers increased during early-July when discharge levels declined.

Discussion

Dike structures provide valuable habitat for fish larvae in the Marmet Pool of the Kanawha River. The results of this study suggest that artificial rock structures (zipper dikes and finger dikes) are good larval fish habitat in large, navigable rivers. We collected greater numbers and had higher catch per unit effort at all artificial structures, than at high quality natural reference areas and low quality natural reference areas. Water velocities were significantly lower within artificial structure habitats than at the other shoreline sites. The decreased water velocities within the structure sites provide shelter to larval fish from the wave action generated by barge tows. Holland (1987) showed that passing barges can create enough wave action to dewater fish larvae and eggs. In addition to serving as low velocities areas, the structure sites are physically more diverse than other shoreline sites as woody debris is accumulating and aquatic vegetation is also increasing between finger dikes. Li et al (1984) suggested that as woody debris accumulation increased within similar structures on the Willamette River, larval fish numbers would increase. Overall the structure sites are providing a more diverse habitat for larval fish.

Other measures of habitat quality also suggest the structures provide valuable larval fish habitat. Taxonomic richness was greater on artificial structures in comparison to high quality and low quality natural reference sites. We also collected higher numbers and observed greater CPUE of some sport fishes (*Percidae* and *Lepomis*) at the dike structures. *Percidae* and *Lepomis* species were more abundant and had greater CPUE on artificial structures than in high quality natural and low quality natural habitats. Previous studies focused on juvenile fish found greater use of dikes by Centrarchidae (Poizant and Pont 1996, Titus 2004). Conversely, Li et al. (1984) found dikes and natural reference areas in Oregon not different in terms of larval fish abundance.

However, in the Li et al. (1984) study the natural reference zones and dikes each had lower velocities associated with them, thus eliminating the need for protection from higher velocities. The use of artificial structures by game species may increase the value of these sites to management agencies and anglers due to the potential benefits. These structures can serve as valuable tools to improve the game fish and overall fish populations within large navigable rivers. Houde (1989) demonstrated that larval fish survival and recruitment are key in structuring the juvenile and adult fish community. Increasing larval fish recruitment and survival within larger rivers can thereby increase fish populations as a whole. Our research shows that artificial dike structures support higher numbers and greater taxonomic richness of larval fish than typical large river habitat. The apparent success of these dike structures may be an important tool in managing navigation and other anthropogenic impacts to river fish populations.

Despite lower velocities at artificial structures than natural areas and our assertion that larval fish use was related to velocity shelters, larval fish CPUE declined when flows increased. This seeming paradox would suggest that larval fish use of structures is related to some factor other than velocity. However, several hypotheses may help to explain this observation. Larval fish CPUE may be lower under high flows due to a decreased catch efficiency of the light traps under high flows. Under high flows larvae may be less active, seeking to maximize their retention in non-turbulent areas (Starnes et al. 1983). Larvae would also have reduced relative swimming ability under increased flow, which may reduce their ability to move towards artificial light sources or enter trap slots, both of which have the effect of reducing gear efficiency under these conditions. A concurrent electrofishing survey of juvenile fish showed increased CPUE in the artificial structures under high flows (Titus 2004). So alternatively, lower larval CPUE under high flows could be due to altered behavior or reduced abundance due to some un-quantified

predatory interaction with juvenile fishes. Whatever the mechanism, larval fish CPUE remained higher on artificial structures than natural sites, even under high flows, substantiating the value of these dikes to larval fish recruitment in large navigable rivers.

Species composition was expected to be similar to other navigable and channelized rivers, such as the Ohio, Mississippi and Missouri Rivers. In our study two *Cyprinidae* types and *Percidae* comprised 93.8% of the total catch. Previous studies on the Kanawha found that freshwater drum, *Clupeidae*, *Cyprinidae*, and common carp were the most dominant species, compromising 86% of the catch (Rider and Margraf 1997). Respectively, *Percidae* compromised 23.5% of the total catch in 2003, previous studies had captured *Percidae* larvae in much smaller numbers (Odom 1987, Scott 1988, Rider 1991). Rider and Margraf (1997) found that *Percidae* species compromised 3.02% of their total catch from the upper Kanawha River. The dominance of *Percidae* species was expected in the early part of the sample season (April and May). Odom (1987) first collected *Percidae* in early May in the lower Kanawha River. Rider and Margraf (1997) found *Percidae* species in the Marmet Pool as late as August 2nd but this was limited to a few individuals (12)(0.71% of total sample). The dominance of *Percidae* into late summer is somewhat unexpected as *Percidae* compromise 62.4 % of the samples from June 24th, 29.1% of the samples from July 1st and 11.3% of the samples from July 31st. *Percidae* spawn at a wide range of temperatures but species known to exist in the Kanawha River typically spawn at temperatures between 3.0-15.0° C (Holland-Bartels et al. 1990). Water temperatures at study sites ranged from 14.7° to 24.0° C between April 15th and July 3rd. However, early life history information does not exist for 5 of the 13 species of *Percidae* found in the Kanawha River, preventing detailed taxonomic composition (, B. Wallus personal communication). The preference that *Percidae* showed for artificial structure habitat over high quality habitat, and high

quality habitat over low quality habitat, suggests that *Percidae* larvae may require habitat that provides cover, increased heterogeneity, or lower velocities. *Percidae* species likely benefited from the high level of cover provided by the structure material, greater forage attraction in the forms of macroinvertebrates, and lower water velocity. *Percidae* species collected were most often post-yolk sac larvae.

River flow and artificial structures

The water velocity generated from river discharge was lowest within artificial structures and highest in low quality natural reference sites. During periods of high flows significantly more fish were found on artificial structures than on natural sites. Since artificial structures are zones of low velocity, larval fish may use them as a source of cover from swift moving water in the main channel. These low velocity areas may be most important to smaller and younger fish susceptible to displacement during high flow events. However, in comparison with low flows in both years we collected fewer fish on artificial structures during periods of high river discharge. This appears to be most evident in 2003, as the catch per unit effort is low until early July. Before early July there were large peaks in discharge and low catch per unit effort numbers, when river discharges decreases catch per unit effort increases. This may be attributable to the fact that during low flow events fish can be attracted to the light traps from further away as currents and turbidity may both be lower under these conditions. In addition, differences may be attributable to the spawning of different species and temperature.

Guidelines set forth for artificial structures

Copeland (1993) set forth a guideline for creation of artificial habitats. A professional engineer should carry out the design of river training works. Spurs or groins may be permeable (constructed of piles, fencing or concrete or timber cribs) or impermeable (constructed of armoured fill). The spacing should vary with channel geometry and spur length. Spur length into the channel should not exceed 15% of the bankfull width for impermeable structures. Generally, structures should be spaced at 3 to 12 times the projected spur length into the channel. Spurs are often designed so that the projection of flow from the tip of the upstream spur meets the root of the downstream spur. Spurs or groins may be angled upstream, downstream or perpendicular to the streambank (Copeland 1993). It is advantageous to angle the spur upstream so that flows overtopping the structure are directed away from the streambank. Permeable structures may accumulate debris and require periodic removal. Spurs or groins should be designed to a height that protects the regions of the streambank impacted by the erosion processes active at the particular site. The structure is often designed to the bankfull height (Copeland 1993). All flow deflection structures should be designed to accommodate scour at the tip of the structure. The construction of a spur or groins increases flow velocities in this area and may create a deep scour hole.

Similarly, Steimle and Zetlin (2000) outlined a series of guidelines for implementation of artificial structures as a source of fish habitat in both marine and freshwater aquatic systems. Steimle and Zetlin (2000) suggest artificial structure projects should act as corridors between habitat types; for Marmet Pool structures this may represent a corridor between the main channel and littoral zones. They further state that artificial structure placement should also result in an increase in cover and may vary depending on factors including time of year, river flow, time of

day, and size. In 2003, larval fish abundance was highest later in the sampling season (July), therefore artificial structures need to appeal to larval fish needs in late summer.

The artificial structures had more larval fish than both the high and low quality natural sites, but some artificial structures had higher numbers of fish than others. Finger dike 4 had the most larval fish in both 2002 and 2003, while finger dike 2 and 3 supported the lowest numbers in 2002 and 2003 respectively. Several reasons can be hypothesized about why the structures supported different numbers of fish. Each of the four finger dikes differed in the overall number of dikes, individual dike length, the orientation to the channel, and total length of shoreline. Finger dike 4 incorporated the longest amount of shoreline at 705 feet, with the highest average dike length (39). In addition, finger dike 4 had 13 overall dikes incorporated into the design, which was the second most abundant following finger dike 2. It should also be noted that finger dike 4 was located approximately 4 river miles upriver from the other structures. This section of the river has considerably less navigation traffic, while the section of river that contains the zipper dike and finger dike 1, 2, and 3 has several coal tipples and a large amount of navigation traffic. Field observations during the 2002 and 2003 sampling season noted that while sampling finger dike 4, barge traffic was minimal. The higher numbers of larval fish associated with finger dike 4 could possibly be attributed to the overall design and length of shoreline, or lower navigation traffic, but it is impossible to make comparisons due to the differences in locations among the dikes. Perhaps building dikes that are similar to finger dikes 1, 2, or 3 in the upriver section might make comparisons of the dikes possible.

Implications for management

Several considerations should be made when designing either habitat enhancement evaluations of fish use or in the design of the enhancement project itself. Artificial structures used in this study provided habitat heterogeneity that was used by larval fish. Artificial habitat enhancement projects will be most successful if a few considerations are included in their design.

First, natural components should be incorporated to make them attractive to a wider variety of species. The rock structures used here were most attractive to *Percidae* species. If natural materials, such as aquatic vegetation and woody debris, are incorporated within these sites beyond rock alone it may attract a greater diversity of organisms beyond fish in addition providing habitats for a wider variety of fish species. Second, enhancement projects should be designed with flow in mind. Structures should be built to withstand river conditions in terms of flow, washout and sedimentation rates. River velocity has a major impact on fish populations; therefore, artificial structures should be able to provide low flow areas along with providing cover and forage. In addition, barge travel creates waves from passing vessels and could have an impact on larval fish similar to a high flow event and the amount of barge travel should be considered. Passing barges and subsequent wave action on shore resuspends sediment and may increase sedimentation within structures while waves displace small fish (Hershfeld et al. 1986). Structures should be inspected after significant flood events for evidence of scour or erosion damage. Structures designed with river conditions in mind will likely be more successful. Kuhnle et al. (2002) found that spur dikes constructed with an angle of 135 degrees to the bank had the most potential benefit to aquatic habitat while ones with 90 degree angles yielded the best potential for protection of the banks. The best design of spur dike was the one that not only protected the stream banks, but also maximized the volume of the scour pool formed by the

structure (Kuhnle et al. 2002). Structures should cover a minimum of 700 feet of shoreline and enhancement projects should be built for long-term use. Habitat enhancement projects in hopes of benefiting fish have a history of failure both structurally and in its ability to achieve the goals of the project (Frissell and Nawa 1992, Bassett 1994, Pratt 1994). Stable pools are an important part of improving aquatic habitats in unstable stream channels (Kuhnle et al. 2002). Lastly, since artificial rock structures are intended for long-term use as habitat enhancement, it is important to consider aesthetic values in their design beyond strictly the needs goals. Structures should be incorporated into the natural river environment and decrease the unnatural appearance of the project. Due consideration of these guidelines for enhancement projects in large rivers may help to deliver the greatest benefit to larval fish populations, as the original conditions of large rivers are unlikely to be restored.

Artificial structures encouraged species and larval fish diversity. Taxonomic richness was higher on artificial structures than in natural reference sites in 2002. In addition, the rock structures created interstitial spaces between rocks that were likely utilized by organisms such as algae and benthic macroinvertebrates. The diversity of habitat available at the artificial structure sites may have contributed to the greater taxonomic richness generally observed there. The artificial structures may have helped to decrease predation, while increasing forage and spawning thereby increasing larval fish survival and subsequent recruitment. Despite clear evidence that larval densities were higher in the treatments than in other areas it is still unclear whether these structures foster the production of fishes or merely aggregate them. In marine (Powers et al. 2003) and freshwater (Kelch et al. 1999) systems it has been argued that artificial structures only concentrate young fish. However, in river systems with turbulent flows like the Kanawha River any areas affording velocity shelter and allowing accumulation of larvae could be considered a

retention area, thereby preventing displacement downstream and potentially leading to increased localized recruitment.

The overall success of these artificial structures on the Kanawha River can prove vital to restoration efforts in large navigable rivers around the United States and the world. Building artificial structures on even a small portion of the thousands of river kilometers maintained by the USACE, could be of substantial benefit to river fish populations through increases in larval fish survival and recruitment. In particular, the preference that larval *Percidae* and to an extent *Lepomis* showed for these structures make them ideal for game fish restoration efforts. Future studies should include an analysis of these structures over 10-20 years to verify the functionality of these dikes as mitigation structures over the long term.

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Table 4. Total number and average number of larval fish per light trap at rock structures and reference areas for 2002 and 2003 combined.

Site	Total Number Caught	Average per Light Trap
ZD	12092	153.1
ZD High Quality	3438	43.5
ZD Low Quality	2660	33.7
FD 1	7494	94.9
FD 1 High Quality	3475	44.0
FD 1 Low Quality	867	11.0
FD 2	9354	116.9
FD 2 High Quality	1121	14.0
FD 2 Low Quality	1383	17.3
FD 3	5677	76.7
FD 3 High Quality	1767	23.9
FD 3 Low Quality	1201	17.4
FD 4	11500	136.9
FD 4 Low Quality	1983	23.6
FD 4 High Quality	4570	54.4

Table 5. Average Number of larval fish per light trap at rock structures and reference areas for 2003 Marmet Pool Larval Fish Survey.

	Artificial Structures	Reference Areas
Sample Date		
6/17/2002	83.5	13.3
6/25/2002	65.3	13.8
6/30/2002	225.1	22.7
7/8/2002	33.9	4.6
7/15/2002	37.2	5.9
7/23/2002	5.9	5.9
7/29/2002	13.0	4.3
8/1/2002	5.9	4.3
4/17/2003	7.0	1.5
5/15/2003	13.5	8.2
5/20/2003	11.8	9.7
5/29/2003	14.9	7.8
6/6/2003	22.2	9.2
6/10/2003	32.8	7.7
6/24/2003	34.5	9.8
7/2/2003	59.3	19.0
7/8/2003	344.4	75.4
7/15/2003	264.8	78.5
7/22/2003	198.2	50.8
7/28/2003	236.2	79.4
7/31/2003	181.2	66.3

Table 6. Average number and standard deviations of larval fish collected per light trap for 2002 and 2003 sampling seasons, at Zipper Dike 1 and reference sites for Marmet Pool Larval Fish Survey.

	Zipper Dike 1		High Quality Natural		Low Quality Natural	
Sample Date	Average	SD	Average	SD	Average	SD
6/17/2002	15.7	(2.1)	7.7	(7.2)	17.3	(5.5)
6/25/2002	45.7	(10.7)	3.7	(4.0)	47.0	(21.4)
6/30/2002	200.3	(15.5)	23.0	(13.1)	8.7	(8.0)
7/8/2002	25.7	(3.8)	4.0	(1.0)	3.3	(3.2)
7/15/2002	34.3	(13.6)	10.7	(6.5)	1.7	(2.1)
7/23/2002	2.0	(1.0)	2.0	(1.0)	2.0	(1.7)
7/29/2002	19.3	(18.4)	10.7	(5.5)	6.0	(1.0)
8/1/2002	0.7	(1.2)	0.0	(0.0)	0.7	(0.6)
5/15/2003	41.4	(26.9)	15.2	(12.9)	10.2	(2.6)
5/29/2003	13.2	(5.4)	10.8	(12.9)	9.8	(17.0)
6/6/2003	40.2	(18.1)	20.6	(38.8)	6.0	(6.0)
6/10/2003	24.6	(22.6)	28.2	(29.1)	3.4	(2.6)
6/24/2003	31.8	(52.2)	6.2	(7.3)	0.6	(0.9)
7/2/2003	105.6	(43.9)	61.8	(57.9)	26.6	(6.0)
7/8/2003	678.2	(792.3)	168.6	(53.5)	152.4	(201.0)
7/15/2003	504.6	(475.9)	55.0	(61.8)	30.2	(21.9)
7/22/2003	171.2	(58.1)	30.2	(7.9)	37.2	(58.2)
7/28/2003	401.8	(255.8)	138.8	(36.8)	48.2	(37.5)
7/31/2003	199.6	(208.0)	115.2	(61.7)	155.4	(101.4)

Table 7. Average number and standard deviations of larval fish collected per light trap for 2002 and 2003 sampling seasons, at Finger Dike 1 and reference sites for Marmet Pool Larval Fish Survey.

	Finger Dike 1		High Quality Natural		Low Quality Natural	
Sample Date	Average	SD	Average	SD	Average	SD
6/17/2002	87.3	(94.5)	7.0	(5.2)	12.7	(11.1)
6/25/2002	119.7	(52.5)	8.3	(11.0)	35.3	(22.5)
6/30/2002	205.0	(37.5)	38.7	(24.6)	5.0	(3.6)
7/8/2002	27.0	(16.8)	3.0	(4.4)	0.7	(1.2)
7/15/2002	32.0	(3.6)	6.0	(2.0)	0.3	(0.6)
7/23/2002	0.7	(0.6)	1.0	(1.0)	3.0	(3.5)
7/29/2002	18.3	(23.1)	0.7	(1.2)	1.0	(1.0)
8/1/2002	3.7	(2.5)	4.7	(1.5)	4.7	(4.0)
5/15/2003	9.0	(10.4)	4.8	(5.4)	4.2	(3.7)
5/29/2003	9.2	(5.0)	1.8	(1.3)	3.8	(4.8)
6/6/2003	19.0	(21.2)	5.4	(11.5)	11.8	(23.7)
6/10/2003	8.8	(4.2)	6.6	(4.1)	8.8	(16.0)
6/24/2003	44.6	(34.6)	1.6	(0.9)	1.4	(1.7)
7/2/2003	140.4	(135.7)	66.2	(74.9)	15.4	(26.7)
7/8/2003	140.0	(114.7)	40.8	(52.5)	39.6	(64.2)
7/15/2003	307.2	(244.1)	231.2	(160.9)	14.0	(7.2)
7/22/2003	177.8	(158.8)	88.6	(94.8)	8.6	(9.0)
7/28/2003	204.6	(97.2)	145.0	(66.4)	16.6	(20.9)
7/31/2003	142.0	(171.0)	61.4	(33.8)	11.6	(9.5)

Table 8. Average number and standard deviations of larval fish collected per light trap for 2002 and 2003 sampling seasons, at Finger Dike 2 and reference sites for Marmet Pool Larval Fish Survey.

	Finger Dike 2		High Quality Natural		Low Quality Natural	
Sample Date	Average	SD	Average	SD	Average	SD
6/17/2002	28.0	(29.6)	1.3	(1.5)	16.0	(15.7)
6/25/2002	56.0	(26.2)	2.7	(1.2)	26.0	(19.7)
6/30/2002	177.3	(16.4)	35.3	(33.0)	5.0	(5.0)
7/8/2002	24.7	(8.5)	2.3	(2.5)	8.7	(1.5)
7/15/2002	28.3	(14.3)	8.0	(2.0)	2.3	(2.1)
7/23/2002	2.0	(2.0)	0.0	(0.0)	0.3	(0.6)
7/29/2002	6.0	(1.7)	0.7	(0.6)	3.7	(0.6)
8/1/2002	2.7	(1.5)	2.0	(1.7)	7.7	(4.0)
5/15/2003	4.2	(4.7)	1.2	(0.8)	2.0	(1.4)
5/20/2003	40.0	(32.8)	16.6	(31.5)	4.2	(8.3)
5/29/2003	34.4	(39.1)	1.8	(1.6)	3.6	(2.9)
6/6/2003	63.0	(61.7)	1.8	(2.5)	0.2	(0.4)
6/10/2003	37.6	(30.6)	18.0	(29.8)	17.6	(15.6)
6/24/2003	51.2	(34.8)	4.2	(7.2)	2.4	(2.3)
7/2/2003	329.6	(476.6)	11.4	(10.9)	28.4	(44.7)
7/8/2003	49.0	(27.5)	14.4	(14.2)	27.6	(26.4)
7/15/2003	231.4	(158.4)	15.0	(11.0)	24.8	(28.2)
7/22/2003	234.4	(144.0)	28.4	(44.6)	28.4	(33.2)
7/28/2003	356.2	(383.3)	24.4	(12.1)	18.8	(9.7)
7/31/2003	240.6	(126.5)	55.6	(32.5)	76.8	(75.1)

Table 9. Average number and standard deviations of larval fish collected per light trap for 2002 and 2003 sampling seasons, at Finger Dike 3 and reference sites for Marmet Pool Larval Fish Survey.

	Finger Dike 3		High Quality Natural		Low Quality Natural	
Sample Date	Average	SD	Average	SD	Average	SD
6/17/2002	7.3	(5.6)	7.7	(0.6)	10.3	(7.6)
6/25/2002	55.3	(17.2)	0.7	(0.6)	2.7	(2.9)
6/30/2002	262.0	(91.0)	41.3	(7.8)	10.3	(5.9)
7/8/2002	45.0	(12.1)	2.7	(2.3)	8.7	(0.6)
7/15/2002	37.3	(15.6)	8.3	(5.5)	0.0	(0.0)
7/23/2002	0.3	(0.6)	0.7	(1.2)	1.0	(0.0)
7/29/2002	3.3	(4.0)	0.7	(0.6)	3.3	(4.0)
8/1/2002	1.7	(1.5)	1.0	(1.7)	2.0	(1.0)
5/15/2003	1.2	(2.2)	1.0	(1.4)	no sample	-
5/29/2003	5.6	(2.5)	1.0	(0.7)	6.8	(5.5)
6/6/2003	6.4	(3.6)	1.2	(2.2)	10.6	(10.1)
6/10/2003	45.4	(54.4)	7.2	(8.6)	11.6	(9.5)
6/24/2003	39.2	(14.8)	9.8	(5.3)	16.6	(24.1)
7/2/2003	no sample	-	no sample	-	no sample	-
7/8/2003	159.0	(251.1)	79.8	(92.3)	66.6	(75.1)
7/15/2003	95.2	(53.2)	11.0	(5.7)	5.2	(8.3)
7/22/2003	106.6	(58.8)	63.8	(20.0)	26.2	(26.4)
7/28/2003	64.6	(51.3)	24.8	(16.4)	41.4	(12.5)
7/31/2003	364.8	(310.9)	116.0	(154.0)	32.2	(25.7)

Table 10. Average number and standard deviations of larval fish collected per light trap for 2002 and 2003 sampling seasons, at Finger Dike 4 and reference sites for Marmet Pool Larval Fish Survey.

Sample Date	Finger Dike 4		High Quality Natural		Low Quality Natural	
	Average	SD	Average	SD	Average	SD
6/17/2002	214.0	(151.5)	19.0	(7.2)	34.0	(27.7)
6/25/2002	49.7	(17.8)	4.3	(4.5)	7.0	(7.0)
6/30/2002	280.7	(43.5)	40.3	(21.6)	19.0	(8.7)
7/8/2002	47.0	(26.9)	8.0	(7.2)	4.7	(5.0)
7/15/2002	54.0	(30.3)	12.7	(9.0)	9.0	(2.0)
7/23/2002	24.7	(8.3)	10.0	(2.6)	16.0	(10.8)
7/29/2002	18.0	(6.1)	11.7	(8.1)	5.0	(7.8)
8/1/2002	21.0	(16.5)	15.3	(4.0)	5.3	(3.1)
4/17/2003	7.0	(10.9)	0.8	(0.4)	2.2	(3.2)
5/15/2003	11.8	(9.6)	2.2	(7.9)	12.8	(4.4)
5/29/2003	12.0	(9.1)	22.2	(38.1)	2.8	(2.5)
6/6/2003	61.2	(102.1)	11.8	(16.7)	0.6	(0.9)
6/10/2003	13.2	(7.0)	17.4	(16.5)	1.8	(2.7)
6/24/2003	6.4	(7.4)	6.0	(9.1)	5.4	(3.9)
7/2/2003	574.2	(657.4)	216.6	(238.9)	120.4	(97.9)
7/8/2003	304.2	(339.9)	63.4	(74.7)	25.8	(25.7)
7/15/2003	315.6	(337.0)	160.2	(206.6)	63.8	(46.2)
7/22/2003	233.6	(151.5)	119.2	(233.7)	12.2	(10.4)
7/28/2003	143.4	(98.7)	105.4	(117.5)	12.6	(8.6)
7/31/2003	157.2	(22.4)	116.0	(179.2)	76.2	(32.9)

Figure 16 : Total catch (among all sample dates combined) for light traps within each of the artificial structures, high quality reference and low quality natural reference sites for 2002 and 2003.

Figure 17 : Total catch (among all 5 sites combined) for light traps on each sample date within each of the artificial structures, high quality reference and low quality natural reference sites for 2002 and 2003.

Figure 18 : Catch per unit effort ((total catch per site/ effort) among all sample dates combined) for light traps on each sample date within each of the artificial structures, high quality reference and low quality natural reference sites for 2002 and 2003. Error bars represent 95% confidence interval.

Figure 19 : Catch per unit effort ((total catch per site/ effort) among 5 sites combined) for light traps on each sample date within each of the artificial structures, high quality reference and low quality natural reference sites for 2002 and 2003. Error bars represent 95% confidence interval.

Figure 20 : Overall taxonomic composition (among all sites combined) for each sample date in 2002.

Figure 21 : Overall taxonomic composition (among all sites combined) for each sample date in 2003.

Figure 22 : Overall taxonomic composition amongst artificial structure, high quality natural and low quality natural reference sites for 2002 and 2003.

Figure 23 : Taxonomic composition amongst artificial structure, high quality natural and low quality natural reference sites on each sample date in 2002.

Figure 24 : Taxonomic composition amongst artificial structure, high quality natural and low quality natural reference sites on each sample date in 2003.

Figure 25 : Average *Percidae* (Average *Percidae* catch (total/ effort) among 5 sites combined) for each sample date within each of artificial structure, high quality natural and low quality natural reference sites in 2002 and 2003. Error bars represent 95% confidence intervals. Notice change of y-axis scale from 2002 to 2003.

Figure 26 : Average *Cyprinidae- Pimephales* type (Average *Cyprinidae- Pimephales* type catch (total/ effort) among 5 sites combined) for each sample date within each of artificial structure, high quality natural and low quality natural reference sites in 2002 and 2003. Error bars represent 95% confidence intervals. Notice change of y-axis scale from 2002 to 2003.

Figure 27 : Average *Cyprinidae-Notropis* type (Average *Cyprinidae-Notropis* type catch (total/effort) among 5 sites combined) for each sample date within each of artificial structure, high quality natural and low quality natural reference sites in 2002 and 2003. Error bars represent 95% confidence intervals. Notice change of y-axis scale from 2002 to 2003.

Figure 28 : Average *Lepomis* (Average *Lepomis* catch (total/ effort) among 5 sites combined) for each sample date within each of artificial structure, high quality natural and low quality natural reference sites in 2002 and 2003. Error bars represent 95% confidence intervals. Notice change of y-axis scale from 2002 to 2003.

Figure 29 : Average *Atherinidae* (Average *Atherinidae* catch (total/ effort) among 5 sites combined) for each sample date within each of artificial structure, high quality natural and low quality natural reference sites in 2002. Error bars represent 95% confidence intervals.

Figure 30 : Average *Catostomidae- Catostomini* type (Average *Catostomidae- Catostomini* type catch (total/ effort) among 5 sites combined) for each sample date within each of artificial structure, high quality natural and low quality natural reference sites in 2003.

Figure 31 : Average taxonomic richness (taxonomic richness among 5 sites combined) for each sample date within each artificial structure, high quality and low quality natural reference sites in 2002 and 2003. Error bars represent 95% confidence interval.

Figure 32 : Average minimum and maximum length for larval fish collected at artificial structures, high quality natural and low quality natural reference areas in 2002.

Figure 33 : Average minimum and maximum length for larval fish collected at artificial structures, high quality natural and low quality natural reference areas in 2003.

Figure 34 : Average water temperature (Celsius) at artificial structure and reference sites during 2002 and 2003 sampling dates.

Figure 35 : Mean monthly discharge for 2002 and 2003 compared to historic mean discharge (1877-2002) for the Kanawha River, West Virginia (Data from USGS gage 03193000 Kanawha Falls, WV).

Figure 36 : Catch per unit effort (total catch per site/ effort) for artificial structures, high quality reference and low quality natural reference sites for each 2002 and 2003 sample date in relation to river discharge. Kanawha River Project

Appendix 1

Larval Fish ID Guide

The following is a breakdown of how larval fish from the Kanawha River Project were identified:

Family Catostomidae (Suckers)

- Separated into 2 sub families
- Subfamily Ictioben (includes Carpiodes and Ictiobus genera)
- Subfamily Catostomini (Includes Thoburnia, Catostomus, Moxostoma, and Hypentelium genera)

Family Clupeidae (Herrings)

- Were identified to family level

Family Polydontidae (Paddlefish)

- Paddlefish were identified to the species level (*Polyodon spathula*), as this is the only species in the Kanawha River

Family Lepisosteidae (Gars)

- Were identified to the genus level (*Lepisosteus*) as there as possibly both Longnose and Shortnose Gar species

Family Esocidae (Pikes)

- Were identified to the Genus level of *Esox*

Family Cyprinidae (Carps and Minnows)

- Separated into four groupings
- Pimephales type (includes *Erimystax*, *Macrhybopsis*, *Nybopsis*, *Phenacobius*, and *Pimephales* genera)
- Nocomis type (includes *Camptostoma*, *Nocomis*, *Rhinichthys*, and *Semotilus* genera)
- *Cyprinus* genera (carp were identified to the genus level)
- *Cyprinidae* (includes all other genera not listed above, includes *Clinostomus*, *Ericymba*, *Exoglossum*, *Notemigonus*, *Margariscus*, *Cyprinella*, *Luxilus*, *Lythrurus* and *Notropis*)

Family Percidae (Perches)

- Were identified to the family level
- Of the 13 possible species in the Kanawha River, only eight have complete larval descriptions

Family Centrarchidae (Sunfishes)

- Separated into four groupings by genus
- *Lepomis*

- *Micropterus*
- *Pomoxis*
- *Ambloplites*

Family Ictaluridae (Catfishes)

- Separated into four groupings
- *Ameiurus* genus (Bullheads)
- *Noturus* genus (Madtoms)
- *Ictalurus punctatus* (Channel catfish)
- *Pylodictus olivarius* (Flathead catfish)

Family Moronidae (Temperate basses)

- Were identified to family level

Family Sciaenidae (Drums)

- Were identified to species level

Family Atherinidae (Silversides)

- Were identified to species level

CURRICULUM VITAE

August 2004

JONATHAN M. NILES

Graduate Research Assistant
Fisheries and Wildlife Resources
West Virginia University

PERSONAL INFORMATION

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EDUCATION AND DEGREES

PhD. Forest Resources Science: Fisheries and Wildlife Resources August 2004- present
West Virginia University

Advisor: K.J. Hartman, Ph.D.

M.S. Fisheries and Wildlife Resources August 2001 – August 2004

West Virginia University. "Larval Fish Use of Experimental Rock Structures in the Kanawha River, West Virginia." Advisor: K.J. Hartman, Ph.D. GPA 3.87

B.A. Biology May 2000, St. Mary's College of Maryland. GPA 3.07

RESEARCH INTERESTS

I am a fish ecologist interested in habitat restoration techniques that increase survival and reproduction in fish. My goals are to understand how habitat enhancement: (1) can improve fisheries production (2) mitigate the impacts of pollution and navigation (3) be used to help species of concern.

PROFESSIONAL POSITIONS

1. Environmental Scientist, American Land Concepts, Reisterstown, MD (January 2001 – August 2001).
2. Natural Resource Biologist I, Maryland Biological Stream Survey; Maryland Department of Natural Resources (May 2000 – December 2000).

RESEARCH

Lab skills: Larval fish identification, specimen preservation, fish identification, captive-rearing of fish, benthic macroinvertebrate identification, elastomer tagging, calibration of water quality instruments.

Computer Skills: ArcView, ArcInfo, ArcGIS TM, SAS TM, JMP TM, Program Mark, NTSYSpc, MS Word, MS Excel, MS Powerpoint, and MS Access.

Additional training: U.S. DOI Motor Boat Operator Certification Course (Spring 2002), U.S. DOI Electroshocking Certification (Fall 2001), American Red Cross CPR Certification, American Red Cross First Aid Certification, Federal Driver Certification, Maryland Biological Stream Survey Field Training (Spring 2000), Maryland Stream Waders Benthic Macroinvertebrate Volunteer Training (Winter 2000).

Field skills: Powerboat operation, backpack electroshocking, boat electroshocking, deep water boat electroshocking, boat towing and trailering, radio telemetry, water quality measurements, seining, trawling and trapping techniques, larval fish sampling, Rosgen stream methodology, EPA Rapid Bioassessment Protocols

TEACHING

Biology 103, Graduate Teaching Assistant: Fall 2001 and Spring 2002. Department of Biology, West Virginia University.

Teaching Assistant, Limnology, St. Mary's College of Maryland: Spring 2000

CLASSES TAKEN

Fish Ecology	Statistical Methods I
Spatial Analysis for Resource Management	Statistical Methods II
Environmental Law	Quantitative Ecology
Fisheries Management	Advanced Ichthyology
Fisheries Seminar	Limnology

MEETINGS ATTENDED

American Fisheries Society Annual Meeting, 2004, Madison, Wisconsin
West Virginia Chapter of the American Fisheries Society Annual meeting, 2002, 2003, 2004
American Fisheries Society Annual Meeting, 2002, Baltimore, Maryland
Wildlife Habitat Council 13th Annual Symposium, 2001, Washington D.C.

RESEARCH PROJECTS

1. Larval Fish Use of Experimental Rock Structures in the Kanawha River, West Virginia. Master's Thesis. Wildlife and Fisheries Resources, West Virginia University, Morgantown, WV.
2. A study of imperviousness in Hilton Run, St. Mary's County, Maryland and its impact on biotic integrity. Department of Biology, St. Mary's College of Maryland, St. Mary's City, MD. Research Conducted for: U.S. EPA; Grant # X-983090-01.

PUBLICATIONS

1. Niles, JM, and RW Paul. April 2000. A study of imperviousness in Hilton Run, St. Mary's County, Maryland and its impact on biotic integrity. For: Department of Biology, St. Mary's College of Maryland, St. Mary's City, MD.

PUBLISHED ABSTRACTS

1. Niles, J.M. A study of imperviousness in Hilton Run, St. Mary's County, Maryland and its impact on biotic integrity. In: Paul, R.W. and Tanner, C.E. 2002. The St. Mary's River Project: Preserving Maryland's Legacy, Final Report Year 2. Report to U.S. H.U.D.; Grant # B-00-SP-MD-0450.
2. Niles, J.M. A study of imperviousness in Hilton Run, St. Mary's County, Maryland and its impact on biotic integrity. In: Paul, R.W. and Tanner, C.E. 2001. The St. Mary's River Project: Preserving Maryland's Legacy, Final Report Year 1. Report to U.S. EPA; Grant # X-983090-01.

PAPERS PRESENTED

1. Larval Fish Use of Experimental Rock Structures in the Kanawha River, West Virginia. American Fisheries Society Annual Meeting, 2004, Madison, Wisconsin
2. Experimental Rock Structures as Larval Fish Habitat. West Virginia Chapter of the American Fisheries Society, Morgantown, West Virginia, February 10, 2004.
3. Larval Fish Use of Experimental Rock Structures in the Kanawha River, West Virginia. West Virginia Chapter of the American Fisheries Society, Morgantown, West Virginia, April 24, 2003.
4. Larval Fish Use of Experimental Rock Structures in the Kanawha River, West Virginia. 7th Annual Graduate Student Paper/Poster Event, West Virginia University, Davis College of Agriculture, Forestry and Consumer Sciences. Morgantown, West Virginia, April 24, 2003.
5. Rock Structures as Larval Fish Habitat in the Kanawha River, West Virginia. Wildlife Habitat Council 13th Annual Symposium (Washington D.C.) November 2001.

POSTERS PRESENTED

Rock Structures as Larval Fish Habitat in the Kanawha River, West Virginia.
Wildlife Habitat Council 13th Annual Symposium (Washington D.C.) November 2001.

ACTIVITIES

- Eagle Scout
- West Virginia University Student Chapter of the American Fisheries Society
- American Fisheries Society 3rd Annual Student Colloquium, Organization Committee
- Trout Unlimited
- USA Rugby Level III Certified Coach
- USA Rugby Level I Certified Referee
- President Mon River Mud Lobster RFC
- Coach Mon River High School Men's RFC

SOCIETY MEMBERSHIPS

American Fisheries Society (Student, Education, West Virginia Chapter)
USA Rugby

HONORS AND AWARDS

Wildlife Habitat Council 13th Annual Symposium Scholarship Winner, November 2001

REFERENCES

Professor Kyle J. Hartman, Wildlife and Fisheries Resources, West Virginia University, Morgantown, West Virginia 26506-6125, 304-293-2941 x 2494 Hartman@wvu.edu (Master's and PhD. Advisor)

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