2000

Habitat utilization of fish species on the Ohio River: preliminary development of a multi-metric habitat index

James P. Hawkes

HABITAT UTILIZATION OF FISH SPECIES ON THE OHIO RIVER: PRELIMINARY DEVELOPMENT OF A MULTI-METRIC HABITAT INDEX

Thesis submitted to
The Graduate College of
Marshall University

In partial fulfillment of the
Requirements for the Degree of
Master of Science
Biological Sciences

By

James P. Hawkes

Marshall University

Huntington, West Virginia

December 14, 2000

This thesis was accepted on December 04, 2000

Month Day Year

as meeting the research requirements for the master's degree.

Advisor Dr. Donald Carter

Department of Biological Sciences

Leonard J. Deutsch

Dean of the Graduate College

Table of Contents

ACKNOWLEDGEMENTS

The completion of this work did not come with out a lot of long hours of data collection, entry, analysis, as well as assistance and support of many people. This work is dedicated to those that influenced my life and made me a better person.

I would like to thank, and dedicate this thesis to, my family. Dad, Mom, John, and Sarah, there are many things that you learn to appreciate when you don't have them surrounding you daily. Family is one of them. I appreciate the love, encouragement, and support that you have given me over the years when I was away capturing my dream. I love you all.

Dr. Tarter, there are no words that describe my appreciation for your taking me on as one of your last students. I've learned a great deal in your classes for the simple fact that there was never a dull moment. Your enthusiasm and creativity made learning easy. Every class and conversation was valuable in my development as a biologist. You're a great advisor, teacher, but most of all a great person. Thank you.

I would like to thank the Marshall University faculty, specifically Dr. Pauley and Dr. Strait. Thank you for being a part of my committee and making suggestions that helped to develop this thesis into a quality product.

Erich Emery, and ORSANCO (Bob Ovies, Jerry Schulte, Jeff Thomas, and others), I thank you with the utmost gratitude for the financial support, experience, opportunity, and friendship that you have given me. The confidence in my ability to perform a variety of complex tasks helped me realize what it takes to be professional and do a quality job.

Frank McCormick, I would like to thank you specifically for the time that you took out of your busy schedule and the help you provided. I don't think that things would have run so smoothly without you.

There is no way possible I can thank my lab-mates/friends that I've met in my two years at Marshall. There are many stories that I would like to relay to relive the good times we had, but that would result in a second volume of this thesis! All I can do is list you in recognition: Bob Row, Jamie Blake, Robin Dolin, Terry Tomasek, Kirk Barnett, Tera Rose, Brian Faulknier, Andy Longenecker, Andy Johnson, Sydney Burke, Beth Burdette, Michelle Herrell, Jessica Wooten, Katie Fleer, Heather

Marcum, Jerry Clay, Steve Foster, Mizuki Takahashi, and my north-country buddies Zach Felix, and Rob Fiorentino.

Matt Wooten and Jeff Ginger you were two of the first people that I met arriving at ORSANCO, and the only people that I knew coming to Marshall. You are true friends and I appreciate everything that you did to help me find my niche at Marshall.

Jenn Wykle, I would like to thank you for your friendship; you are someone that I could poke fun at during any given time for any variety of reasons. Thank you.

Ben Lowman and Jason Morgan, you're two great friends. I will miss the fishing, camping, and hiking adventures, as well as your companionship. I hope that we never lose touch, and hopefully take part in other adventures in the years to come. I hope you get a chance to come to Maine and experience a "real" fishery so you can get shut out there as well as you did in your home state!

Lastly, for those of you I may have missed I would like to first apologize, and secondly spread a blanket of thanks. Friendship is something that I consider one of the most important things in a person's life. I am fortunate to have many close friends. I hope that you all keep in touch and remain a part of my life. Oh, by the way, if you're ever in New England look me up!

ABSTRACT

Development of a habitat index requires an understanding of the longitudinal distribution of habitat, fish assemblages, and how the two interact. Because of the complexity and size of the Ohio River, this understanding has not been reached. Habitat analysis has long been considered, and is essential, in assigning impaired and reference condition of habitat quality. The Ohio River is diverse in the distribution of its habitat within pool and river-wide. An Analysis of Variance (ANOVA) was used to analyze these distributions. Within pool assessment of % habitat composition revealed woody cover and vegetation types were significantly greater in the lowest quarter of each pool ($p \leq 0.05$), whereas river-wide, fine sediment types dominate downstream. Distribution of fish species is often dependent on habitat types present. Many studies have been performed to develop a better understanding of the relationship between habitat and fish assemblages in smaller streams, but not in such a dynamic system like that of the Ohio River. In this study, a multi-metric fish assemblage index for large rivers was used to determine the relationship of habitat and fish composition on the Ohio River. Habitat types (sediment, depth, and woody/ vegetation cover) were found to weakly describe fish community variability as much as 19.58% individually (Pearson's correlation analysis) and 25.42% as a composite (stepwise multiple regression) for particular metrics. It was found through analysis this variability was strongly explained by sediment types and depth. The influence of woody cover was minimal as a result of its location in zones assessed. Although the relationships observed were found to be weak, a better understanding of this diverse system's ecology has been made. These discoveries will be useful in the future to develop a predictive model of fish community response to habitat in "optimal" and "degraded" conditions.

CHAPTER I

INTRODUCTION

The Ohio River is a large, complex system that contains very diverse habitats and supports an extreme diversity in fish populations. Little is known about the relationship that exists between fishes and their habitat in this large system. Large rivers have been studied less extensively than small streams and lakes, partly because they are difficult to sample, and also because there is no basis for how large river ecosystems operate (Johnson et al., 1995). In order to assess the quality of a stretch of river below an impact (i.e., point, non-point source, and etc.), an understanding of what ichthyofauna should be observed in "reference" or "least impaired" conditions. Development of a habitat index is necessary to make predictions, or estimate stream potential, but an understanding first must be made of how fish species utilize the habitat in a large complex system like the Ohio River.

There are many variables that could play a part in the distribution of fish species. One of the most important variables may be that of the river-continuum concept. This concept notes physical changes throughout the system from its headwaters to the mouth (Johnson et al., 1995). The Ohio River, although considered a large river, at its confluence possesses some of the characteristics of a headwater in a smaller stream. Coarse substrate consisting primarily of cobble and boulders with a narrow stream width (compared to the lower river) are found in its upper reaches. The habitat downstream includes sand and fines incorporated into the mix of sediment forms with an increased stream width. In the last hundred miles to the mouth, the habitat consists primarily of sand and fines. Not only is the river wider (almost a mile across), but the depth is more uniform and much shallower than the upper section of the river.

Habitat indices have been modified and used to best assess the system being evaluated. In a survey taken by Bain et al. (1999) to assess different forms of habitat evaluation, it was found that sampling methods were mostly suited to wadeable streams, with few applicable to larger rivers. Cost and difficulty of sampling determine variables included in the assessment of a body of water. General measurements that are taken to determine functional relationships with organisms and their physical environment include: flow velocity, substrate composition, water depth, and percent occurrence of in-stream structure (Muhar and

Jungwirth, 1998). Habitat indices are developed with the premise that habitat quality scoring will occur, generally with a theoretical range of "poor" to "optimum" according to physical composition, and/or variable impacts. Once a habitat index has been developed and used, aquatic biota is often sampled to assess their relationship. Fish, the organism of choice for biological surveys, are found near or at the top of food webs, incorporate processes indicating the status of various trophic levels (producers, and consumers) (Harris, 1995), along with being relatively easy to identify (Hocutt, 1981). The Index of Biotic Integrity (IBI)(Karr, 1981), often used in the assessment of water quality, incorporates species richness and composition, trophic composition, fish abundance, and condition. The IBI with slight to moderate modifications has been used to assess streams with various forms of impacts (Shields et al., 1995). This fish index is often modified as in the case of habitat indices to best suit the region, type, or size of river system. The Ohio River, before 1991, did not have any modified form of this IBI to be used in assessing water quality. This was until the Ohio River Water Sanitation Commission (ORSANCO) of Cincinnati, Ohio, in cooperation with academia and biologists at the state and federal levels, started developing a multi-metric fish assemblage index suited for the Ohio River as a part of their biological criteria development (Simon and Emery, 1995). This multi-metric fish assemblage index suited for large rivers will be used to determine if particular sites or sections of the river are performing as expected (river health). These fish assemblage metrics are currently being developed as a driving factor or backbone behind biological criteria development for the Ohio River. This study will help create a better understanding of how habitat is distributed river-wide, and how it is utilized by the fish community.

The purposes of this study are to: (1) determine differences in habitat composition within pools, and river-wide, (2) note the distribution of fish assemblage metrics river-wide in order to establish what longitudinal trends exist, (3) pinpoint any relationships that exist between individual habitat variables and fish assemblage metrics in order to ascertain if the response is expected (positive or negative), and (4) highlight what habitat parameters most influence, or are the best predictors of, the individual fish assemblage metrics.

CHAPTER II

DESCRIPTION OF STUDY AREA

The Ohio River starts at the confluence of the Allegheny and Monongahela rivers. It flows from the confluence of these two rivers at Pittsburgh, Pennsylvania, in a southwesterly direction for the total length of approximately 1,600 km (981 miles) where it empties into the Mississippi River at Cairo, Illinois (Mitsch, 1989) (Fig. 1). The Ohio River basin has a drainage area of 530,000 km^2 (204,000 square miles)(Frost and Mitsch, 1989). The watershed includes parts of 14 states, New York to the Mississippi River.

Before human intervention, the Ohio River had characteristics of smaller rivers and streams with riffles, runs, and pools. This was until the economic value of the Ohio River was realized and dams were constructed to allow for easier transport of large vessels. Twenty high-lift navigational dams were constructed, along with a minimum channel depth of nine feet that is required for transportation vessels (Frost and Mitsch, 1989). Today the river is in essence a series of navigable lakes, which act as a major transport link from the eastern United States to the Gulf Coast. The Ohio River's importance was summed up when it was once referred to as the nation's "Industrial Aorta" (Mitsch, 1989). The Ohio River's physical dimensions include a mean depth of 23.9 feet, an average width of 1947.5 feet, and an average stream flow of 14.4 cubic feet/second (ORSANCO, 1994).

As in the case of many large rivers, the Ohio River has been affected greatly by human activity. The resultant degradation is a primary consequence of accessibility, transportation, and other uses. Many of the cities located along the Ohio River are highly dependent on water quality, because the river is an important source of residential and industrial water. The Ohio River is a source of drinking water for over three million people in the basin (ORSANCO, 1994). Commercial transportation is the primary use of this "aorta". Goods such as coal, timber, iron ore, salt, clay, and oil are shipped along its reaches (Frost and Mitsch, 1989). Various other uses include industry, sink for WWTP overflow, discharge, and recreation.

CHAPTER III

MATERIALS AND METHODS

Fish Population Sampling

Fish population studies were conducted on the Ohio River by means of boat mounted electrofishing surveys. This collection technique is recommended for nonwadeable/large river systems (Yoder and Smith, 1999), and is frequently used by various agencies (Madejczyk et al., 1998; Simon and Emery, 1995).

Fish collections for this study used an 18-ft aluminum John-boat equipped with 12 volt Smith-Root type VI-A boat mounted electrofishing unit. Data collected for this study included one round of electrofishing events at 145 sites sampled between the months of July and October 1991-98.

Electrofishing events began just after dark, and continued until the zones designated were complete. Primary reasons for nighttime surveys are: (1) increased foraging of fishes (greater activity), and (2) better visibility of shocked fish due to reduced glare on the water (Dumont and Dennis, 1997; Sanders, 1992). Six 75-watt floodlights were attached to the bow of the boat, which aided in better visibility of stunned fish as they floated to the surface. Lights and the electrofishing unit were supplied electricity from a 5000-watt gas powered generator. A 10-ft aluminum boom was used to extend a steel ball (source of pulsed DC current) six feet from the bow of the boat. The placement of the boom helped to increase the effective sampling area of the emitted electric current.

The survey area consisted of a 500-meter near shore zone. This "zone" was designated with up and downstream markers using a bright paint or reflectors to identify the two endpoints. The effective sampling field of the emitted electricity unit is 10-15 feet. Therefore, the samples were collected near-shore so shocked fish could easily be seen. Zones were surveyed by maneuvering the boat downstream in a zigzag pattern perpendicular to the shore to ensure a thorough representative sample. All in-stream habitat (submerged logs/trees, stumps, brush, and submerged vegetation) were carefully detailed and all fish were removed that might be utilizing these microhabitats. Isolation of each zone by means of a large net or some other barrier would have been ideal to make collections of all fish in the zone, but this was not feasible because of cost and time. Therefore, data collected in this study is considered a "conservative estimate" rather than a count of the populations (Lehtinen et al., 1997). Time (seconds) was recorded during each event and used in catch-per-unit-effort (CPUE) estimates. Average time for each event was approximately 2,000 seconds.

A sampling crew consisted of three individuals, two netters, and a boat operator. The responsibility of the netter is to collect all stunned fish as they float to the surface. The boat operator can assist in the collection of any fish that are missed by the netter(s) on the bow, but the primary responsibility is maneuvering the boat. Once netted, fish were placed into a 55 gallon aerated tub so they could be processed and released alive at the end of each event. At the completion of each electrofishing event fish were identified to species, weighed (to nearest gm), measured (to nearest mm), and released. Unidentifiable specimens were preserved and identified at a later date.

Classification of Fish Species for Analysis

Data from fish species collection was classified into metrics that described structural and functional aspects of the Ohio River fish assemblage. The metrics included are the following:

Total Number of Species

Number of Sucker Species

Number of Centrarchid Species

Number of Great River Species

Number of Intolerant Species

Percent Tolerant Individuals

Percent Simple Lithophils

Percent Detritivores

Percent Invertivores

Percent Top Piscivores

CPUE (Catch Per Unit Effort estimates)

Habitat Assessments

For this study, 145 habitat surveys were conducted for the sites where electrofishing events occurred.

Measurements of habitat in each 500-m zone consisted of six groups recorded at points 0, 100, 200, 300, 400, and 500-meters along the shore. For each of these six points 11 measurements of depth and sediment were taken at 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100 feet from shore.

Sediment types were classified by a modified version of the Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers (EPA, 1999). This modified index classified sediment in the following ways: boulders >10″, cobble 2.5-10″, gravel 0.1- 2.5″, sand/fines 0.004-2mm, and hardpan. Sand and fines were combined due to the difficulty of distinguishing between the two sediment types. A copper pipe was used for sediment assessment; this

20-ft, 1-in diameter copper pipe was marked off in one-foot sections to get accurate estimates of sediment and measurements of depth. After multiple practice runs were made to determine if estimates were accurate, sediment data were recorded based on feel and sound. Sediment type was estimated by probing the substrate three to five times with the rod. If the depth exceeded 20 feet, a Hummingbird depth finder was used to take measurements, but sediment was not recorded.

Once sediment and depth measurements were completed in the 500-meter zone, estimates were made of vegetation and woody cover. These estimates were: percent overhanging vegetation, percent brush, percent stumps, percent fallen trees and logs, and percent submerged vegetation. Estimates were made for 100-meter segments, then an average was calculated for the zone. Estimates were made due to the fact other methods are either not available, time consuming, or too expensive (Wang et al., 1996). All estimates and measurements were taken by the same crew to prevent any variability in the sampling results.

Within Pool, and River-wide Analysis of Habitat

A General Linear Model (ANOVA) was used to assess the different relationships or trends that exist within pools and river-wide in regard to habitat.

Within pool assessment was performed by dividing pools into quartiles. The test of the null hypothesis is:

$$H_o: \mu_{\text{first quartile}} = \mu_{\text{second quartile}} = \mu_{\text{third quartile}} = \mu_{\text{fourth quartile}}$$

River-wide assessment was made by dividing the river into three sections. To assess river-wide variability sites were assigned to upper (river-mile 0-341), middle (river-mile 341.4-606.8), and lower (river-mile 606.9-981) segments (Pearson and Krumholtz 1984). Comparisons were made to determine differences in habitat composition river-wide testing the null hypothesis:

$$H_o: \mu_{\text{upper}} = \mu_{\text{middle}} = \mu_{\text{lower}}$$

Correlation Analysis

Pearson's product moment correlation was used in this analysis to determine the nature of the relationship (+/-) and how strong (r = correlation coefficient, and description of variabiltiy = r^2) the relationships observed are between the fish assemblage metrics, river-mile, and habitat data. Through this assessment it will be determined how the fish assemblage metrics respond (positively, and negatively) and how much variability is explained by individual habitat parameters. River-wide data were used to derive correlation results.

<u>Stepwise regression analysis</u>

Forward stepwise multiple regression analysis was used to rank each habitat parameter versus each fish assemblage metric. This form of analysis takes each independent variable (habitat) and enters it into a regression model ($y = B_0 + B_1 * X_3 + B_2 * X_1 + B_3 * X_4 \ldots$.) to determine how it influences the dependant variable (fish assemblage metric)(Statsoft, 1999). This "stepwise" process takes each independent variable and enters it one at a time, ranking it in the order of its influence. This analysis will help to further the findings of habitat's influence in describing the variability of fish communities (fish assemblage metrics), and how good of a predictor these variables are.

CHAPTER IV

Results

Within Pool Assessment of Habitat

In the 145 sites assessed, there were no significant within pool differences in depth or sediment types. Woody cover and submerged vegetation were significantly different ($p \leq 0.05$) (Table 1). Differences are found between the lowest quarter and the upper three-quarters of each pool in percent composition of brush (1^{st} = 0.33%, 2^{nd} = 1.27%, 3^{rd} = 1.58%, and **4^{th} = 4.57%**), stumps (1^{st} = 1.46%, 2^{nd} = 0.56%, 3^{rd} = 2.37%, and **4^{th} = 10.59%**), and submerged vegetation (1^{st} = 0.38%, 2^{nd} = 0.14%, 3^{rd} = 0.51%, and **4^{th} = 3.34%**). Percent submerged logs and trees were found to be dissimilar between the upper half and lowest quarter of each pool (1^{st} = 1.30, 2^{nd} = 1.03, 3^{rd} = 4.84, and **4^{th} = 8.52**).

River-wide Assessment of Habitat

Sediment types were found to be significantly different ($p \leq 0.05$) among river segments (Table 2). Percent vegetation parameters showed significant differences in all three sections of the river. Mean percentage of overhanging vegetation for the upper, middle, and lower thirds of the river were 6.67, 0.75, and 3.96, respectively. Submerged vegetation showed the highest mean occurrence in the middle third (2.49), while upper (0.89), and lower (0.16) sections of the river followed in order of their mean percent composition. Gravel significantly decreased in percent composition between the upper and lower thirds of the river. The upper third had a mean of 32.87% while the lower third 16.32% (a 50.35% decrease in mean percent composition). Sand and fines showed a significant increasing trend in percentages downstream from 57.91% (upper third) to 77.21% (lower third) which accounted for a 33.33% increase in mean composition downstream.

Correlation Analysis

-River-wide Assessment of Fish Assemblage Metrics-

The result of river-wide correlation of fish assemblage metrics vs river-mile showed significant trends in nine of the eleven fish metrics, with one positive and eight negative relationships observed (Fig. 2). River-mile was positively correlated with % top piscivores ($p = 0.0087$), and negatively correlated with number of sucker species ($p \leq 0.0001$), % invertivores ($p \leq 0.0001$), CPUE ($p = 0.0408$), number of great river species ($p = 0.0410$),

% simple lithophils ($p \leq 0.0001$), number of intolerant species ($p = 0.0001$), % tolerant species ($p = 0.0001$), and total number of species ($p = 0.0003$). Metrics that did not show significant trends were number of centrarchid species ($p = 0.1954$) and % detritivores ($p = 0.0904$).

-Habitat vs Fish Assemblage Metrics-

Fish assemblage metrics were weakly correlated with many habitat variables (Table 3).

Sediment

Significant relationships were observed by five of eleven fish metrics with substrate types. Only two of the three coarse substrate types (cobble, gravel) were found to have significant relationships ($p \leq 0.05$) with an r value greater than 0.20. The only fish assemblage metric to have a negative response to the coarse substrate types was % top piscivores vs % gravel. Percent sand and fines, the only fine sediment variable recorded, was found to have a significant negative correlation with three of eleven fish assemblage metrics and one positive, as well as the strongest, relationship observed (% intolerant species vs % sand and fines, $r = - 0.4425$).

Woody Cover and Vegetation

There was only one significant correlation observed with woody cover and vegetation with an r value ≥ 0.20. This trend observed was total number of species vs % overhanging vegetation, a positive relationship. Also, no one woody cover or vegetation variable was observed to explain more than 4.58% of fish assemblage metric variability (Table 3). Because of these results, further analysis was conducted to determine why the fish metrics did not show any strong relationships with woody cover and vegetation variables. Through this analysis it was discovered woody cover was found to be associated with shallow depths and fine sediment types (Figs. 3, 4).

Percent stumps were found to occur in water as deep as six feet but the majority of the observed composition was found in depths between zero and two feet. Percent submerged logs and trees were found to have a mean depth as much as 15 feet, but the most frequent occurrence was found to be from zero to four feet. Percent brush and % submerged vegetation did not fare any better with depths found no deeper than four and a half feet with the majority at the zero to three foot range.

The next step in the investigation was to determine what sediment forms are present with the cover type estimates. Using a Pearson's product moment correlation, running woody cover and vegetation types vs sediment, five significant trends were observed (Fig. 4) -- three positive and two negative. The positive trends observed were % stumps vs % sand and fines ($p = 0.0118$), % submerged logs and trees vs % sand and fines ($p = 0.0016$), and % stumps vs % hardpan ($p \leq 0.0001$). The negative is % submerged logs and trees vs % gravel ($p = 0.0022$) and % stumps vs % gravel ($p = 0.0043$). These results might help to better explain why fish communities did not respond to these forms of habitat.

Depth

Average depth had a significant positive relationship with three of the eleven fish assemblage metrics, while standard deviation was found to have a positive relationship with four (Table 3).

Because depth measurements are a direct result of sediment formation on the river bottom, further comparisons were run to determine what trends exist between sediment and depth and how they relate to each other (Figs. 5, 6).

Of the five sediment types, only three where found to have a significant correlation with depth, two being positive and one negative (Fig. 5). Positive relationships vs average depth were found between % boulders ($p = 0.0004$)

and % cobble (p = 0.0001). The negative relationship observed was found with % sand and fines (p = 0.0062). Through this analysis it is determined that sand and fines are associated with shallow areas, while boulders and cobble are more likely to be found in deeper areas.

As for the standard deviation analysis, the relationships were found to be similar in significant comparisons (Fig. 6). The positive relationships observed vs standard deviation of depth are % boulder (p = 0.0042) and % cobble (p = 0.0015) % sand and fines were again found to possess a negative relationship (p = 0.0371) which tells me that as % sand and fines increase the deviation of the zone depth decreases. These results help to clarify the depth formation in the presence of these sediment types and homo- or heterogeneity of the river bottom. The greater the deviation of depth, the more likely the diversity of habitat is experienced.

Stepwise Regression Analysis

In-stream habitat in the form of sediment types, woody and vegetation cover types, and depth, at most explained 19.58% of fish assemblage metric variability (Table 3). Therefore, a stepwise multiple regression was run to determine if combined independent habitat variables will better explain the variability of fish assemblage metrics so predictions can be made (Table 4). The result of the stepwise regression model helped to explain more of the variability for most of the fish assemblage metrics, but not significantly. As in the case of the Pearson's product moment correlation analysis, sediment types and depth appear to be the most influential in being able to predict, or best explain, the variability of each fish assemblage metric. The models helped to explain 18.12% of the number of centrarchids, 25.42% of the number of intolerant species, and 19.70% of invertivores metrics. Habitat variables that may not have been significant in the Pearson's product moment correlation were found to influence the models as much as 4.73% (as in the case of % overhanging vegetation vs number of intolerant species).

CHAPTER V

Discussion

Within Pool, and River-wide Analysis of Habitat

Within pool and river-wide assessment of habitats showed significant differences in woody cover, vegetation, and sediment types (Table 1).

Within pool comparisons found the last quarter or section of pools to have the highest mean percent composition of woody cover and submerged vegetation. This within pool scenario is likely a result of the navigational dams, which have had a significant influence on the velocity of the river. When a dam is built and there is an altering effect on flow of sediment and water, habitat will change—sometimes drastically (Ligon et al., 1995). As a result, present conditions of the Ohio River are deeper and slower than they once were (ORSANCO, 1994). This has resulted in the lower end, or last quarter of these pools to be more lentic, or lake-like for a majority of the year, rather than lotic or free-flowing conditions. This lake-like morphology has resulted in a buildup of woody debris and growth of vegetation that will likely remain until a flood event occurs, thus reshaping the physical habitat.

River-wide results found significant differences in vegetation (overhanging and submerged) and sediment types (Table 2). It would be expected overhanging (riparian) vegetation would decrease traveling downstream, but this was not the case. The greatest overhanging vegetation in mean composition was found in the upper third of the river followed by the lower and middle. Because overhanging vegetation was found in such low amounts river-wide, it is hard to determine if composition estimates are accurate. These estimates may be inaccurate although the same crew was used in assessing sampling sites. It is often hard to make visual estimates of % composition for one site, as well as 145 sites river-wide. Wang et al. (1996) addressed the issue of accuracy in the evaluation of three southern Wisconsin streams; they noted "even when estimates are similar among observers, habitat values may be biased. Because of the difficulties of obtaining unbiased habitat values, the accuracy of visual habitat estimates has not been extensively investigated". The ability to QA/QC composition estimates does not currently exist and may explain the random jump in the estimation values observed during this study.

Percent submerged vegetation showed the highest mean % composition in the middle third of the river. This result is deceiving because a small number of sites possessed submerged vegetation (n = 20 of 154 sites, 13 upper, 5 middle, and 2 in the lower river). It would be expected that the vegetation presence would be much greater in a large, slow-flowing, regulated system like the Ohio River. Dams reduce the turbidity downstream and create conditions that would be considered ideal for aquatic plant abundance (Johnson et al., 1995). The Ohio River may not abide by these principles because it is unlike any other large system. What makes this river unique is dam influence as well as the large tributaries that feed it, especially during rain events. These rain events create runoff into small streams that eventually feed the Ohio River resulting in high turbidity. Occurrence of these events may be frequent enough to prevent light penetration required for significant aquatic plant growth. Another influence comes in the form of boat traffic. Everyday, millions of tons of cargo are transported along the Ohio River's reaches. Barges transporting these goods create wakes, or wave action, that is enough to stir up sediment, and create an environment that may not allow significant plant colonization and growth to occur.

Sediment results showed significant differences between up and downstream composition of % gravel and

% sand and fines. These two sediment variables are the most likely to change river-wide or show a trend due to the response of the river's hydrology or flood events. According to Gore and Shields (1995), the overall distribution of substrate particles is related to frequency and magnitude of flood events. Unlike smaller sediment types, boulders, cobble, and hardpan change little over time and are not likely to have a longitudinal distribution river-wide as a result of the river's hydrological forces.

Correlation Results

-Fish Assemblage Metrics vs River-Mile-

The results of the longitudinal trends of fish assemblage metrics showed nine significant correlations with river-mile (one positive and eight negative) (Fig. 2). These findings were found to contradict some of the findings in a similar study by Horwitz (1978) where, in 15 United States rivers, species diversity was found to increase traveling downstream. Also, it was found feeding guild metrics showed increasing trends down-stream in diversity. Fish assemblage metrics: total number of species, number of sucker species, and number of centrarchid species metrics were found to either decrease in diversity or stay constant (Fig. 2). For feeding guild trends, it is hard to determine species diversity using fish assemblage metrics because they are measured in % composition, and Horwitz (1978) was found to use counts of individuals. It is observed that the % composition was found to decrease in two of the three feeding guild metrics, with % top piscivores responding positively. It would be expected a metric like % invertivores to drop off with less than adequate conditions created by increased sands and fines traveling downstream (Table 2), but not by % detritivores which was found to show no trend. This is unexpected because this metric should increase with increasing sand and fines observed. Tolerance (number of intolerant individuals, and % tolerant), and % simple lithophils metrics, were found to drop off in numbers or exhibit no change for the length of the river.

-Habitat vs Fish Assemblage Metrics-

It was demonstrated through analysis significant relationships exist between fish assemblage metrics and habitat variables especially in the form of sediment and depth (Table 3).

Sediment

Sediment types cobble, gravel, sand and fines were found to show significant trends. A majority of fish assemblage metrics responded positively to cobble and gravel sediment types with one negative relationship observed. The majority of the response was expected because the coarse substrate is considered a "positive" habitat parameter. These coarse sediment types are considered positive because they provide diverse habitat that is utilized readily by macroinvertebrate and fish communities. Habitat provided by these substrate types (boulder, cobble, gravel) provides lotic species with interstitial space used for egg deposition (i.e. simple lithophils), nursery area, refuge (predation, current), and feeding.

When referring to sand and fine sediment types the word "positive" is not readily used. These fine sediment types are often associated with low flow, homogenous, shallow flats along the length of the Ohio River (Figs. 5,6). These areas of increased sedimentation are often associated with degradation of fish communities in warm and cold water streams. Most of the cause being attributed to the loss of spawning habitat, lowering of interstitial dissolved oxygen, loss of habitat space, and reduction of benthic production (Rankin, 1995). Macroinvertebrates, a significant part of the forage base, are often a driving factor behind many fish communities. These macroinvertebrate communities for the most part are found to be diverse, and abundant in stable sediment types. Although, some species of ephemerid mayflies (*Hexagenia* sp., *Ephemera* sp.) and many genera of the family Chironomidae are found to inhabit softer sediment types (Merritt and Cummins, 1996), these areas are often found to be reduced in abundance and richness (Gore and Shields, 1995). It would be expected that the fish community would respond negatively with exception of species that possess specialized trophic guilds requiring increased amounts of sand and fines. Although the % detritivores metric did not respond as strongly as expected, other observations were made according to assumptions. Percent invertivores showed a strong negative response to the sand and fine sediment type, which is expected because the provided habitat is not conducive to their food base. Likewise, % simple lithophils were negatively correlated with sand and fines because this habitat is not beneficial to their life history requirements. In fact, it has been found numbers of lithophilic spawners decrease with decreasing amounts of interstitial pore space (Simon and Emery, 1995).

Woody Cover and Vegetation

Woody cover and vegetation results showed only one fish metric to have significant correlation (Table 3).

This finding was not expected because, a significant positive relationship exists between fish and woody cover or vegetation types. Lehtinen et al. (1997) found significant differences between woody snags and control sites on the upper Mississippi River, with more piscivores, invertivores, and prey fishes at the snag sites compared to the control. Through further investigation into this lack of expected response, it was discovered these woody cover types were found to be common on shallow sand and fine flats (Figs. 3, 4). These findings are significant because the presence of woody cover is nullified by the depth and sediment composition as a contributing habitat influence that normally would be associated with increasing fish community. Through earlier investigation it was found the presence of sand and fines had a negative effect on fish community. Now, it is observed even in the presence of woody cover the fish community does not respond. Another reason why woody cover results are not what would be expected could be attributed to accuracy of estimation results.

Depth

Depth (average and standard deviation) was found to have a number of significant correlation responses, and is considered to be a positive metric as well. Depth measurements, considered a form of cover have been noted to increase community diversity (Gorman and Karr, 1978), promote habitat partitioning of species (Newcomb et al., 1995), and the source of refuge (Goddard and Mathis, 1997). It was observed that average depths were found to be greater in boulder and cobble sites than in sites with significant composition of sand and fines. The greatest deviation of depth also was found to be positively associated with increasing amounts of boulder and cobble. Likewise, it was found sites dominated by sand and fines had little deviation, or found to be homogenous in composition. The complexity of the zone is influenced heavily by how variable the river bottom is.

Stepwise regression analysis

Driving factors behind fish assemblage metric variability although weak appeared in the form of sediment and depth primarily.

Total Numbers of Species results were similar to that of Gorman and Karr (1978). They discovered fish communities of a stream segments are characterized by complexity of habitats present. This explains why standard deviation of depth was found to be the best descriptor of this metric (Table 4). Variability of depth in this case means a more diverse riverbed in the form of boulders and cobble present which intern results in habitat diversity (Fig. 6). Diversity in the river's habitat can result in habitat specific fish populations, which may cause species shifts that have specific habitat requirements. Observing variable forms in substrate types in a small area can make it easy to determine how diverse a habitat type is. Areas with high amounts of fine sediments are more than likely not going to express this diversity. So an increase in species diversity should be expected with habitat diversity.

Number of Sucker Species metric is best explained by % gravel composition. This relationship is expected because it has already been observed that distributions of sucker species exist on the Ohio River. Emery et al. (1999) found round bodied suckers to be more common in the upper reaches of the Ohio River. This was attributed to breeding ground availability in tributaries. Gravel distribution river-wide might also play a role in this distribution pattern. Sucker species significantly drop off at river-mile 450 (Emery et al., 1999)(Fig. 2). Sucker species have a greater affinity for the upper river and coarse substrate as shown by an increase in species richness. As amounts of sand and fines increase downstream (Table 2), the sucker species metric decreases as well (Fig. 2). This drop-off in species composition is likely attributed to poor habitat for reproductive and feeding requirements of these species (Emery et al., 1999).

Number of Centrarchid Species was best described by average of depth for species composition, followed by stumps, hardpan, and boulders on the Ohio River. These findings are supported by two studies. Goddard and Mathis (1997) found that the longear sunfish have a preference of depth over cover for refuge in a laboratory setting. Newcomb et al. (1995) observed different uses of habitat by various year classes of smallmouth bass on three West Virginia rivers. Use of boulder, cobble, and bedrock was variable ranging from protection against predation and current to forage base potential. This diverse family of fishes encompasses a variety of species with different requirements. Black bass species *(Micropterus* spp.) are found to be dependent of habitat and predatory in all stages of their life cycles. Many sunfish (*Lepomis* spp., *and Pomoxis* spp.) species are invertivores, or lesser predators and require specific habitats as well. It would be assumed different habitat requirements exist between species and life-stages. With an even distribution of this metric river-wide, an expected score of centrarchids might be easy to assign. This could come in the form of a general habitat expected score instead of one that is habitat specific.

Number of Great River Species did not show a significant relationship with any of the habitat variables. This result is likely attributed to the composition of species frequently caught during fish population surveys. A majority of these species lack habitat requirements and are primarily found to be pelagic or free swimming in the water column, while the species that do have habitat requirements are less frequently caught. Paddlefish, a species of this metric, was observed by Zigler et al. (1999) to travel great distances and have diel movement from deep water during the day (>6-meters) to shallow (>2-meters) at night on the upper Mississippi River. Other species included in this metric that would be considered pelagic are shortnose gar, skipjack herring, mooneye, and goldeye. Habitat generalists include catfish species and bowfin (Pflieger, 1975). Remaining species in the list have specific habitat requirements that come in the form of substrate, flows, or stream size. These species are: channel darters, river darters, ghost shiner, river shiner, blue sucker, and the Mississippi silvery minnow (Page and

Burr, 1991). Again because of the low occurrence of these species it may be hard to observe trends.

Number of Intolerant Species had the highest explained variability of all the fish metrics by habitat (Table 3). Percent sand and fines were the most influential metric in describing fish assemblage variability. This finding helps to explain the river-wide distribution observed for this tolerance guild, with increasing % sand and fines lesser numbers of intolerant species are observed. These findings back up an assumption by Karr (1981) in which he stated the number of intolerant species will decline with decreasing water quality, habitat degradation, or a combination of the two resulting in high amounts of suspended solids producing increased amounts of siltation. Species described by Karr (1981) are different in composition, but there is the same underlying principle developed for the fish assemblage metrics.

Percent Tolerant Individuals showed no significant relationship with habitat. This was expected because many of these species are generalists in regard to feeding and habitat requirements as well as their ability to live in less than favorable conditions. It would be expected % tolerant individuals would increase in the presence of human disturbance because of their ability to thrive in poor conditions. The trend river-wide showed the metric to decrease with river mile. Major metropolitan areas with human influence are found in the upper river (Fig. 2).

Percent Simple Lithophils was found to have the most variability explained by % sand and fines. This metric is directly related to habitat quality, specifically sediment. Lithophilic egg deposition according to Balon (1975) uses rock or gravel substrate for the embryos to develop, occurring in streams, rivers, and oligotrophic lakes. Thus, it would be expected the % composition to be greatest in the upper river where low amounts of siltation are present and more boulder, cobble, and gravel exist. This was found to be the case where % composition decreased traveling downstream (Fig. 2) as sediment changed from gravel in the upper river, to sand and fines in the lower river. The next most descriptive habitat types were found to be % boulders followed by standard deviation of depth. These habitat types are common in the upper-river and are associated with areas of low siltation.

Percent Detritivores was another fish metric that had no significant habitat contribution. It was found that % sand and fines best describe the fish community, but not significantly (Table 4). It would be assumed that a stronger relationship between fish and fine sediment types would exist, but this was not the case. Maderjczyk et al. (1998) observed quillback carpsuckers and gizzard shad (two fish in the % detritivores metric) along with other species to prefer bare shallow shoreline to other forms of habitat. Quillback, river, and highfin carpsuckers, gizzard shad, common carp, goldfish, white suckers, fathead, and bluntnose minnows were found in this metric. It is not understood why this metric did not increase in abundance downstream. Generally, species in this metric are expected to be in greater abundance in degraded habitat conditions.

Percent Invertivores is another metric that requires the interstitial space provided by boulder, cobble, and gravel for refuge, and forage (Greenberg, 1991), as well as woody cover (Lehtinen et al., 1997). Percent sand and fines were the best predictor of this fish assemblage metric. With increasing sand and fines there has been noted a decrease in macroinvertebrate communities. It would be presumed that this feeding guild metric dependant on macroinvertebrates would follow this negative trend (Fig. 2).

Percent Top Piscivores is a metric that did not perform as expected in terms of being described by habitat. This metric should be considered as dependent of habitat as the centrarchid metric because a significant part of this metric's composition is made up of this family. Percent sand and fines was the only significant influence of habitat observed, unlike the response of other metrics this was a positive relationship. The positive relationship with sand and fines could be explained in that these species are primarily free swimming in the water column in search of forage fish. Piscivores may be found to be associated with the sluggish, turbid waters found in the lower river (Fig. 2). Species in this metric are also found in greater numbers in the lower river thriving in conditions with high turbidity. Examples of fish that thrive in these conditions are the bowfin (Pflieger, 1975), and shortnose gar (Etnier and Starnes, 1993). Other species that do not have particular habitat preferences and are found to be pelagic for the most part, are the skipjack herring, striped bass, white bass, and longnose gar (Pflieger 1975). Because this metric's variability was only described by one habitat parameter, it might be necessary to investigate further into the habitat fish relationship.

CPUE did not have any significant contribution from habitat to help explain the metric variability. The river-wide distribution may explain the lack of significance (Fig. 2). Throughout the entire river there was little difference observed in catch per unit effort estimates. My findings agree with Madejczyk et al. (1998) in comparing sites with more structure to sites with bare shore in that the CPE (Catch-Per-Effort) estimates were found to be similar on the upper Mississippi River. Therefore, it is hard to associate a trend to a particular habitat type. Unlike the total number of species metric CPUE counts all individuals during events surveyed. This metric can be significantly influenced by a large number of a particular species (i.e. gizzard shad, emerald shiners). Even a degraded site with poor diversity has the ability to score well.

CHAPTER VI

Conclusions

(1) Percent composition estimates for habitat were observed to vary within pool and river-wide.

(2) Trends were observed for fish assemblage metrics river-wide, with the majority decreasing downstream.

(3) The relationship of habitat and fish assemblage metrics was found to be weak, but best described by sediment, and depth variables.

(4) By combining habitat variables (through stepwise regression analysis) it was observed that more variability of the fish community was explained, but not substantially.

(5) The trends observed between habitat and the fish assemblage metrics although weak, were what we would expect.

LITERATURE CITED

Bain, M.B., Hughes, T.C., and Arend,K.K. 1999. 'Trends in methods for assessing freshwater habitats', Fisheries, 24, 16-21.

Balon, E.K. 1975. 'Reproductive Guilds of Fishes: A Proposal and Definition', J. Fish. Res. Board Can., 32, 821-864.

Dumont, S.C, and Dennis, J.A. 1997. 'Compairison of day and night electrofishing in Texas reservoirs', N. Amer. J. Fish. Mang., 17, 939-946.

Emery, E.B., Simon, T.P., and Ovies, R. 1999. 'Influence of the Family Catostomidae on the Metrics Developed for a Great River Index of Biotic Integrity' in Simon, T.P.(Ed), *Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities.* CRC, New York, pp 203-223.

EPA. 1999. *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, Periphyton, Benthic Macroinvertebrates and Fish 2nd Ed.* EPA 841-B-99-002, Washington, DC.

Etnier, D.A., and Starnes, W.C. 1993. *The Fishes of Tennessee*. The University of Tennessee Press, Knoxville. pp 681.

Frost, S.L., and Mitsch, W.J. 1989. 'Resource development and conservation history along the Ohio River', Ohio, J. Sci., 89, 143-152.

Goddard, K., and Mathis, A. 1997. 'Microhabitat preferences of longear sunfish: low light intensity versus Submerged cover', Environ. Biol. Fish., 49, 495-499.

Gore, J.A., Shields, F.D.Jr. 1995. 'Can large rivers be restored?', BioSci., 45, 142-152.

Gorman, O.T. and Karr, J.A. 1978. 'Habitat structure and stream fish communities', Ecology, 59, 507-515.

Greenberg, L.A. 1991. 'Habitat use and feeding behavior of thirteen species of benthic stream fishes', Environ. Biol. Fishes, 31, 389-401.

Harris, J.H. 1995. 'The use of ecological assessments', Aust. J. Ecol., 20, 65-80.

Hocutt, C.H. 1981. 'Fish as indicators of biological integrity', Fisheries, 6, 28-30.

Horwitz, R.J. 1978. 'Temporal variability patterns and the distributional patterns of stream fishes', Ecol. Monogr., 48, 307-321.

Johnson, B.L., Richardson, W.B., and Naimo, T.J., 1995. 'Past, present, and future concepts in large river Ecology', Biosci., 45, 134-141.

Karr, J.R. 1981. 'Assessment of Biotic Integrity using Fish Communities', Fisheries, 6, 21-27.

Lehtinen, R.M., Mundahl, N.D. and Madejczyk, C. 1997. 'Autumn use of woody snags by fishes in backwater and channel border habitats of a large river' Environ. Biol. Fishes, 49, 7-19.

Ligon, F.K., Dietrich, W.E. and Trush, W.T. 1995. 'Downstream ecological effects of dams', Biosci, 45, 183-192.

Madejczyk, J.C., Mundahl, N.D. and Lehtinen, R.M. 1998. 'Fish assemblages of natural and artificial habitats within the channel boarder of the Upper Mississippi River', Am. Midl. Nat., 139, 296-310.

Merritt, R.W., and Cummins, K.W. 1996. An Introduction to the Aquatic Insects of North America. Kendall/Hunt, Iowa. pp 862.

Mitsch, W.J. 1989. *The Ohio River, Its History and Environment*. The Ohio Journal of Science, Columbus. Pp 213.

Muhar, S., and Jungwirth, M. 1998. 'Habitat integrity of running waters-assessment criteria and their biological relevance', Hydrobiologia, 386, 195-202.

Newcomb, T.J., Perry S.A. and Perry, W.B. 1995. 'Comparison of habitat suitability criteria for smallmouth bass (Micropterus dolomieu) from three West Virginia Rivers', Rivers, 5, 170-183.

Ohio River Valley Water Sanitation Commission. 1994. *The Ohio River Fact Book*, Ohio River Valley WateSanitation Commission, Cincinnati, Ohio.

Page, L.M., and B.M. Burr. 1991. *Freshwater Fishes.* Houghton Mifflin Co, Boston. pp 432.

Pearson, W.D., and K.A. Krumholtz. 1984. *Distribution and Status of Ohio River Fishes.* ORNL/SUB/79-7831/1. US Department of Energy, Oakridge National Laboratory, Oakridge, Tennessee.

Pflieger, W.L. 1975. *The Fishes of Missouri*. Missouri, Dept. Cons, Jefferson City. pp 343.

Rankin, E.T. 1995. 'Habitat indeces in water resource quality assessments', in Davis, W.S. and Simon, T.P. (Eds), *Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making*. Lewis, Ann Arbor. pp 179-206.

Sanders, R.E. 1992. 'Day versus night electrofishing catches from near-shore waters of the Ohio and Muskingum Rivers', Ohio J. Sci., 92, 51-59.

Simon, T.P., and Emery, E.B. 1995. 'Modification and assessment of an Index of Biotic Integrity to quantify water resource quality in great rivers', Regul. River: Res. Mgmt., 11, 283-298.

Statsoft. 1999. *Statistica(Volume I)*. Statsoft Inc., Tulsa. pp 1001-1878.

Wang, L., Simonson, T.D., and Lyons, J., 1996. 'Accuracy and precision of selected stream habitat estimates. North Amer. J. of Fish. Manag., 16, 340-347.

Yoder, C.O., and Smith, M.A. 1999. 'Using Fish Assemblages in a State Biological Assessment and Criteria Program: Essential Concepts and Considerations' in Simon, T.P.(Ed), *Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities*. CRC, New York, pp. 17-52.

Zigler, S.J., Dewey, M.R., and Knights, B.C. 1999. 'Diel movement and habitat use by Paddlefish in navigational pool 8 of the Upper Mississippi River', North Am. J. Fish Manage., 19, 180-187.

APPENDIX

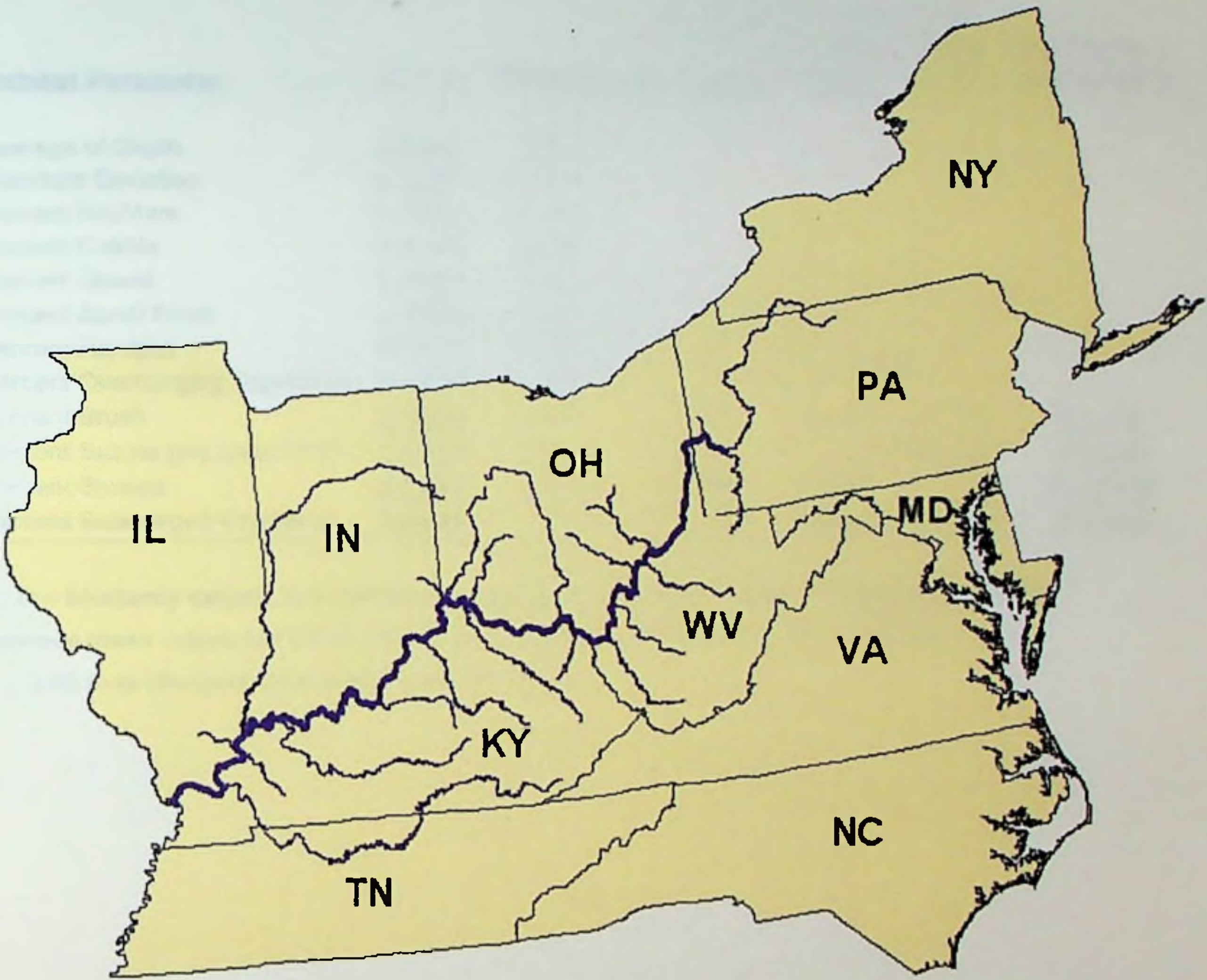

Figure 1. Ohio River Basin

Table 1. General Linear Model (ANOVA)—
Within Pool Comparison of Mean Percent Composition of Habitat Parameters

Habitat Parameter	**Pr > F**	**F-Value**	**Within Pool Comparison** A,B= Similarity Value (Mean Percentage) **1st (Upper)**	**2nd**	**3rd**	**4th (Lower)**
Average of Depth	0.6998	0.48				
Standard Deviation	0.3050	1.22				
Percent Boulders	0.3090	1.21				
Percent Cobble	0.5056	0.78				
Percent Gravel	0.2057	1.55				
Percent Sand/ Fines	0.2942	1.25				
Percent Hardpan	0.3313	1.15				
Percent Overhanging Vegetation	0.1199	1.98				
Percent Brush	**0.0006**	6.21	A (0.33)	A (1.27)	A (1.58)	**B (4.57)**
Percent Submerged Logs/ Trees	**<0.0001**	7.68	A (1.30)	A (1.03)	AB (4.84)	**B (8.52)**
Percent Stumps	**0.0003**	6.60	A (1.46)	A (0.56)	A (2.37)	**B (10.59)**
Percent Submerged Vegetation	**0.0038**	4.69	A (0.38)	A (0.14)	A (0.51)	**B (3.34)**

A, B = Similarity values. If the letters are the same (i.e. A vs A) there is no significant difference between mean values, but if they are different (i.e. A vs B) there is a significant difference at $p \leq 0.05$ level (designated by bold, underlined letters).

Table 2. General Linear Model (ANOVA)—
River-Wide Comparison of Mean Percent Composition of Habitat Parameters

Habitat Parameter	**Pr > F**	**F- value**	**River-Wide Comparison** A,B= Similarity Value (Mean Percentage) **Upper**	**Middle**	**Lower**
Average of Depth	0.3447	1.07			
Standard Deviation	0.1035	2.31			
Percent Boulders	0.4598	0.78			
Percent Cobble	0.1119	2.23			
Percent Gravel	**0.0005**	8.06	A (32.87)	AB (25.58)	**B (16.32)**
Percent Sand/ Fines	**0.0016**	6.79	A (57.91)	A (60.81)	**B (77.21)**
Percent Hardpan	0.4332	0.84			
Percent Overhanging Vegetation	**0.0137**	4.43	A (6.67)	**B (0.75)**	AB (3.96)
Percent Brush	0.1227	2.13			
Percent Submerged Logs/ Trees	0.2942	1.23			
Percent Stumps	0.2929	1.24			
Percent Submerged Vegetation	**0.0033**	5.98	AB (0.89)	A (2.49)	**B (0.16)**

A, B = Similarity values. If the letters are the same (i.e. A vs A) there is no significant difference between mean values, but if they are different (i.e. A vs B) there is a significant difference at $p \leq 0.05$ level (designated by bold, underlined letters).

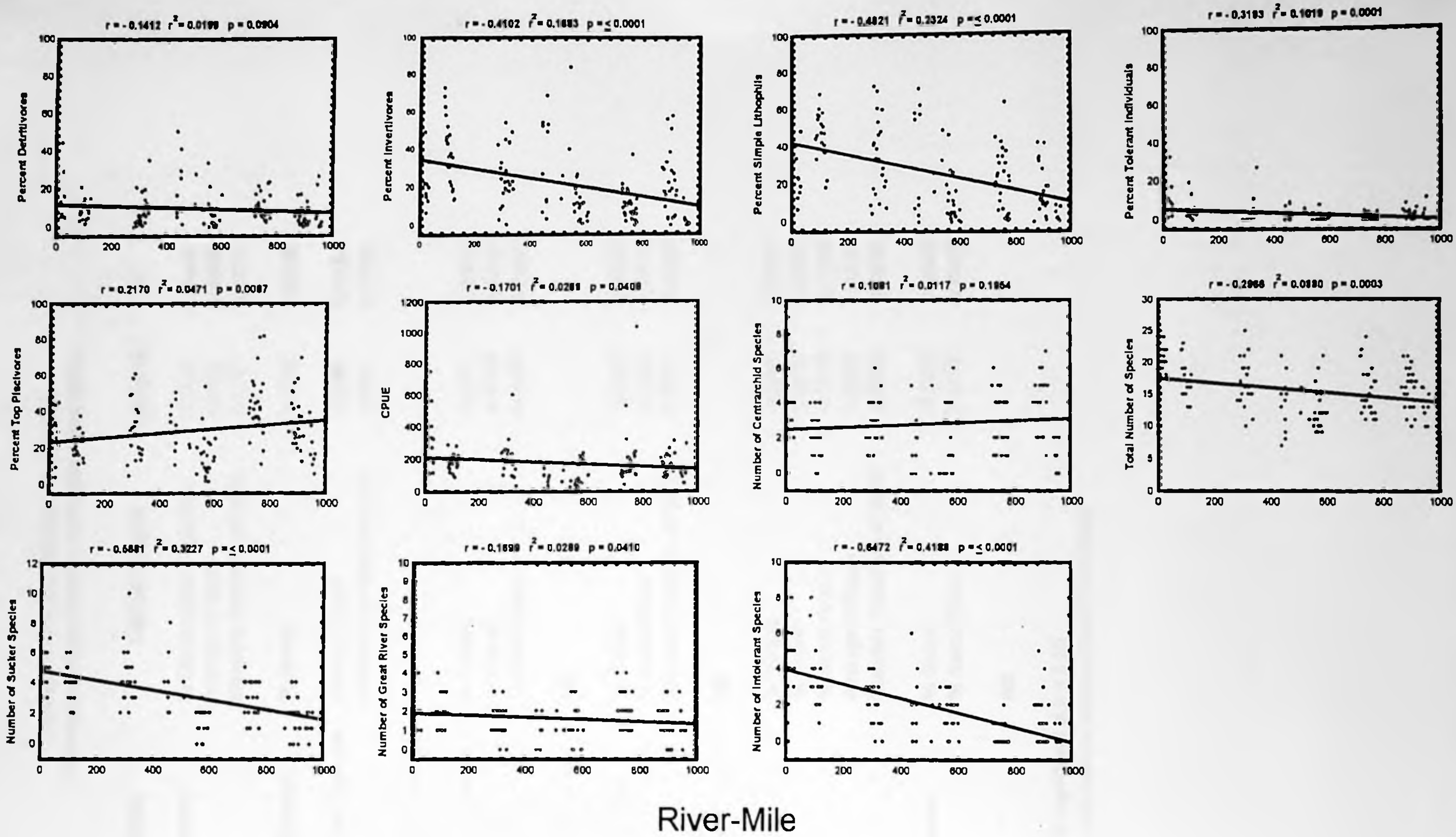

FIGURE 2. Fish Assemblage Metrics vs River-Mile

Table 3. Pearson's Product Moment Correlation – Fish Assemblage Metrics vs Habitat Parameters

Fish Assemblage Metric	Habitat Variable	Pearson's r	r^2
Total Number of Species	% Overhanging Vegetation	0.2140	**0.0458**
	Average of Depth	0.2163	**0.0468**
	Standard Deviation of Depth	0.2387	**0.0570**
Number of Sucker Species	% Gravel	0.2118	**0.0448**
Number of Centrarchid Species	Average Depth	0.3456	**0.1194**
	Standard Deviation of Depth	0.3384	**0.1145**
Number of Great River Species	NS		
Number of Intolerant Species	% Cobble	0.2371	**0.0562**
	% Gravel	0.4113	**0.1692**
	% Sand/ Fines	-0.4425	**0.1958**
Percent Tolerant Individuals	NS		
Percent Simple Lithophils	% Gravel	0.2456	**0.0603**
	% Sand/ Fines	-0.2791	**0.0779**
	Standard Deviation of Depth	0.2061	**0.0425**
Percent Detritivores	NS		
Percent Invertivores	% Cobble	0.2361	**0.0557**
	% Gravel	0.2985	**0.0891**
	% Sand/ Fines	-0.3578	**0.1280**
	Average of Depth	0.2877	**0.0828**
	Standard Deviation of Depth	0.2562	**0.0656**
Percent Top Piscivores	% Gravel	-0.2120	**0.0449**
	% Sand/ Fines	0.2149	**0.0462**
CPUE	NS		

Bold = $r \geq 0.20$ and all significant at $p \leq 0.05$

NS = Not significant relationships observed at $p \leq 0.05$ level

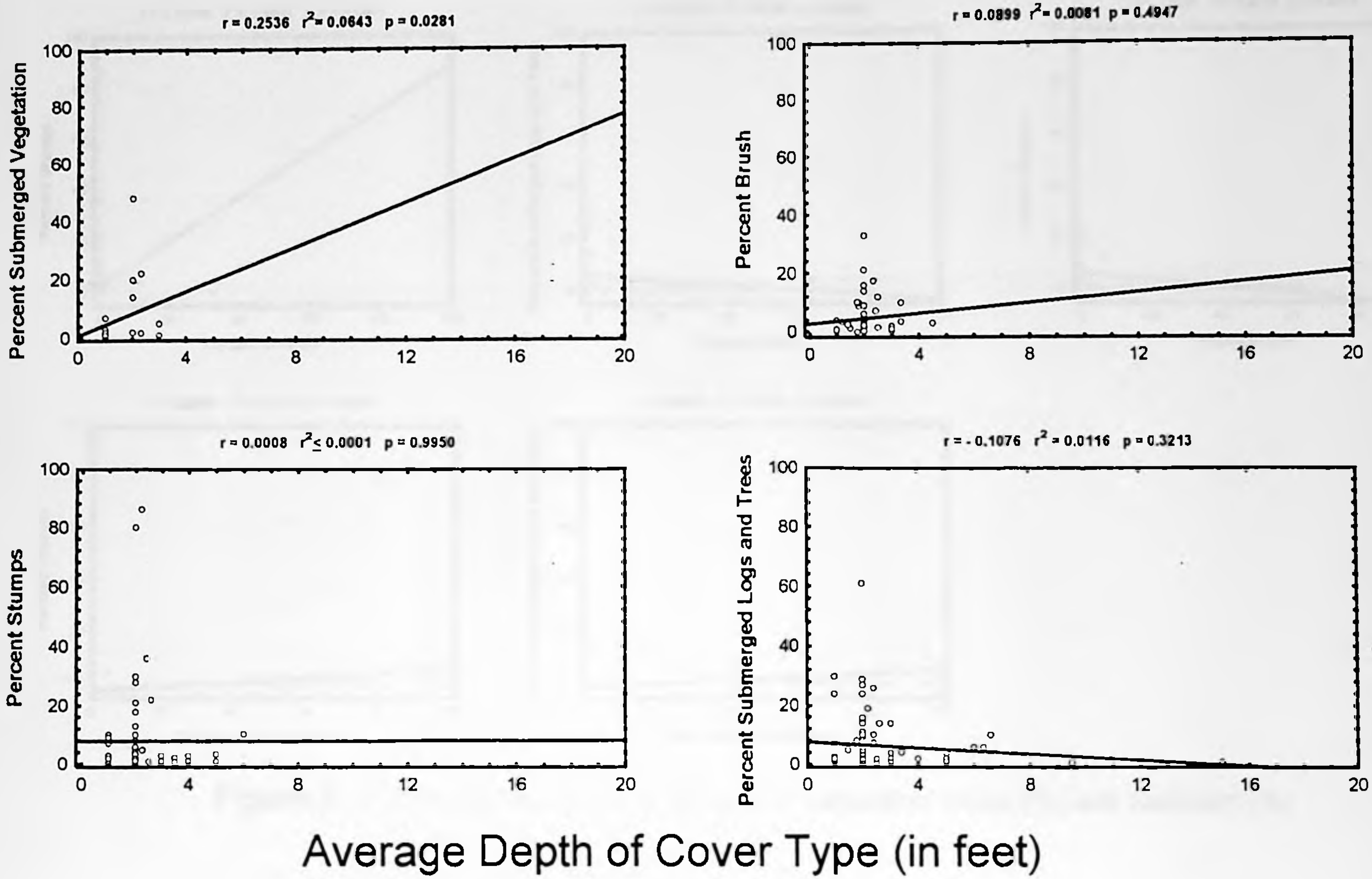

Figure 3. Percent Woody/ Vegetation Cover vs Average Depth of Cover Type

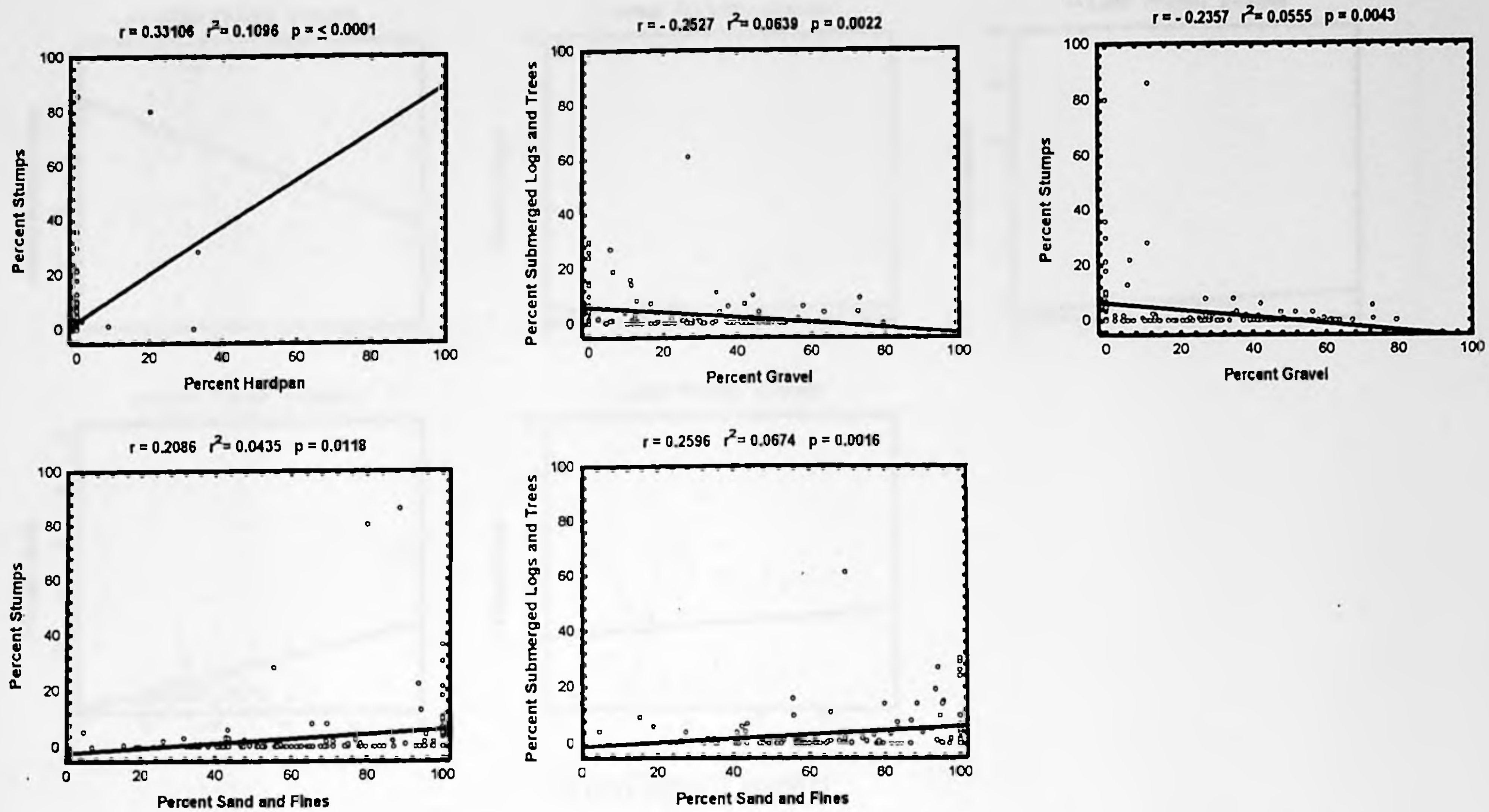

Figure 4. Significant Relationships of Woody/ Vegetation Cover (%) and Sediment (%)

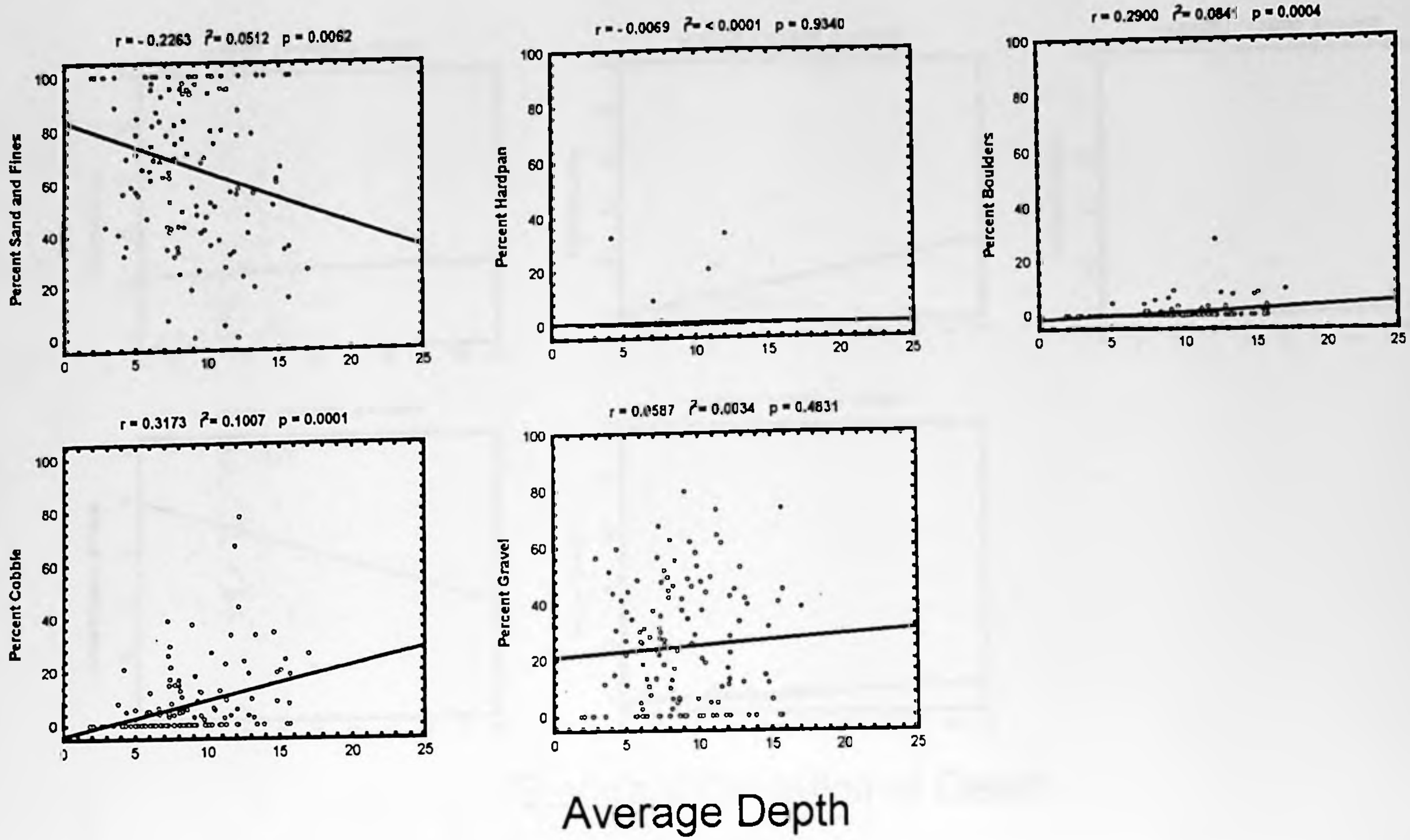

Figure 5. Percent Sediment Composition vs Average Depth

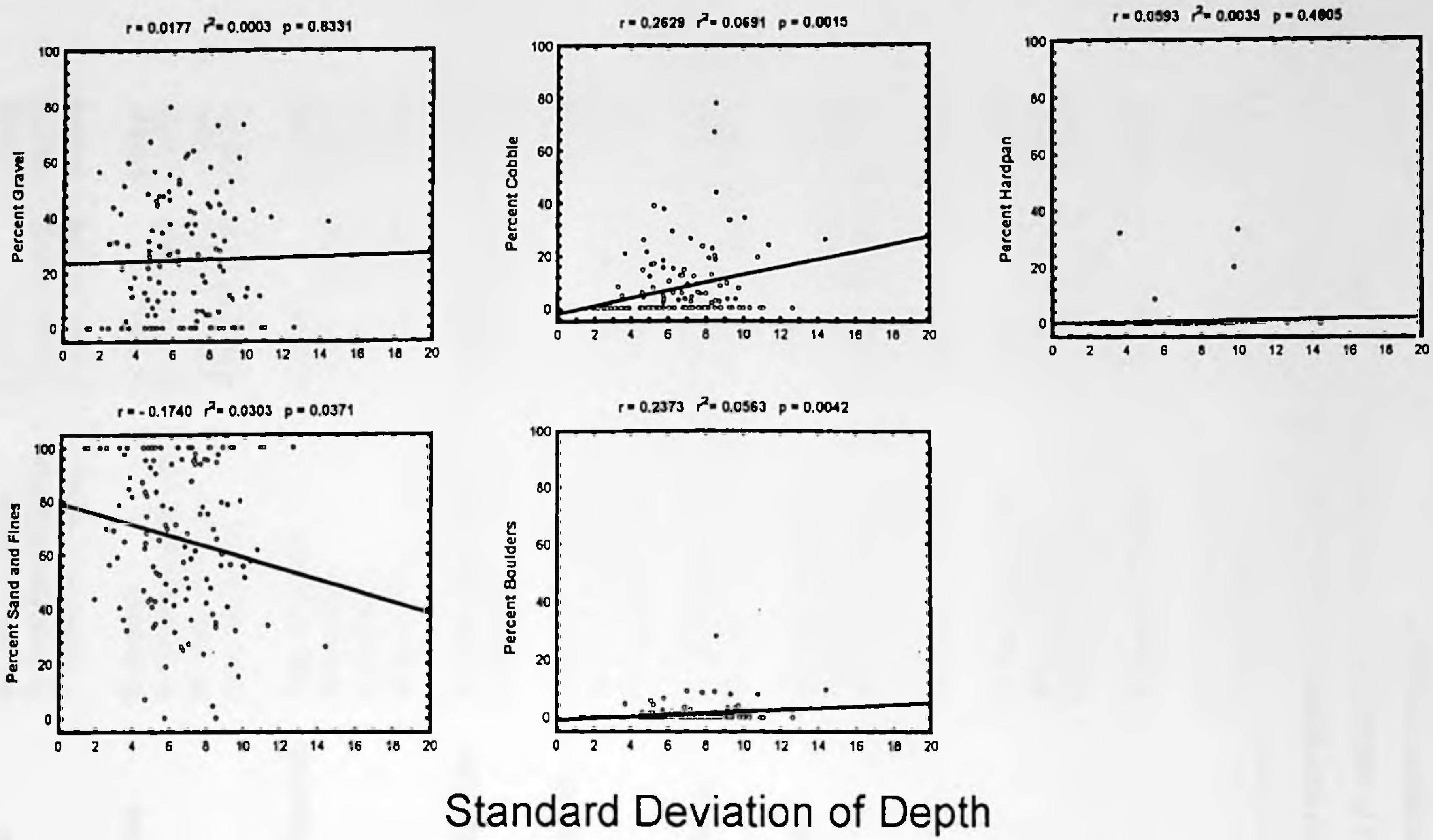

Figure 6. Percent Sediment Composition vs Standard Deviation of Depth

Table 4. Stepwise Regression of Fish Assemblage Metrics vs Habitat Parameters

Dependant Variable	Independent Variable	R^2	ΔR^2	p-value
Total Number of Species	**St. Dev. of Depth**	**0.0570**		**0.0038**
	% Overhanging Veg.	**0.0956**	**0.0386**	**0.0150**
	% Sand and Fines	**0.1245**	**0.0289**	**0.0325**
Number of Sucker Species	**% Gravel**	**0.0448**		**0.0106**
	% Overhanging Veg.	**0.0777**	**0.0329**	**0.0259**
	St. Dev. of Depth	0.0891	0.0113	0.1875
	Ave. of Depth	**0.1242**	**0.0351**	**0.0192**
Number of Centrarchid Species	**Ave. of Depth**	**0.1194**		**$\leq$ 0.0001**
	% Stumps	**0.1536**	**0.0342**	**0.0179**
	% Hardpan	0.1701	0.0165	0.0965
	% Boulders	0.1812	0.0111	0.1696
Number of Great River Species	% Submerged Veg	0.0170		0.1175
	% Boulder	0.0340	0.0170	0.1172
Number of Intolerant Species	**% Sand and Fines**	**0.1958**		**$\leq$ 0.0001**
	% Overhanging Veg.	**0.2431**	**0.0473**	**0.0034**
	% Submerged Veg.	0.2542	0.0111	0.1499
Percent Tolerant Individuals	% Overhanging Veg.	0.0210		0.0823
	% Gravel	0.0420	0.0210	0.0800
Percent Simple Lithophils	**% Sand and Fines**	**0.0779**		**0.0007**
	% Boulders	**0.1044**	**0.0265**	**0.0419**
	St. Dev. of Depth	**0.1412**	**0.0368**	**0.0152**
Percent Detritivores	% Sand and Fines	0.0260		0.0527
Percent Invertivores	**% Sand and Fines**	**0.1280**		**$\leq$ 0.0001**
	Ave. of Depth	**0.1731**	**0.0451**	**0.0062**
	% Overhanging Veg.	**0.1970**	**0.0239**	**0.0422**
Percent Top Piscivores	**% Sand and Fines**	**0.0462**		**0.0095**
CPUE	% Overhanging Veg.	0.0261		0.0524
	Ave. of Depth	0.0366	0.0105	0.2146

The individual best predictor (R^2) of each dependant variable (fish metric) is listed first under the independent variable (habitat). ΔR^2 represents the next best predictor in the stepwise model (value must be $\geq$ 0.0100 to be included in assessment).

Bold = Significant at $p < 0.05$ level