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James E. Garvey
Southern Illinois University Carbondale

Stuart Welsh
West Virginia University

Kyle J. Hartman
West Virginia University

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Winter Habitat Used by Fishes in Smithland Pool and Belleville Pool, Ohio River

Principal Investigators:

James E. Garvey[1,2], Stuart Welsh[3,4], and Kyle J. Hartman[4]

Research Assistants:

Benjamin J. Braeutigam[1,2], Andrew T. Plauck[1,2], Kathryn A. Emme[1,2] and
Ben Lenz[4]

[1]Fisheries and Illinois Aquaculture Center
[2]Department of Zoology
Southern Illinois University
Carbondale, IL 62901-6511

[3]USGS, WV Cooperative Fish and Wildlife Research Unit
[4]Wildlife and Fisheries Resources Program
Division of Forestry
West Virginia University
322 Percival Hall
Morgantown, WV 26506-6125

Final Combined Project Report

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Executive Summary

Introduction

For many fishes that inhabit large rivers, winter poses a challenge to both age-0 and older life stages. Swimming ability is compromised at low temperatures in many species. Further, energetic condition often declines as food availability declines during winter. Hence, fishes occupying rivers may congregate in warm, low velocity shelters with abundant food to avoid poor growth and survival. If these sites are in proximity to vessel traffic in navigable systems such as the Ohio River, displacement may compromise fish success.

Approach

We conducted a literature review to assess the potential habitat use of several Ohio River fishes during winter. Using predictions generated by this review, we identified general sites in the Smithland Pool (Southern Illinois University Carbondale: SIUC) and Belleville Pool (West Virginia University: WVU) of the Ohio River that may provide winter habitat: artificial, island backwater, tributary, and main channel (about 30 sites per river pool, stratified equally across habitat types). Artificial sites were defined as scours associated with structures in the main channel (e.g., wing dams). Island backwaters were areas between channel borders and islands. Tributaries were sampled near the confluence with the Ohio River. Main channel sites were directly adjacent to or in the main channel. Catch per hour of fish was quantified using variable-depth alternating current (AC) electrofishing (identical units at both institutions) at depths ranging 3-14 m during the winters of 2002 and 2003. This gear was chosen because of its ease of standardization and ability to sample in a variety of river macrohabitats. Further, fish were expected to aggregate in deep water areas with low flow velocities during cold temperatures. This gear effectively sampled fish in areas difficult to sample with other active gear types. Water quality characteristics that were quantified included dissolved oxygen concentration, secchi depth, temperature, and flow rate. In addition to the coordinated joint effort, each research group collected additional data in other habitats (e.g., island tips, embayments) and with other gears (e.g., gill nets).

Literature Review

The literature revealed that most species require low velocity refuges when temperatures < 4°C. Swimming ability is compromised at these low temperatures. However, overwintering in low velocity backwater habitats that may become hypoxic may also negatively affect winter survival. Species will likely differ in their ability to persist in areas in proximity to the main channel. Channel catfish, a common species in the Ohio River, should be able to tolerate relatively high flows at low temperatures. Conversely, survival of species such as largemouth bass should be compromised if they cannot successfully seek low velocity refuges away from the main channel. Use of habitat by fishes during winter should be affected by trade-offs between swimming ability in the main channel and surviving potentially low oxygen conditions in backwaters.

Site Description

Smithland (river miles: 162-204) and Belleville (river miles: 843-913) Pools of the Ohio River differ in size, elevation, and abiotic characteristics. Each pool is created by lock and dams that maintain a 2.7-m deep (9 foot) navigation channel at low discharge. Smithland Pool, currently the southernmost impoundment of the Ohio River, is 115 km long with an area of 11,134 ha during normal pool. Belleville Pool, to the north of Smithland Pool and at a higher elevation, is 70-km long with a smaller surface area of 2,850 ha. Island and artificial habitats were much more limited in Belleville than in Smithland Pool. Smithland Pool did not contain the extensive embayment area that was present in Belleville Pool. Depths of sites sampled were somewhat shallower, on average, in Belleville Pool. Artificial sites in Smithland ranged 8-11 m (mean = 9 m). Only one artificial site was sampled by WVU in Belleville Pool. Island backwaters sites ranged 5-8 m (mean=6 m) in Smithland Pool and 2-6 m (mean=5 m) in Belleville Pool. Main channel sites were 6-9 m (mean= 8 m) and 3-9 m (mean=6 m) in Smithland and Belleville Pools, respectively. Tributary habitats ranged 3-8 m (mean = 5 m) in Smithland Pool and 2-9 m (mean = 6 m) in Belleville Pool. WVU included a separate "deep hole" category for distinct, main channel scour holes that ranged 7-14 m (mean = 9 m). These sites were similar in depth and characteristics of many of the main channel sites chosen in Smithland Pool by SIUC.

Winter conditions

Winter conditions differed between Smithland and Belleville Pools during winters 2002 and 2003. Discharge was quite high and variable during both sampling years in Smithland Pool, with river stage frequently increasing by 8-10 m within a few days (see Figure 2-2, Chapter 2). Consequently sampling was often compromised, and we were relegated to sampling during periods of relatively low flow in the pool. In Belleville Pool, discharge was less variable and relatively lower, with stage only increasing by a maximum of 2.5 m relative to base flow (Figure 3-3, Chapter 3). Flow rates quantified in

Belleville Pool during both winters were often higher (reaching or exceeding 1.0 m/s) in main channel sites than in Smithland Pool. This occurred because WVU could sample during periods of moderate discharge, whereas these moderate flow conditions never occurred in Smithland Pool. In both pools, depth-stratified profiles revealed that water chemistry (e.g., dissolved oxygen concentration, conductivity) and temperature did not vary appreciably with depth. During warmer months, dissolved oxygen concentrations in tributaries of Smithland Pool but not Belleville Pool declined below levels (< 4-5mg/L) preferred by fish and other organisms. Unlike Belleville Pool, dissolved oxygen concentrations in Smithland Pool tributaries were typically lower than at other sites associated with the main channel during all sampling sessions. Specific conductance, a factor that affects electrofishing efficiency, differed between pools, with conductivity often being higher in main channel sites of Smithland Pool.

Habitat-specific Conditions

We used multivariate analyses to assess macrohabitat-specific abiotic characteristics during winter including flow, dissolved oxygen, conductivity, and temperature. In Smithland Pool, habitats did separate out with respect to physical conditions, but often not in direct correspondence with our predetermined habitat delineations. Tributaries clustered with respect to low dissolved oxygen concentration, high water clarity (as estimated with secchi readings), and low flow. In Belleville Pool, sites typically did not show specific clustering with respect to the abiotic variables quantified, although tributaries did have consistently lower flow rates. During some winter periods, tributaries were colder than main channel sites in Belleville Pool.

Fish Habitat Use

Species richness (i.e., number of species sampled) differed between Smithland and Belleville Pools during the two sampling winters. In Smithland Pool, a total of 19 species was sampled each year. Species richness was much higher in Belleville Pool, with AC electrofishing generating a total of 28 species. During both years in Smithland Pool, freshwater drum and blue catfish dominated samples, often comprising > 90% of fishes. In Belleville Pool, freshwater drum were often abundant, but channel catfish was the dominant catfish species. These species typically comprised 80% of fishes sampled, with other species such as gizzard shad being important as well.

Winter habitat use by fishes differed between the pools. During both winters in Smithland Pool, catch per unit effort (CPUE; number of fish per hour) was higher in sites adjacent to the main channel (i.e., main channel and artificial) than in tributaries (Table 1). CPUE varied considerably among sites in Belleville Pool, with maximum average catch rates exceeding those in Smithland Pool (Table 1). Catch rates of fish were higher in tributaries in Belleville than in Smithland Pool, with catch rates of fish in Belleville Pool being higher in sites associated with the main channel in 2003 (Table 1).

Species richness in macrohabitats of Smithland Pool varied with abiotic factors during both winters. Both tributary and island backwater sites had high species richness at cold temperatures. Further, species richness in tributaries increased with a slight rise in flow rates. When dissolved oxygen concentrations declined below 5 mg/L in Smithland tributaries (which occurred at warm, late-spring temperatures), fish species richness declined. Small, young freshwater drum were associated with tributary sites during winter in Smithland Pool, suggesting that these areas may provide some refuge for early life stages. In Belleville Pool, high catch rates and richness in tributaries during winter were likely due to the low flow rates in these macrohabitats. However, when temperatures in these areas declined below 4^{o}C, fish were more abundant in main channel areas, suggesting that fish leave cold water areas to inhabit relatively warmer but higher flow areas in the river. In Belleville Pool, shallow areas with large woody debris were also sampled with DC surface electrofishing, revealing the presence of other fish species not sampled with the variable depth AC gear.

Variable-depth electrofishing was compared with other gear types such as sonar and gill nets. Gill netting conducted by WVU in Belleville Pool revealed low catch rates with species composition similar to that generated by electrofishing. Low catch rates with active gill netting are not unexpected given the cold temperatures and low activity of fishes. Both groups conducted some comparisons between sonar and variable depth electrofishing and found no strong relationships between abundance as estimated by the two gears. A study conducted during winter 2002 in Pool 25, upper Mississippi River by SIUC in collaboration with the Missouri Department of Conservation and the US Army Corps of Engineers, St. Louis District, compared variable depth AC electrofishing with purse seining and trawling behind chevron dikes. AC electrofishing generated similar sizes and species as the other gears, further confirming that this technique provides a relatively clear picture of fish assemblages at depths > 3 m.

Conclusions and Implications

During both winters and in both pools of the Ohio River, fish assemblages and abundance differed among the macrohabitats we identified at the outset. In Smithland Pool, habitats adjacent to the main channel appeared to be important for fish during the winter. Particularly, island backwaters and submerged boulders at the channel border were areas that contained large aggregations of fish during cold, winter conditions. Deep scours created by artificial structures (e.g., submerged wing dikes) also provided refuge for fish at cold temperatures. Tributary macrohabitats in Smithland Pool only appeared to provide important winter habitat when temperatures were low and when these areas were connected to the main channel. Tributaries in Smithland Pool are often disconnected from the main channel by a shelf of sediment and debris that may inhibit the passage of fish from the main channel. In Belleville Pool, tributaries and an embayment area appeared to play a critical role for wintering fishes. However, these macrohabitats may cool more than the main channel during some winter periods (e.g., as might be expected during a period of snow melt), necessitating the movement of fish into warmer main channel areas. Surface electrofishing of shallow areas adjacent to the main channel revealed that different fish assemblages may be using these areas during winter.

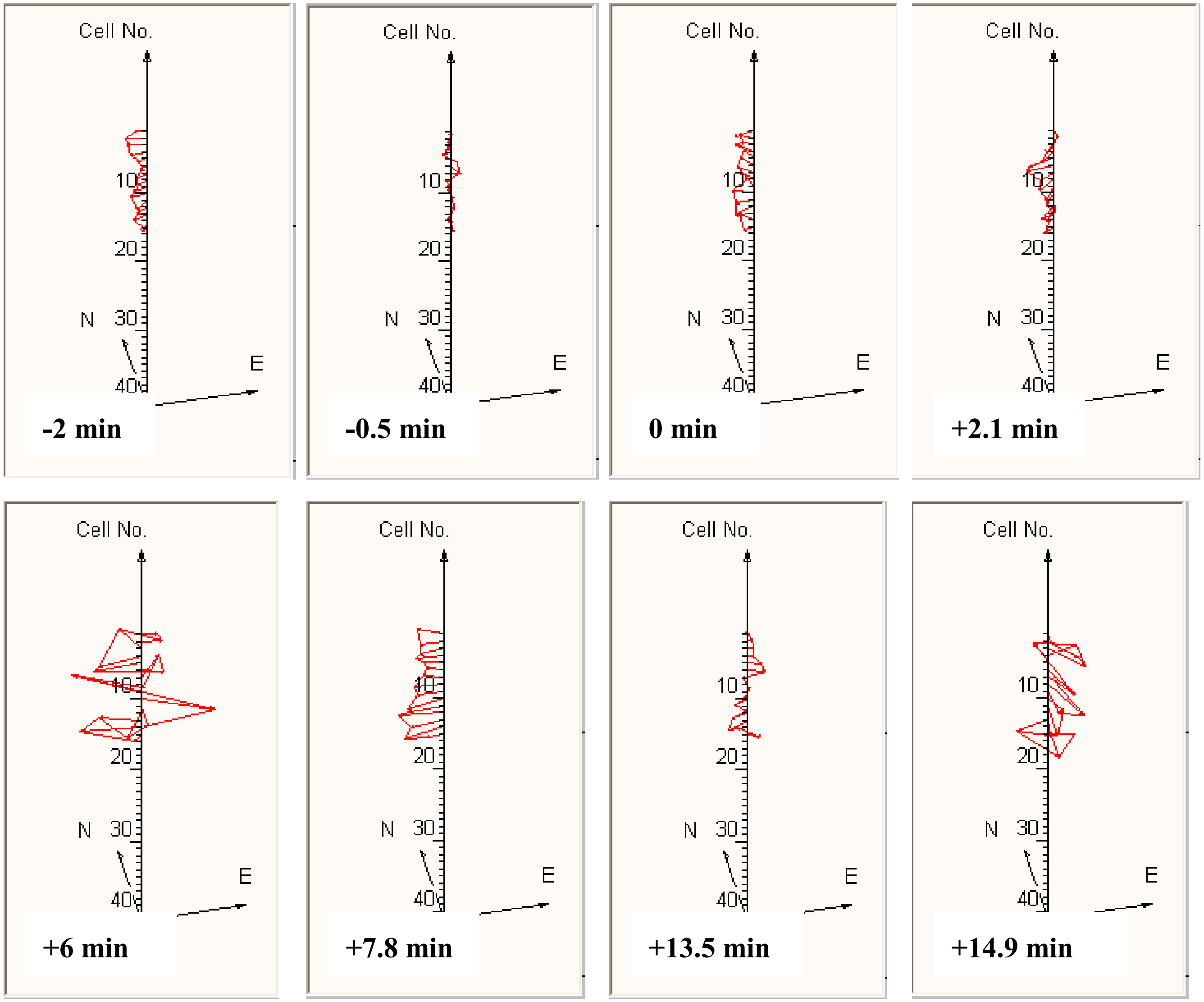
When fish use main channel habitats during winter, they may be subjected to changes in flow as barges move into their proximity. Fish with impaired swimming ability at cold temperatures (e.g., freshwater drum; see Table 1-1, Chapter 1) may be displaced by changes in flow direction and velocity. Preliminary data quantified with an acoustic doppler profiler behind wing dikes of the middle Mississippi River support this supposition. This instrument quantifies both flow velocity and direction at 0.5-m intervals from the surface to the bottom. In our study, we profiled flow at fixed points behind wing dams before, during, and after barges passed (Spier, Braeutigam, and Garvey unpublished data). Although our results are admittedly tentative, we found that flow was relatively low with coherent directionality as barges approached (Figure 1). After barge passage, displacement of water caused flow velocity to increase and an incoherent (i.e., multidirectional) flow pattern to occur (Figure 1). Flow rates continued to be affected by barges 15 minutes following passage of the bow (Figure 1). Thus, fish seeking typically low velocity deep water habitats behind river structures may be displaced if low temperatures reduce swimming ability. Again, we will continue to view these results with caution until more data are collected, but the pattern is compelling and is congruent with other studies.

This unique opportunity to conduct parallel research projects in two impounded Ohio River reaches during the same winters has provided insight into the potential effects of anticipated increased navigation on fish assemblages. Tributary habitats are clearly important to wintering fish, and reduced connectivity in Smithland Pool likely compromises the success of many species. Improved connectivity, perhaps through dredging at confluences, may improve winter success of fishes in this pool. Higher species richness and greater tributary use by fishes in Belleville Pool suggest that connectivity may not be problematic in this impounded reach. Many fishes such as commercially important channel and blue catfish use sites adjacent to the main channel in Smithland Pool. Similarly, channel catfish use the main channel in Belleville Pool. Artificial sites such as wing dikes in Smithland Pool create scours that are used by river fishes, although some concern about displacement by barges does persist, requiring further exploration. Island backwater areas appear to be particularly important for fishes during winter. These areas provide flow breaks and are relatively sheltered from barge activity. River habitat management that enhances/maintains accessibility to these areas should be beneficial to wintering fish in the Ohio River.

Table 1. Mean number of fish per hour (CPUE) sampled with variable-depth electrofishing during winters 2002 and 2003 at common macrohabitats sampled in both Smithland Pool and Belleville Pool, Ohio River. * depicts site not sampled. In 2003, only one artificial (wing dam) site was sampled in Belleville Pool.

		Mean number of fish per hour			
Pool	Year	Artificial	Island Backwater	Main Channel	Tributaries
Smithland	2002	85	21	113	41
	2003	41	51	62	7
Belleville	2002	*	5	4	115
	2003	203	10	27	70

Figure 1. Flow velocity and vector profile behind a wing dam in the Mississippi River during December 2003. Each cell is 0.5-m in depth. The site was about 7.5-m deep. Times on the graph depict when the bow of a barge was approaching (negative), at (zero), and past (positive) the wing dam site. Direction of vectors represents the direction of flow (the thalweg was west of the profiler). Magnitude of flow is estimated by the length of the vectors.



General Introduction

Winter is a critical period in which high mortality occurs in fishes (Oliver et al. 1979; Cunjak 1996; Garvey et al. 1998). Many temperate fishes undergo a torpor-like state when exposed to prolonged cold temperatures and short days (Crawshaw 1984) and, as such, may be highly susceptible to vessel-passage induced displacement from velocity shelters. Because the Ohio River extends through mid-temperate latitudes, inter-annual variability in winter temperature may translate to highly variable responses of fish populations to acute abiotic perturbations (see Garvey et al. 1998) such as changes in flow velocity and flow direction with navigation. Laboratory (Sheehan et al. 1990; 2000a) and field studies (Sheehan et al. 1990b; Logsdon 1993; Johnson et al. 1998) showed that a number of Mississippi River fishes overwinter in stratified backwater areas, when they have access to them, or in low velocity areas in channels. Relatively small (0.08 to 0.16 $m \cdot s^{-1}$) velocity changes, such as those that can be induced by vessels, can displace small bluegill and channel catfish from low velocity habitats when water temperatures are low (1 to 4 ^{o}C) (Sheehan et al. 2000b). If fish are displaced into flowing channels at such temperatures, mortality will probably increase (Bodensteiner and Lewis 1994; Sheehan et al. 2000a).

Fish are an important economic and ecological component of the Ohio River ecosystem. Understanding how abiotic characteristics (e.g., latitude, channel morphometry, depth) regulate winter habitat use of critical fish species is the primary objective of this research. Habitat characteristics affecting winter survival of fish may well vary locally among adjacent pools as well as geographically between the upper and lower reaches of the Ohio River. We have completed an intensive literature review

(Chapter 1), quantifying winter habitat associations in fishes commonly found in the Ohio River. We also have completed a 2-year, winter survey of a lower (Smithland; SIUC, Chapter 2) and upper (Belleville; WVU, Chapter 3) pool of the Ohio River.

The literature review and field reconnaissance generated *a priori* expectations about habitat use of fish during winter (see Chapter 1). In Chapters 2 and 3, we present results from an intensive winter field effort conducted during winters 2002 and 2003 to fill in the gaps about winter habitat associations of common Ohio River fishes and their potential responses to winter navigation.

Chapter 1 – Literature Review

James E. Garvey, Southern Illinois University

Winter often is a critical period influencing the condition and survival of fishes in marine (Sogard 1997; Schultz and Conover 1997; Schultz et al. 1998; Hurst et al. 2000) and freshwater (Hubbs and Carlander 1935; Aggus and Elliott 1975; Gutreuter and Anderson 1985; Cunjak 1988; Garvey et al. 1998) temperate-zone systems. Winter mortality is typically highest for young-of-year (YOY) fish, with survival probability increasing with increasing body size (e.g., Toneys and Coble 1979; Ludsin and DeVries 1997; Garvey et al. 1998; Foy and Paul 1999). Thus, the extent of first-year growth, fall body size, and winter severity may regulate year-class strength in some species and systems. For age-0 fish as well as older life stages, rivers can be particularly challenging environments in which to reside during winter because a host of abiotic characteristics limit survival and growth (Sheehan et al. 1990; Bodensteiner and Lewis 1992; Cunjak 1996; Jakober et al. 1998). As such, fish must choose the most benign habitat available during winter to increase their probability of surviving. In the mainstem Ohio River, the quantity and availability of winter refuge may well determine the relative survival and abundance of resident fish populations. The ability of these habitats to provide refuge from vessel-induced displacement is essential, given the anticipated increases in barge traffic in the Ohio River. To determine what habitat-specific factors influence winter growth and survival of fish in the mainstem Ohio River, we reviewed > 300 articles pertaining to the winter physiology and ecology of fish, focusing on fishes commonly occurring throughout this system. Articles were obtained using standard abstracting services such as Biological Abstracts, Science Citation Index, and Aquatic Sciences and

Fisheries Abstracts, Dissertation Abstracts, and the U.S. Fish and Wildlife Reference System. Major reviews such as Carlander's Handbook of Freshwater Fishery Biology, Volumes 1-3 provided a source for early research articles (Carlander 1968, 1977, 1996).

Mechanisms influencing the Overwinter Condition and Survival of Riverine Fish

Overview

Several mechanisms may work either exclusively or in concert to affect the growth and survival of cool- and warm-water riverine fishes during winter. Failure to tolerate cold temperatures, flowing water, low food availability, or low dissolved oxygen concentrations can negatively affect fish throughout the Ohio River. The relative importance of these factors may vary as a function of reach-specific factors including (but not limited to) latitude, winter severity, within-pool location, and river morphometry.

Two major overwintering habitat types - main channel and backwater - can be categorized within the Ohio River, although much variation exists within each (e.g., Sheehan et al 1990; Logsdon 1993). Main channel reaches are oxygen-saturated with temperatures that likely differ among latitudes. Mainstems of northern river reaches (e.g., upper Mississippi River) are typically $< 1^{o}C$ during winter (Sheehan et al. 1990; Johnson et al. 1998). In contrast, main channel water temperatures in southern reaches may be warmer and more variable. For example, temperatures below the Smithland Pool of the lower Ohio River only declined below $2^{o}C$ for about 1.5 weeks during one of three winters (Shawnee Fossil Fuel Electric Power Utility). Among years, water temperatures varied between 4 and $9^{o}C$ in early January at this site (also see Chapter 2 for 2002). Hence, fish residing at different latitudes within the main channel may be confronted by fundamentally different temperature-dependent challenges during winter that vary among years. Flow velocity within the main channel during winter is typically greater than that tolerated by many fish species at cold temperatures (see **Species Requirements**). However, fish may use various structures within the channel such as wing dams that provide relatively deep, low-velocity flow breaks (Heese and Newcomb 1982; Logsdon 1993), although these areas may be susceptible to vessel-induced displacement by barges (Todd et al. 1989). Low-flow sites connected to the main channel (e.g., backwaters) may provide refuge for fish during winter (Greenback 1956; Sheehan et al. 1990; Knights et al. 1995; Raibley et al. 1997). Temperatures stratify in these sites, providing elevated thermal habitat near the bottom (Sheehan et al. 1990; Johnson et al. 1998). However, dissolved oxygen can decline in these areas (Sheehan et al. 1990). In the following sections, we review how temperature, flow, energetic condition, and dissolved oxygen affect Ohio River fishes during winter. We then review winter habitat requirements of several species commonly found in this system.

Cold tolerance

Environmental temperatures dramatically affect physiological processes in fishes (Love 1980). Much research has been devoted to determining upper lethal thermal limits of fish (Hart 1952; Cvancara et al. 1977; Spotila et al. 1979). Lower lethal limits have received much less attention, although the lower thermal tolerances of many species likely exceed temperatures that occur in temperate rivers during winter (see **Species Requirements**). Researchers also have sought to determine the final thermal preferenda of temperate species (Reuter and Herdendorf 1974; Cherry et al. 1975; Kelsch and Neill 1990); preferred temperatures are typically absent during winter (Sheehan et al. 1990). Interestingly, if preferred temperatures become available to temperate species acclimated to winter temperatures, they may seek them, even if the temperature difference is great (e.g., $\geq 10^{o}$C; Kelsch and Neill 1990). During winter, species may track even slight temperature differences, seeking the warmest temperatures available (see Chapter 2). Residing at cold temperatures is clearly not advantageous for most species in the Ohio River.

Cold temperatures may compromise the growth and survival of fish for several reasons. Typical winter temperatures are well below the maximum metabolic scope (Fry 1947) of Ohio River fishes. As such, consumption and activity rates are limited, greatly reducing growth potential. Rapid declines in temperature can cause cold shock, a condition in which fish lose equilibrium (Cichra et al. 1982) and may become susceptible to predators (Coutant et al 1974). In rivers, fish undergoing cold shock may be displaced into the open channel, with little opportunity to regain position in low velocity habitats (Lewis and Bodensteiner 1994; Sheehan et al. 2000). Although river temperatures may supercool to -0.1 C (Devik 1944), fish will not freeze because their internal salinity depresses their freezing point between -0.5 and -0.65 C (DeVries 1971). Physiological problems associated with declining temperature rather than freezing are apparently responsible for cold shock and associated mortality.

Cold tolerance may depend on body size (Edsall and Colby 1970), leading to the patterns of size-dependent winter survival documented for many fish species. Although all Ohio River fish species are considered pokilothermic, core body temperatures typically exceed those of the environment, with large fish generating as much as 0.5^{o}C more heat than small fish (Stevens and Fry 1970; 1976). When environmental temperatures decline abruptly, internal body temperature of small fish declines to a new, lower stable state much more rapidly (within 10 minutes) than that of large fish (2.5

hours for 4 kg fish; Spigarelli et al. 1974). Although the evidence is somewhat tenuous, the morphology of species may affect temperature tolerance, whereby laterally compressed species such as gizzard shad and white bass are less tolerant to temperature shock than heavy bodied species such as ictalurids and common carp (Reuter and Herdendorf 1976). Hence, small, laterally compressed fish species may be more susceptible and respond more rapidly to the negative physiological effects of extremely low temperatures in the Ohio River.

Because temperature strongly affects growth and survival, distribution of fishes in aquatic ecosystems is often associated with temperatures near or at their thermal preferenda (Crowder et al. 1981). In winter, we predict that the availability of "warm" ($\geq 4^{o}$C) water will be a primary factor affecting habitat choice in the Ohio River, regardless of river reach and latitude. Backwaters in the Upper Mississippi River provide such elevated thermal refuges. Indeed telemetry studies (e.g., Pitlo 1987; Knights et al. 1995; Raibley et al. 1997) and active and passive sampling efforts (Sheehan et al. 1990) during winter have demonstrated robust use of these habitats by riverine fish. Other structures such as cobble may elevate microhabitat temperatures sufficiently to facilitate survival (Smith and Griffith 1994). Warm effluent from thermal power generation may also harbor high densities of fish within localized points in the Ohio River (see Adams et al. 1982), although these areas can cause mortality due to cold shock if thermal effluent subsides. The Ohio River extends across about 3.5^{o} N latitude, with the northern reach of the river receiving water from the northern Allegheny River and the relatively mountainous Monongahela River. Hence, water flowing into the northern Ohio River should be substantially colder than that in the south, which often is $>4^{o}$C. We may surmise that seasonal and regional differences in winter temperature along the river influence the duration and intensity of thermal refuge use, with relatively shorter stays occurring in the southern reach.

Swimming

A common response of many cold-, cool-, and warm-water fishes is to seek low velocity habitat during winter months. Although cool- or cold-water fishes may swim generally well at cool temperatures, swimming to maintain position can cause them to deplete limited energy reserves during winter (Cunjak 1987). Cederholm et al. (1987) found that increasing the quantity of large woody debris in streams created flow breaks, improving survival of coho salmon during winter. Young salmon seek low-flow, off-channel lentic habitats during winter (Bryant 1988), apparently to avoid the energetic costs of maintaining position. Warm-water fish attempting to maintain position at winter water temperatures and flows within their swimming tolerance also may incur energetic costs that may cause depletion of energy reserves and mortality.

Swimming ability of warm-water fishes can be impaired during winter (Sheehan et al. 1990). Species such as smallmouth and largemouth bass acclimated to winter photoperiods and temperatures do have improved swimming performance (Larimore and Duever 1968; Kolok 1991), but these adaptations are insufficient if flow rates exceed a critical point or temperatures decline below a critical minimum. Sheehan et al. (1990) and Logsdon (1993) determined experimentally that swimming ability of several fish species was compromised at temperatures $< 4^{o}$C, although the degree of responses differed among species. Swimming ability of YOY walleye, a cool-water species, did not decline with declining temperature (see **Species Requirements**). Conversely, the swimming ability of warm-water YOY channel catfish, largemouth bass, and bluegill declined with declining temperature. Within the limited range of lengths used, size did not affect swimming ability in any of the species tested at 0^{o}C (Sheehan et al. 1990). At higher temperatures, swimming ability increased with increasing size in several of the species (Sheehan et al. 1990). Failure to maintain position due to impaired swimming ability at low temperatures may cause fish to become displaced into the main channel (Bodensteiner and Lewis 1994; Sheehan et al. 2000), with the same potentially lethal consequences as cold shock. Improved swimming ability with increasing size may well mean that variable growth and first-year size affects patterns of survival of warmwater fishes in the Ohio River.

Habitat selection of Ohio River fishes during winter should depend on the relative effect of flow and temperature. If flow is low in the main channel (< 1 cm/s), these fish may not require low-velocity refuges (Johnson et al. 1998). At higher flow velocities, responses likely depend on species-specific tolerances to low temperatures. If temperatures vary along a gradient within the river, we may expect to see different fish responses (e.g., duration of refuge use) depending on river location. Under relatively mild winter temperatures ($\geq 4^{o}$C) that occur during some years in the lower Ohio River, many species may remain active but incur energetic costs of maintaining position, similar to cold-water fish at higher latitudes. These warm-water fish may seek low-flow velocity habitat not to reduce the negative effects of cold, but to reduce energetic costs. Clearly, these mechanisms need to be explored for fish assemblages in mid-latitude rivers such as the Ohio River.

Energy depletion

At temperate latitudes, ecosystem production declines during winter as temperatures and day length decline. As such, food availability for most fishes declines, requiring that energy reserves be used to offset metabolic costs (Thompson et al. 1991; Miranda and Hubbard 1994a; Ludsin and DeVries 1997; Wright et al. 1999; Fullerton et al. 2000). Within populations of warm-water species, some individuals undergo an inactive, torpor-like state during winter (Sullivan 1984; Crawshaw 1984), minimizing metabolic costs but also eliminating energy intake. Other individuals within species may forage intermittently during winter at "intermediate" temperatures (e.g., 5-6°C for some species; Sullivan 1984; Garvey et al. 1998; see Chapter 2). In an overwinter pool experiment in which YOY largemouth bass were presented with invertebrate prey, some fish fed with variable success (i.e., some grew and others lost weight), whereas others did not feed or foraged rarely during the entire winter (Miccuci et al. in press). On average, non-feeding individuals lost less wet mass than those that foraged unsuccessfully (i.e., lost mass) in this experiment. If these variable responses to food availability during winter are typical within species, they may affect patterns of relative condition and survival in riverine systems at "intermediate" (> 4°C) temperatures.

The negative relationship between length and survival of YOY fishes during winter at temperate latitudes has often been attributed to size-specific differences in energy reserve depletion (Oliver et al. 1979; Miranda and Hubbard 1994a; Ludsin and DeVries 1997). Small fish typically have higher mass-specific metabolic rates and lower energy reserves than large counterparts, increasing their probability of depleting energy stores and dying when food is scarce during winter. This has been shown for a variety of species typically found in the Ohio River (see **Species Requirements**). However, patterns of size-selective mortality can vary among populations within a species (Garvey et al. 1998), suggesting that system-specific factors such as food availability (Fullerton et al. 2000), temperature (Toneys and Coble 1980; Sheehan et al. 1990), and perhaps size-selective predation (Green 1982; Miranda and Hubbard 1994b; Miranda and Pugh 1997; Garvey et al. 1998) are important.

The cause of mortality at cold temperatures may be due to osmoregulatory dysfunction (Oliver 1977; Toneys and Coble 1980; Bodensteiner and Lewis 1992) and high associated energetic costs (Toneys and Coble 1980). Because of potential size-dependent differences in cold tolerance and energy depletion, small fish may suffer greater mortality than large counterparts as a function of this mechanism. Bodensteiner and Lewis (1992) found that freshwater drum residing in 4^{o}C backwater habitats of the upper Mississippi River had higher plasma osomolalities than those in $0\text{-}1^{o}$C channel habitats, supporting the hypothesis that cold temperatures challenge water balance in the field. However, size-dependent energy depletion of largemouth bass, green sunfish, yellow perch, and brook trout at winter temperatures did not differ under freshwater and relatively isosmotic conditions (Toneys and Coble 1980). Although cold temperatures incur negative osmoregulatory effects on both small and large fish, they apparently do not affect patterns of energy depletion in these species.

How winter affects growth and survival of fish may also depend on the interactions among winter temperature, duration, body size, and food availability. In northern rivers (perhaps including the northern reach of the Ohio River), winter is long and cold. Conversely, winter duration is considerably shorter in southern systems. Fullerton et al. (2000) simulated northern (45^{o}N) and middle (40^{o}N) latitude winter conditions in experiments to determine how YOY largemouth bass respond to winter temperatures, photoperiods, and food availability. Largemouth bass that were fed fish prey during winter lost and maintained weight in the northern and middle-latitude winters, respectively. Mass-balance bioenergetics models for largemouth bass predicted much greater loss of weight than occurred in either winter, suggesting that the fish reduced metabolic costs more than experimentally derived metabolic relationships predicted (Wright et al. 1999). Starved largemouth bass lost similar weight between the long, northern, simulated winter and the short, middle-latitude one (Fullerton et al. 2000). Apparently, the energetic costs of winter fasting do not increase with increasing latitude, because declining temperature-dependent metabolic costs offset the increased duration of starvation. We predict that winter food availability may differentially affect the condition and growth of largemouth bass and perhaps other fish with similar physiological/life history adaptations in northern and southern reaches of the Ohio River.

Oxygen

Declining oxygen during winter has long been recognized as an important factor structuring fish assemblages in north temperate lakes (Petrosky and Magnuson 1973; Klinger et al. 1982; Tonn and Pazkowski 1986). Species-specific tolerances for low oxygen and access to oxygen refuge (e.g., streams), determine the intensity of winterkill within these systems. Although oxygen is typically abundant in the main channel of rivers, oxygen availability in backwater refuges may decline when ice forms (Gent et al. 1995; Knights et al. 1995) or oxygen-poor groundwater inundates (Sheehan et al. 1990). Because 4^{o}C water at the bottom of these systems may overlap with oxygen-poor conditions near the profundal zone due to high biological oxygen demand, fish may be restricted to cooler water higher in the water column. If the total water-column oxygen concentration declines below the tolerances of resident fish, telemetry movement studies have shown that they will leave these backwater habitats until oxygen concentrations return to tolerable quantities (e.g., Gent et al. 1995).

By understanding the thermal- and oxygen-tolerance limits of riverine fish, we may improve backwater habitat during winter. Dissolved oxygen concentrations can be increased in backwaters by introducing water from the main channel through culverts (Johnson et al. 1998). This approach worked generally well in the Finger Lakes, a system of six backwaters of the upper Mississippi River, although stratification created by the influx of cold mainstem water limited the quantity of thermal habitat (Johnson et al. 1998). In the Ohio River, the availability and quality of backwater habitat also may be critical for overwintering fishes. Careful consideration of temporal variation in oxygen and temperature within these habitats will be necessary to determine their contribution to fish assemblages in this system. From this, we will be able to determine if management of oxygen within these habitats is necessary to improve overwintering success.

Synthesis

The Ohio River is a complex system with channel characteristics, tributaries, embayments, backwaters, and winter conditions etc. that vary among pools. How winter conditions affect fish assemblages depends to a great degree on the behavioral and physiological responses of individual species and the availability of critical refuge habitat within each segment. This habitat, typically defined as $\geq 4^{o}$C, low flow, and high oxygen, may vary in utility, depending on winter conditions along a latitudinal gradient within the river. Fish in northern reaches of the Ohio River may seek these refuge habitats primarily to avoid channel temperatures $< 4^{o}$C that compromise swimming ability and osmoregulatory function. Counterparts in lower reaches typically do not experience such low temperatures. However, given low food availability and energetic costs of maintaining position during winter, fish may still seek low velocity habitats to avoid energy depletion. The critical importance of winter habitat in a northern and southern pool of the Ohio River was assessed during winter 2001-2002 with a coordinated field effort between West Virginia University and Southern Illinois University. Because several of these habitats are vulnerable to water displacement by barges, navigation in the Ohio River during winter may be a critical determinant of fish assemblage structure.

Species Requirements

Overview

In this section, we review how several commonly occurring Ohio River species respond to winter conditions (see Table 1-1). These responses plus published surveys of winter habitat use provide insight into potential habitat use/requirements in the Ohio River. For some species (e.g., largemouth bass), a fair amount of information is available about physiological and behavioral responses to winter conditions. Scant information exists for others. This information will be used to generate generic- or species-specific predictions for winter habitat use of fish in both the northern and southern reaches of the Ohio River.

Largemouth bass (Micropterus salmoides)

Largemouth bass from northern populations (*M. salmoides salmoides*) acclimated to winter temperatures can tolerate 0^{o}C (Garvey et al. 1998; Sheehan et al. 2000). Sheehan et al. (1990) quantified higher mortality of YOY largemouth bass at 0^{o}C (40%) than at 4^{o}C. However, in outdoor pool experiments in Ohio under a winter photocycle and temperatures, mortality was often 0%, even though temperatures occasionally reached 0°C (Garvey et al. 1998). Both the duration of exposure and the rate of cooling may affect tolerance to temperatures < 4°C. The Florida subspecies of largemouth bass (*M. salmoides floridanus*) cannot tolerate temperatures < 4°C (Isely et al. 1987; Garvey et al. 1998), and likely cannot persist at the latitudes that the Ohio River spans.

Largemouth bass swimming ability declines with declining temperature. Individuals were placed in a variable-velocity swimming tunnel in which flow velocity was increased by 10 cm/s every 10 minutes (Sheehan et al. 1990). Mean swimming duration declined from 8.81 minutes to 0.63 minutes at 4 °C and 0°C, respectively. Mean swimming duration did not differ between 11 °C and 4°C, suggesting that the ability for largemouth bass to maintain position in main channel habitat is primarily compromised at temperatures < 4°C. Thus, we should only expect this species to require low velocity shelters when temperatures decline below this threshold. Swimming performance increased with body size at temperatures ≥ 4°C (Sheehan et al. 1990).

Some individual largemouth bass will forage actively during winter when temperatures are ≥ 6°C (Micucci et al. 2003). Below this temperature, feeding appears to occur very rarely (Fullerton et al. 2000). At latitudes encompassing the Ohio River, largemouth bass will forage and grow when food is highly abundant during winter (Garvey et al. 1998). However, it is more likely that food will be scarce and energy reserves will be used to offset winter fasting (Ludsin and DeVries 1997). Although some studies have demonstrated that small largemouth bass exhaust energy reserves more rapidly than large counterparts (Miranda and Hubbard 1994a), others have not (Garvey et al. 1998). We predict that largemouth bass will forage rarely during winter in the Ohio River. Rather, they will seek low velocity habitats in which energy costs are minimized.

At warm temperatures (> 20°C), largemouth bass are unable to tolerate oxygen concentrations below 1.5 ppm (Moss and Scott 1961) and will avoid these areas (Whitmore et al. 1960). Minimum oxygen concentrations at winter temperatures are lower (0.5-1 ppm). However, this species is quite susceptible to winterkill in lakes, suggesting that prolonged exposure to these or lower oxygen concentrations will eliminate them. Therefore, we predict that largemouth bass will occur at high densities in areas of high oxygen concentrations during winter.

Both surveys and telemetry demonstrate that largemouth bass seek backwater habitats in the upper Mississippi River, likely to exploit warm temperatures (Raibley et al 1997; Sheehan et al. 1990). Largemouth bass and smallmouth bass may school under winter conditions (Townsend 1916). If oxygen concentrations decline in backwater habitats during winter, radio-telemetry has demonstrated that they will depart and not return until concentrations rise (Gent et al. 1995). Thus, the avoidance of low oxygen likely is a major factor influencing movement of largemouth basin the Ohio River during winter.

Channel catfish (Ictalurus punctatus)

Channel catfish acclimated to winter conditions can tolerate temperatures reaching 0^{o}C (Sheehan et al. 1990). When acclimated to warmer temperatures, and placed in cold (4^{o}C) water, this species will experience cold shock (Smith and Griffith 1994). Swimming ability declined with declining temperature (Sheehan et al. 1990), although to a lesser extent than for other species (see above for largemouth bass). Mean swimming time declined from 11.5 minutes to 3.0 minutes when temperatures declined from 4^{o}C to 0^{o}C (Sheehan et al. 1990). Apparently, channel catfish are better adapted than several other warm-water species at maintaining position at moderate flows in riverine habitats. We might expect this species to have moderately flexible habitat use in the Ohio River.

Channel catfish can tolerate oxygen concentrations of $\geq$ 1 ppm at warm (>20°C) temperatures (Moss and Scott 1961). Minimum lethal oxygen limits likely decline at cold temperatures, although this species is subject to winterkill when oxygen is depleted. Growth continued during winter in the Mississippi River (McInerny and Held 1995), suggesting that foraging and growth may continue during winter.

Channel catfish will congregate in low flow areas such as backwater habitats (Sheehan et al. 1990) and deep-water scour holes (Heese and Newcomb 1982; Newcomb 1989; Logsdon 1993) during winter. They also will use main channel flow breaks such as cobble or debris (Hawkinson 1980, Lubinski 1985). Their tolerance of cold temperatures and moderate flow should allow them to use the main channel Ohio River during winter. We predict that this species has a more cosmopolitan distribution in the Ohio River during winter by not being restricted solely to backwater habitats and continuing to forage. However, individuals in main channel flow breaks or scour holes may be more susceptible to vessel-induced displacement (Todd et al. 1989).

Black crappie (Pomoxis nigromaculatus)

Black crappie tolerate 0°C when acclimated to winter conditions (Sheehan et al. 1990). This species swims poorly at all winter temperatures, with mean swimming durations of 1.4 and 1.3 minutes at 4°C and 0°C (Sheehan et al. 1990). As such, it appears that black crappie is not well adapted for maintaining position in current during winter and must seek low flow areas. In support of this, Knight et al. (1995) found that radio-tagged black crappie in backwaters of the upper Mississippi River always sought water velocities < 1 cm/s. Also, this species always remained in areas of > 2 ppm oxygen, even if this required relocating to lower water temperatures (Knight et al. 1995). Fluctuating oxygen concentrations (1.8 -4.1 ppm) during experimental winter conditions prevented spawning of black crappie relative to those at higher fluctuating oxygen concentrations (Carlson and Herman 1979). Apparently, high oxygen concentrations and low flow are higher priority characteristics for winter habitat than temperatures $\geq 4^{o}$C. Both black and white crappie cease feeding at temperatures < 10^{o}C (Mathur 1972; McInerny and Held 1995); white crappie schools during winter (Hancock 1954). Although information is less complete than that for other species, we predict that black and white crappie are restricted to low-flow, high-oxygen habitats in the Ohio River during winter across a wide range of temperatures.

Walleye (Stizostedion vitreum)

Walleye acclimated to winter conditions suffered 25% mortality at 0^{o}C in cold tolerance experiments (Sheehan et al. 1990). Mortality was negligible at 4^{o}C. Walleye in outdoor pool experiments during winter in Ohio experienced occasional 0^{o}C temperatures and exhibited no mortality (Kershner 1998). Apparently, this species can tolerate the extreme cold temperatures that occur in river sections. Walleye swimming performance was strong at all winter temperatures in a swimming tunnel experiment (Sheehan et al. 1990). Mean swimming durations were 13.9 and 12.4 minutes at 4^{o}C and 0^{o}C, respectively. Hence, this species is well adapted to maintaining position in flowing water during winter.

Walleye appear to have high oxygen requirement relative to other co-occurring riverine species. At warm temperatures (>20^{o}C), walleye begin to experience stress at 2 ppm oxygen and mortality at 1.6 ppm (Moss and Scott 1961). Under winter conditions, walleye seek oxygen-rich water (Ager 1976; Sheehan et al. 1990; Coon 1998). Walleye forage actively during winter (Ager 1976; Kershner 1998). In one telemetry study in the Cedar River, Iowa, walleye were usually active in deep backwater areas at temperatures > 2.8°C (Paramagian 1989). Available forage in the fall may improve winter condition and facilitate spring spawning success of walleye (Madenjian et al. 1996).

Small YOY walleye suffered higher mortality than large individuals in some systems (Joy 1975), but not in others (Copeland and Carline 1998). Although cannibalism has been suggested to contribute to these patterns of mortality (Forney 1976), Joy (1975) found no evidence of this mechanism in diets of adult walleye during winter. Hence, size-dependent energy depletion was implicated (Joy 1975). However, Copeland and Carline (1998) found no linkage between lipid depletion and overwinter mortality in laboratory experiments and Pennsylvania lakes. YOY saugeye experienced no size-selective overwinter mortality in Ohio reservoirs (Donovan et al. 1998).

Walleye and perhaps sauger should tolerate relatively high flow rates and temperatures in the Ohio River. However, we predict that *Stizostedion* spp. will avoid habitats with moderate to low oxygen concentrations. At the temperatures common to the southern extent of the Ohio River, walleye and sauger may well remain active for most of the winter.

Bluegill (*Lepomis macrochirus*)

Bluegill are intolerant of the cold temperatures that may occur in the main channel of rivers during winter (Sheehan et al. 1990). In cold tolerance experiments, bluegill survival was high at 4°C but declined to 44% at 0°C (Sheehan et al. 1990).

Bluegill swimming performance declined significantly with declining temperature, from 5.6- to 0.3-minute mean duration at 4°C and 0°C (Sheehan et al. 1990). Lower lethal oxygen concentrations for bluegill acclimated to winter conditions vary from 0.5-3.6 ppm (Cooper and Washburn 1949; Petrosky and Magnuson 1974). This species is relatively susceptible to winterkill in north temperate lakes (Pertrosky and Magnuson 1974; Tonn et al. 1980).

Although foraging activity of this species has been documented under the ice (Moffett and Hunt 1943), telemetry studies in eastern Tennessee demonstrated that activity is low for this species during winter (Gatz and Adams 1984). If foraging does occur, it is apparently insufficient for growth because several field studies have demonstrated that energy reserves are depleted in a size-dependent fashion in bluegill populations (Bulow et al. 1991; Booth and Keast 1986; Cargnelli and Gross 1997). Further, growth increments on otoliths decline dramatically as temperatures decline in fall (Garvey et al. in press). In YOY bluegill, mortality apparently does increase with declining body size during winter in some systems (Cargnelli and Gross 1996; Garvey et al. in press) but not others (Toneys and Coble 1979). Bluegill occupying shallow water during winter may be highly susceptible to wading shorebird predation (Glahn et al. 1998).

Bluegill must seek backwater habitat with 4°C, low flows, and moderately high oxygen during winter in the Ohio River (see Knights et al. 1995). Apparently, if these habitat requirements are not met, high mortality will occur, as it did in the upper Mississippi River (Bodensteiner and Lewis 1994).

White bass (Morone chrysops) and congeners

Very little information is available about the physiological requirements of white bass during winter. A congener, white perch, that is currently not present in the Ohio River, cannot tolerate temperatures ≤ 2.5°C, with greater mortality occurring in small YOY individuals (Johnson and Evans 1990, 1991). Survival is high for white perch at 4°C, when food is available (Johnson and Evans 1990, 1991). Striped bass, another congener, persists at cold temperatures typically found in river main channels during winter (Hurst et al. 2000; also see Harrell et al. 1988). Although white bass are found as far north as Lake Erie (Barans and Tubb 1973), they appear to have strong thermal preferences, actively seeking warm-water effluent from power plants during winter (Schneider et al. 1977) or areas of greatest temperature under natural winter conditions (Barans and Tubb 1973). During winter, white bass tend to move to deeper, offshore areas in lakes (Beck and Willis 2000) and occupy backwater habitats in the Mississippi River (Sheehan et al. 1990). Growth ceased in white bass when temperatures declined below 18°C in Navigation Pool 9 of the Mississippi River (McInerny and Held 1995). Taken in concert, this limited information suggests that white bass should become relatively inactive and seek warm-water refuges during winter in the Ohio River.

Freshwater Drum (Aplodinotus grunniens)

Freshwater drum is widely distributed throughout North America and reaches high abundances in river ecosystems (Scott and Crossman 1973; Braaten and Guy 1999). Thus, we may expect that this species tolerates a host of winter conditions to persist so widely. In a laboratory experiment, freshwater drum held at 1°C and 5°C experienced higher mortality than those at 10°C (Bodensteiner and Lewis 1992). When temperatures declined to 0°C, these fish lost equilibrium. Freshwater drum at cold temperatures were less able to maintain osmotic balance than those at relatively warmer ones (Bodensteiner and Lewis 1992). In the Mississippi River, freshwater drum occupy deep water scour holes (Heese and Newcomb 1982; Logsdon 1993) or backwaters, apparently to exploit temperatures $\geq$ 4°C, low velocity, and high oxygen concentrations. If these conditions are not met in the Ohio River, high mortality may occur as was observed in the Mississippi River (Bodensteiner and Lewis 1994). Freshwater drum apparently cease foraging and growth at < 10°C (McInerny and Held 1995).

Green sunfish (Lepomis cyanellus)

Green sunfish are a common member of river fish assemblages. However, Sheehan et al. (1990) found that this species suffered high mortality at $\leq$ 4°C. Presumably, this species must search for > 4°C water and remain inactive to persist during winter. Although field information is limited, winter survival of YOY green sunfish appears to be unrelated to size (Toneys and Coble 1979) or osmoregulatory dysfunction (Toneys and Coble 1980). This species is found in backwaters of the Mississippi River (Sheehan et al. 1990) and is likely restricted to these habitats during winter in the Ohio River as well.

Other Ohio River species

Gizzard shad *Dorosoma cepedianum* are common and abundant in Ohio River fish assemblages. This species typically is found in river backwaters (Sheehan et al. 1990; Bodensteiner and Lewis 1994) and scour holes associated with main channel flow breaks (Logsdon 1993) during winter. This species is quite susceptible to cold shock, with high mortality occurring in many populations during winter months (Miller 1960; Walburg 1964). This species stores energy as fat in fall (Pierce et al. 1980), with a subsequent decline in stores through winter. The abundance of gizzard shad in fall and during winter can affect survival (Adams et al. 1982) and reproductive success (Madenjian et al. 1996) of sportfish during winter. In our view, gizzard shad should be an important component of Ohio River food webs, with survival in backwater habitats potentially affecting the success of piscivores.

Large cyprinid species such as river carpsucker (*Carpiodes carpio*) and common carp (*Cyprinus carpio*) overwinter in deep scour holes (Heese and Newcomb 1982) and backwaters (Sheehan et al. 1990) of rivers. The minimum lethal temperature of common carp is 0.7^{o}C (Bardach and Berstein 1954), suggesting that this species has broad tolerance to winter temperatures in rivers. Common carp can remain relatively active during winter, when attempting to avoid ice or high flow velocities (Brown et al. 2000). We predict that common carp will occupy a variety of winter habitats both in the main channel and backwaters of the Ohio River.

Although information about overwintering shovelnose sturgeon (*Scaphirhynchus platorynchus)* is scarce, shortnose sturgeon (*Acipenser brevirostrum*) remain in areas of reduced flow in the main channel during winter (Moser and Ross 1995), presumably to reduce energetic costs of maintaining position (Kynard et al. 2000). Activity during winter varies for this species from relatively high in the Lower Cape Fear River, North Carolina (Moser and Ross 1995) to low in two Massachussetts rivers (Kynard et al. 2000). Paddlefish (*Polyodon spathula*) appear to use main channel habitats of the lower Alabama River during winter (Hoxmeier and DeVries 1997). Tagged paddlefish moved between lakes and tributaries in the Lower Cumberland and Tennessee Rivers, Kentucky

(Timmons and Hughbanks 2000). During winter in Alabama and Texas, diets of paddlefish included copepods, cladocerans, and mayfly nymphs (Hoxmeier and DeVries 1997; Moore and Cotner 1998). This information suggests that sturgeon and paddlefish should remain relatively active and use main channel habitat in the Ohio River during winter.

Species such as blacknose dace may move into crevices beneath rubble (Cunjak and Power 1986). Other cyprinid species may become hyporheic, burrowing into gravel at depths of 0.5 m (Emery et al. 1978). Bullheads can burrow into the substrate within backwaters presumably to take advantage of elevated thermal conditions (Loeb 1964; Bouvet et al. 1985). Overwintering tactics of many often overlooked species in the Ohio River (i.e., those with little commercial or recreational value) may be quite unique.

Summary

Winter habitat requirements of Ohio River species will revolve around the relative impacts of temperature, oxygen concentration, flow velocity, and perhaps food availability. Fish assemblages will contain species with varying tolerances to these winter conditions, affecting their habitat fidelity, condition, and survival. Because many species found in the Ohio River likely home to the same overwintering locations each year, as they do in other riverine systems (e.g., Pitlo 1987), these areas are likely very important for survival during this critical period (Sheehan et al. 1990). Winter temperatures vary in severity and duration throughout the Ohio River. Hence, constraints on overwinter success and factors influencing habitat use may vary depending on river mile. In addition, the vulnerability of fish to vessel-induced displacement during winter will depend largely on the interaction among winter conditions, habitat availability, and habitat use. Future work exploring fish-habitat associations during winter in the Ohio River will begin to lend insight into these important issues.

Table 1-1. Predicted habitat used by fish species commonly found in the Ohio River during winter.

		Performance at < 4°C			Winter Habitat Use	
Species	Survival	Swimming Ability	Low oxygen	Activity/ Foraging	Upper River	Lower River
Largemouth Bass*	Medium	Low	Low	Low	Backwater	Backwater/ Channel
Channel Catfish*	High	Medium	Medium	Medium	Backwater/ Channel	Backwater/ Channel
Crappie*	Medium	Low	Low	Low	Backwater	Backwater/ Channel
Walleye	High	High	Low	Medium	Backwater/ Channel	Backwater/ Channel
Bluegill*	Low	Low	Low	Low	Backwater	Backwater/ Channel
White Bass*	Low	Low	N/A[a]	Low	Backwater	Backwater/ Channel
Freshwater Drum*	Low	Low	Low	Low	Backwater	Backwater/ Channel
Gizzard Shad*	Low	Low	Low	Low	Backwater	Backwater/ Channel
Carp*	High	Medium	Medium	Medium	Backwater/ Channel	Backwater/ Channel
Sturgeon/Paddlefish*	High	High	N/A[a]	High	Open Channel/ Channel	Open Channel

[a] Not Available

*Species encountered during winter 2002-2003 sampling

Chapter 2 – Smithland Pool Field Sampling 2001-2003

James E. Garvey, Benjamin J. Braeutigam, Andrew T. Plauck,
and Kathryn A. Emme
Southern Illinois University Carbondale

Introduction

Winter is a critical period in which high mortality occurs in fishes (Oliver et al. 1979; Cunjak 1996; Garvey et al. 1998). Many temperate fishes undergo a torpor-like state when exposed to prolonged cold temperatures and short days (Crawshaw 1984) and, as such, may be highly susceptible to vessel-passage induced displacement from velocity shelters. Because the Ohio River extends through mid-temperate latitudes, inter-annual variability in winter temperature may translate to highly variable responses of fish populations to acute abiotic perturbations (see Garvey et al. 1998) such as changes in flow velocity and flow direction with navigation. Laboratory (Sheehan et al. 1990; 2000a) and field studies (Sheehan et al. 1990b; Logsdon 1993; Johnson et al. 1998) showed that a number of Mississippi River fishes overwinter in stratified backwater areas, when they have access to them, or in low velocity areas in channels. Relatively small (0.08 to 0.16 $m \cdot s^{-1}$) velocity changes, such as those that can be induced by vessels, can displace small bluegill and channel catfish from low velocity habitats when water temperatures are low (1 to 4 ^{o}C) (Sheehan et al. 2000b). If fish are displaced into flowing channels at such temperatures, mortality will probably increase (Bodensteiner and Lewis 1994; Sheehan et al. 2000a).

In this chapter, we describe research conducted in Smithland Pool, Ohio River during winters 2002 and 2003 to determine the habitat use of fish and to assess the relative vulnerability of species and habitats to potential displacement by barge traffic. Fish were sampling with variable-depth AC electrofishing. Their relative abundance was then analyzed as a function of water quality parameters quantified at each site and sampling date.

Study Site

Smithland Pool was created by the formation of Smithland Lock and Dam in 1981. It is 115 km long and 11,134 ha at normal pool. After Smithland Lock and Dam was completed, water levels rose 5 m. Twenty six tributaries enter the pool, with the Wabash and Saline Rivers being the largest. Smithland Pool is currently the last pool of the Ohio River, with open river extending the reminder of its length to the confluence with the Mississippi River.

Methods and Approach

Habitat Assessment

During November 2001 we selected thirty sampling sites in the Smithland Pool of the Ohio River. These sites were selected to represent the five main macrohabitat types found in this section of the river (artificial, backwater, island, main channel, and tributary). Due to the scarcity of backwater habitat in the Smithland Pool, we combined backwater and island sites into one habitat category to represent the areas upstream, downstream, and on the non-channel side of islands (now called "Island"; Table 2-1). Main channel sites were typically located at areas with submerged boulders and other submerged structures that provide potential velocity shelters (Table 2-2). The sites were divided equally between the upper and lower halves of the pool and were stratified relative to habitat type abundance in these halves (Table 2-2, Figure 2-1). During both 2002 and 2003, the abiotic characteristics of each site (specific conductance, dissolved oxygen, flow, secchi depth, and temperature) were quantified during each sampling trip with a Hydrolab Quanta water quality meter. Dissolved oxygen-temperature profiles were taken at each site. Quantities presented herein are water column averages, because neither temperatures nor dissolved oxygen concentrations varied by more than about 1% from the surface to the bottom at all sites and dates (i.e., stratification was absent). Six hobo-temp temperature-data recorders were placed in the pool near the bottom during both years. We also obtained daily discharge data during the study period from a USGS gauging station at Metropolis, Illinois.

Objective 2: Winter Fish Sampling

During 2002 and 2003, we used variable-depth, three-phase AC electrofishing (Multiquip 5000- watt generator with Honda motor) to quantify the habitat-specific relative abundance, species composition, size structure, and age structure of fishes in Smithland Pool during mid winter through late spring. The AC electrofisher consisted of three weighted electrodes that were lowered to a desired depth (usually 5-9 m). Current output typically ranged between 7-10 amps.

Sampling session 1 of the first sampling year occurred during January 2002. Session 2 of year 1 was conducted during late February through early March 2002. The third sampling session of year 1 was completed in June 2002. During the second sampling year, we sampled a small number of sites during fall 2002, although conditions deteriorated rapidly, thereby preventing us from including these data in most analyses. The first full sampling session of year 2 (i.e., henceforth session 1, 2003) was completed during February through March 2003. The second session of year 2 was conducted in April 2003. The third session occurred during June 2003. Unavoidable factors during 2002 (elevated water levels, high flow rates, and extremely low conductivity) hindered sampling four sites during session one and two sites during session two (see Figure 2-2). Spring flooding delayed the third sampling effort during year 1 (Figure 2-2, upper panel). Similarly, during 2003, adverse conditions prevented sampling of most artificial sites during session 1 and nearly all sites during session 2 (Figure 2-2, bottom panel).

Sampling of all sites consisted of thirty minutes of non-continuous pedal time when possible. We idled backwards down-river to keep the probes at desired depths (5-9 m) beneath the boat. When possible, we distributed sampling effort at each site across two or three transects stratified across different depths. Sites that covered only a small area or contained high densities of fish were sampled during a shorter time. Fish collected were either taken back to the laboratory or measured in the field to the nearest 1 mm and released. All freshwater drum (*Aplodinotus grunniens*), channel catfish (*Ictalurus punctatus*), white bass (*Morone chrysops*), and crappie (*Pomoxis* spp.) were frozen and processed in the laboratory as per the approved scope of work. We grouped black crappie (*Pomoxis nigromaculatus*) and white crappie (*Pomoxis annularis*) into a single generic category. Because our sampling during year 1 revealed that blue catfish were abundant in Smithland Pool, we also collected individuals of this species for analysis during year 2. In the laboratory, the four target species and blue catfish were weighed (to the nearest 1 g) and measured (to the nearest 1 mm). Otoliths (and pectoral spines for catfish) were then removed for age determination. Two readers independently read all structures. For age estimates that were not in 100% agreement, readers consulted until agreement was met. If the readers could not agree, the structure was dropped from the analysis. We also removed stomachs of a size-stratified sample of freshwater drum from the two winter sampling sessions during year 1 to determine whether foraging occurred during winter.

Results

General Patterns Both Years

Our reconnaissance of habitat in Smithland Pool suggests that low velocity, deep-water areas that may provide shelter for fish during winter are quite limited, particularly given the lack of extensive backwater habitats. Discharge was typically high during winter through late spring of both years (Figure 2-2). During both winters, we were only able to sample during three relatively short periods of low discharge and low gage height (Figure 2-2). During the remainder of both winters, water levels were typically 3-6 m above that conducive to effective, safe sampling (Figure 2-2). Only one temperature recorder was successfully retrieved from the bottom of Smithland Pool during 2002 and no loggers were retrieved during 2003. The one logger that was found revealed that temperatures declined to 4^{o}C during a brief period in early January 2002 and then remained 5-7^{o}C through the second sampling session (Figure 2-3, upper panel). During mid-May through June 2002, temperatures rose, exceeding 25^{o}C by the end of sampling session 3 (Figure 2-3, upper panel).

Because all of our loggers were lost in 2003, we obtained daily water temperatures from the Shawnee Fossil Power Plant below Smithland Dam (Figure 2-3, bottom panel). These temperatures are quantified at a fixed level that is near the surface at normal flow. The logger's daily temperatures were related to that of the power plant (R^2=0.88, slope= 1.08), suggesting that the temperatures obtained from this source during

2003 reflected those occurring in the pool. However, surface temperatures were more variable than those at the bottom during winter (particularly at surface temperatures 5-15°C; Figure 2-3, bottom panel) revealing that temperatures at the bottom of Smithland Pool appeared to be more stable during this time. Daily temperatures from the power intake suggest that temperatures were likely near zero in Smithland Pool during the first sampling session of 2003. Temperatures were 11-12 °C during the second session and averaged 20 °C during the third session.

Water Quality

<u>2002 Conditions</u>

During sampling session 1 of 2002, mean water column temperatures ranged from 2.58 to 4.62 °C across sites (Table 2-3). Mean dissolved oxygen for the first session of this year ranged from 4.92 to 7.52 mg/L (Table 2-3). Sites during the first session had low flow rates with many (N=14) having no measurable flow (Table 2-3). Conductivity for five of the seven tributary sites sampled was lower than artificial, island, or main channel sites with values as low as 0.213 mS/cm (Table 2-3). Aside from those tributary sites, remaining conductivity values ranged between 0.500 and 0.700 mS/cm (Table 2-3). Water temperatures in session 2 of 2002 were warmer, ranging between 5.39 °C and 9.75 °C (Table 2-4; Figure 2-3). This wide range of temperatures may be attributed to varying factors (such as a longer sampling period, increased flow rates, and weather events). Dissolved oxygen during session 2 of this year ranged from 4.64 to 7.12 mg/L (Table 2-4). Flow rates during session 2 of 2002 were higher than in session 1 at 13 sites (Table 2-4; also see Figure 2-2). Twenty-two sites in session 2 had lower conductivity than during session 1 (Table 2-4). By June 2002, water temperatures were higher and dissolved oxygen concentrations were lower in all sites relative to the other sampling dates (Table 2-5). Dissolved oxygen concentrations in tributaries were lower than in the other sites. In fact, several of the tributary sites were inaccessible due to low flow and low water depth.

To summarize conditions during winter 2002, sites could be characterized by flow, temperature, dissolved oxygen, specific conductance, and secchi depth during the coldest sampling session in January, although they did not separate by our habitat type definitions. Through the entire season, temperatures increased in all sites (Table 2-6). Mean dissolved oxygen declined more in tributaries than in other sites by spring 2002 (Table 2-6). Water clarity declined as average flow rates increased in the sites associated with the main channel (but not the tributaries) during late winter through late spring (Table 2-6). These results suggest that the tributary sites became more physically distinct (i.e, lower flow and oxygen) than those associated with the main site during late winter through spring (Table 2-6).

2003 Conditions

During the 2003 sampling session 1, temperatures were typically low (< 3°C) at all sites (Table 2-7; Figure 2-3). Higher temperatures at tributary site are due to the relative late sampling (mid March) of these sites relative to the main channel ones (mid February), a consequence of the high discharge and frequently truncated sampling effort. Dissolved oxygen concentrations during session 1 of 2003 were high at all sites (Table 2-7). Flow rates were higher at island and main channel sites, resulting in lower water clarity than in the tributary sites (Table 2-7). Specific conductance during session 1 was lower in tributaries than in sites associated with the main channel (Table 2-7). Persistent, high discharge during sampling session 2 of 2003 made sampling difficult, and only a subset of sites were sampled. Conditions were similar among all sites during session 2, although flow was much lower (or zero) in tributaries (Table 2-8). By June through early July 2003, flow was near zero in tributaries and dissolved oxygen concentrations were low (Table 2-9). In other sites, flow rates and dissolved oxygen concentration were higher, with lower water clarity (Table 2-9).

In summary, water quality and flow patterns during our 2003 sampling were similar to those during winter 2002. Chronically high discharge rendered sampling challenging. Temperatures increased during the season, with dissolved oxygen concentrations declining more in tributaries than at other sites associated with the main channel (Table 2-10). Tributary sites during 2003 again became more distinct as the year progressed, although they typically had lower flow, higher water clarity and lower dissolved oxygen concentrations (Table 2-10).

Winter Multivariate Analysis

Because this was the coldest period during winter, we further explored abiotic characteristics of sites during 2002 and 2003 with principle components analysis (PCA), including temperature, dissolved oxygen concentration, secchi depth, flow rate, and conductivity in the analysis. The first two principle components explained 70% of the variance in the data. Principle component 1 had strong positive associations (eigenvectors > 0.4) with secchi depth and negative associations with flow and dissolved oxygen (Figure 2-4). Principle component 2 was negatively associated with temperature and dissolved oxygen and positively associated with specific conductance (Figure 2-4). Sites clustered somewhat by our defined habitat types (i.e., artificial, island, main, and tributary; Figure 2-4). Tributary sites typically sorted out on the right side of the ordination plot, which corresponded with low dissolved oxygen, high secchi depths, and low flow (Figure 2-4). The four tributary sites in the lower right-hand quadrant of the plot are those that were sampled relatively late during winter 2003, and thus had higher temperatures than other sites (Figure 2-4). Three other clusters of sites occurred that did not appear to be closely related to out habitat delineations, although most were associated with the main channel. Typically all these sites corresponded with high conductivity and low temperatures but were probably separated primarily by flow and dissolved oxygen concentration (Figure 2-4). The two main channel sites clustered in the upper left quadrant of the plot were characterized by high flow, high dissolved oxygen, and cold temperatures (Figure 2-4). Artificial sites that created deep scour holes appeared to be intermediate in characteristics between tributaries and the main channel (Figure 2-4). These results suggest that sites do differ in abiotic characteristics during winter. If we understand species-specific requirements during winter, then these sites might be categorized for management.

Winter Fish Assemblages- Annual Patterns

Fish 2002

Samples from session 1 in January 2002 were dominated by freshwater drum (N= 333) and blue catfish (*Ictalurus furcatus*) (N= 58), accounting for > 89% of fish captured (Tables 2-11 through 2-13). Only two other species, emerald shiner (*Notropis atherinoides*) (in the island habitat type) and crappie (in the tributary habitat type), accounted for > 5% of the catch for any given habitat type (Table 2-12). Overall catch per unit effort (CPUE) was highest in artificial habitat types (60.30 fish per hour) followed by main channel (49.50 fish/hr), tributary (44.65 fish/hr), and island (38.57 fish/hr) (Table 2-13). Tributary sites contained the most species (N=11) whereas the main sites contained only freshwater drum (Table 2-13). Artificial and island sites adjacent to the main channel contained intermediate numbers of species including channel catfish, blue catfish, and gizzard shad (Table 2-13).

Patterns for sampling session 2 during February through March 2002 were similar to those for session 1 of that year. Freshwater drum (N= 514) and blue catfish (N= 334) (Tables 2-14 through 2-16) accounted for > 97% of all fish captured during this session (Table 2-15). Island and tributary habitats contained far fewer fish (23.14 fish/hr and 36.92 fish/hr respectively) than did artificial and main channel habitats (110.53 fish/hr and 176.67 fish/hr respectively) (Table 2-16). Catch rates at the artificial and main channel sites were much higher than those at the same sites during session 1. Three sites (one tributary site from session 1 and one artificial and one island site from session 2) were excluded from these results due to extremely high catch rates (primarily consisting of freshwater drum and blue catfish). The number of species found in tributaries declined to eight during session 2 (Table 2-16). Channel catfish, blue catfish, and gizzard shad were captured in addition to freshwater drum at main sites during this time (Table 2-16). Artificial and island sites again contained intermediate numbers of species (Table 2-16), with blue catfish dominating catches in artificial sites.

By June 2002, total catch rates had declined at all sites (1.50 – 5.00 fish/hr; Tables 2-17 through 2-19). Although still dominant in the catch, freshwater drum and blue catfish only comprised about 71% of species captured (Table 2-18). Most of this decline occurred because catch rates in artificial and main sites declined (Table 2-19). Twelve species were sampled with channel catfish and gizzard shad becoming more prevalent;

only two species occurred in tributaries. Freshwater drum were absent and gizzard shad were abundant in tributary sites during this time (Table 2-19).

In summary for 2002, freshwater drum and blue catfish were the most abundant species sampled (Table 2-20). The majority of fish were associated with scour areas near artificial habitats (Table 2-20). Main channel sites produced the second highest number of fish (Table 2-20). It is important to note that this interpretation does not incorporate relative effort at each site. We will explore these issues in depth in a future section below.

Fish 2003

During February through March of 2003, freshwater drum and blue catfish dominated samples, accounting for 92% of fish captured (Tables 2-21 through 2-23). Other species that were moderately abundant in samples included goldeye, channel catfish, and smallmouth buffalo (Table 2-22). Overall catch per unit effort (CPUE) was highest in main channel sites, largely due to the high densities of freshwater drum (Table 2-23). CPUE in artificial and island habitats were equivalent, whereas tributary catch rates were quite low (Table 2-23). Artificial sites contained the most species (N=11) and tributary contained the least (N=4).

During session 2 of 2003, total number of species sampled were much lower, (Tables 2-24 through 2-26), largely due to our truncated sampling. Again, blue catfish and freshwater drum were the most abundant, primarily in artificial habitats (Table 2-26). The number of species captured was much lower (N=4 artificial, N=3 island, N=4 main, N=2 tributary).

Total catch rates were still low in June 2003, although our effort was much greater. Blue catfish were the dominant species captured, with freshwater drum being less abundant (Tables 2-27 through 2-29). These two species again accounted for the majority (89%) of species sampled. Overall CPUE was much lower than the session 1, 2003 sample, although catch rates were still highest in main channel and artificial sites (Table 2-29). Species richness was again much lower than during the first sampling session of 2003 with a maximum of six species sampled in the artificial and main sites and only two in tributaries.

As in 2002, freshwater drum and blue catfish were the most abundant species at our sites (Table 2-30). Again, artificial sites followed by main channel ones harbored the highest number of fish (Table 2-30). The composition of species differed somewhat from 2002, but the total number of species sampled was the same between years (N= 19 each year).

General Fish Assemblage Patterns

To explore the effect of date and habitat type on habitat use by the three most common species (freshwater drum, blue catfish, and channel catfish), we combined the fish CPUE data across the two years and conducted a two way ANOVA (main effects: date and habitat). For freshwater drum, both session ($F_{2,98}$=7.48, P=0.001) and habitat ($F_{3,98}$=7.67, P=0.0001) affected CPUE, which likely occurred because overall CPUE declined through the season and CPUE was consistently higher in main channel habitats (Figure 2-5, upper panel). For blue catfish, neither habitat nor date affected CPUE (Figure 2-5, middle panel). However, it is important to note that catch of blue catfish was consistently low in tributaries (Figure 2-5). Channel catfish CPUE was only affected by habitat ($F_{3,98}$=5.12, P=0.002), which likely occurred because abundances were consistently higher in main and island sites (Figure 2-5, lower panel).

We conducted a species assemblage PCA for each year to further explore how habitats differed among sampling dates. Only the 2002 analysis produced interpretable patterns. And in this analysis, the first and second principle components only explained 45% of the variance in the data set, suggesting that differentiating species assemblages by our site designations only weakly captured the variation in the data. Significant loadings did not occur for any of the abundant species such as freshwater drum, blue catfish, and channel catfish, perhaps because they were present in all sites during some dates. Species expected to reside in tributary sites were indeed associated with tributaries during the January and February-March 2002 sampling sessions (Figure 2-6). In January, tributaries were characterized by relatively high catches of flier, crappie, redear sunfish, and spotted bass (right upper quadrant, Figure 2-6). By session 2 of 2002, bluegill, longear, and warmouth were more closely associated with tributaries (lower left quadrant, Figure 2-6). By June, the tributary sites were more similar to the cluster of main, island, and artificial sites (upper left, Figure 2-6). This analysis suggests that tributaries had different assemblages (more lentic type species) than main channel sites during winter. This distinction declined by June 2002, perhaps as dissolved oxygen concentrations declined in the deeper waters of tributaries and most species moved into shallower water. Recall, richness of these tributary sites declined by June (Table 2-19).

To further explore relationships among species abundances, sites, and abiotic characteristics during the winter 2002 and 2003 sampling sessions, we used another ordination technique, non-metric multidimensional scaling (NMS). Only the three most abundant species (freshwater drum, blue catfish, and channel catfish) were included in the analysis. As with the PCA, no structure was found in the 2003 data set, so we only present the results for the 2002 analysis (PC ORD, using the Sorenson distance measure). Abiotic characteristics had little influence on the data structure during winter 2002. However, we did find insightful associations between species and habitats. Blue catfish clustered with artificial sites (Figure 2-7). As our ANOVA (see above) demonstrated, freshwater drum were more closely associated with main channel habitats, whereas channel catfish appeared to cluster with island sites (Figure 2-7).

Body size may influence the habitat used by fish. Across all of the sites, no apparent pattern of size-specific habitat use arose, with the exception of freshwater drum during both 2002 and 2003 (Figure 2-8). When freshwater drum were present in the tributaries, average sizes were smaller than those of counterparts in the main channel sites. These small freshwater drum were absent from tributaries by late spring. We generally confirmed this interpretation with a two way ANOVA including data from the first two sampling sessions each year. For 2002, neither session nor habitat appeared to effect size of freshwater drum. However, in 2003, both session ($F_{1,19}$=6.89, P=0.02) and habitat ($F_{3,19}$=48.28, P=0.0001) did affect mean size of freshwater drum, with sizes being much smaller in tributaries.

By combining data for both years, we explored how species richness changed with abiotic factors in each habitat type. Because our power was low, we used an alpha of 0.1 as our cutoff for significance in our linear regressions. Species richness declined with increasing temperature at both island and tributary sites and remained unchanged in the artificial and main channel habitats (Figure 2-9). At only the island sites was species richness positively related to dissolved oxygen concentration (Figure 2-10), with no other apparent relationships occurring. Flow only appeared to affect richness in tributary sites, with the highest richness occurring when tributaries had moderate flow (Figure 2-10).

Species-Specific Patterns

The five species targeted for in-depth analysis were freshwater drum, channel catfish, black/white crappie, and white bass. During 2003 we added blue catfish. During 2002, average lengths of channel catfish were greater than those of the more abundant blue catfish (Table 2-20). Freshwater drum averaged 212 mm (Table 2-20). Average size of the six white bass caught was 277 mm (Table 2-20). During 2003, average lengths of channel catfish were again greater than those of blue catfish (Table 2-30). Average size of freshwater drum during 2003 was similar to 2002 at 239 mm (Table 2-30). Age ranges differed among species (Figure 2-12). Ages of freshwater drum spanned 28 years (Figure 2-12). Individuals of the other three species were never older than 12 years (Figure 2-12). The von Bertalanffy length at age relationship was $L=708(1-\exp(-0.094(t+1.06))$ for freshwater drum. For channel and blue catfish, growth did not appear to decline during later years, suggesting that we did not capture the oldest individuals in the population. Supplemental sampling, perhaps using different gear types (e.g., gill nets, fyke nets), is needed to collect more channel catfish, crappie, and white bass to generate robust age and growth information.

During the two winter sampling sessions, lengths of freshwater drum ranged from 80 to 700 mm, with an average of 205 mm (Figure 2-13). By June 2002, total catch rates declined and small, young individuals < 200 mm were absent from our catch (Figure 2-13). The same pattern occurred during fall 2002 through late spring 2003 (Figure 2-14). Using analysis of covariance (ANCOVA) in which length was the covariate and sampling session was the main factor, we found that these regression lines differed among sampling sessions (ANCOVA: $P < 0.05$), with the intercept declining by June. For both years, we computed relative weight (W_r) for freshwater drum, finding that these values ranged widely between 70 and 150% (Figures 2-15 and 2-16). Although fits were poor ($R^2<0.07$ for most sessions), regression revealed that W_r increased slightly with length ($P<0.05$, both regressions) during the first two sessions of 2002 (Figure 2-15) and during February and April of 2003 (Figure 2-16). By June of both years, condition was unrelated to length (Figure 2-15 and 2-16). Small freshwater drum had a lower proportion of empty stomachs than large counterparts during the two cold winter sessions (Figure 2-17). Of the 28 individuals that contained food, 53%, 11%, and 35% contained mayfly larvae, mollusk/gastropods, and crayfish, respectively.

Channel catfish sizes ranged from 150 – 650 mm total length during winter through late spring 2002 and 2003, with two apparent age classes dominating the distribution in 2002 and one in 2003 (Figures 2-18 and 2-19). Relative weight did not vary with length during 2002 (Figure 2-20). In 2003, relative weight only increased with length during the last sampling session, although this was the only session in which fish > 600 mm were sampled (Figure 2-21). Average condition was 102 in 2002, ranging from 80 to 130 (Figure 2-20). In 2003, average condition was 87 (Figure 2-21), lower than 2002.

In contrast to freshwater drum, blue catfish length frequency distributions did not change appreciably during the winter through spring in 2002 or 2003 (Figures 2-22 and 2-23). Because standard weight equations are not readily available for blue catfish, we conducted an ANCOVA on length-weight relationships to compare growth during each session of each year (Figures 2-24 and 2-25). During both 2002 ($P=0.0001$) and 2003 ($P=0.0001$), intercepts but not slopes differed among sessions, suggesting that average fish weights changed during the year. During both years, the intercepts declined through the year, suggesting that weight declined as the winter progressed, although the biological relevance of this change is uncertain (Figure 2-24 and 2-25).

Discussion

Unlike the upper Mississippi River in which extensive backwater systems provide wintering habitat for fishes, our field reconnaissance of Smithland Pool revealed that this portion of the Ohio River does not contain these habitats. Rather, deep-water, low velocity, and high temperature sites in this system often required by fish during winter (see Chapter 1) may be associated with the island, artificial scours, and tributary sites. Unlike backwater habitats in other systems, our sites generally did not stratify because oxygen concentrations and temperatures were similar throughout the water column. Understanding how these sites provide shelter both from negative winter conditions as well as from potential displacement by navigation is paramount for predicting the impacts of increased navigation traffic or climate change.

Results generated during January through June 2002 and during a similar period in 2003 suggest that sites associated with the main channel (including the artificial and island areas) often differ subtly in their abiotic conditions during winter. Tributary sites fell out as distinct during winter, with low flow, high clarity, and low oxygen. Even given the subtle physical differences that emerged, most sites had relatively warm temperatures ($\geq 4^{o}$C), low flow rates, and moderate dissolved oxygen concentrations relative to northern rivers in which channel temperatures reach much lower temperatures and higher flow velocities during winter (Chapter 1). Still, subtle differences among sites in Smithland Pool did affect fish abundance. Species exhibited some site-specific habitat use. And, finally, we could only sample during rare periods of low discharge, although flow rates in the main channel were frequently much greater than those we quantified.

Thus, species habitat use we quantified may reflect much greater differences in flow among sites during times when we could not sample. To gain more resolution about how these sites contribute to fish habitat preference and influence susceptibility to navigation, more complete physical information through time is necessary to determine how physical characteristics vary on a daily basis.

We selected variable depth electrofishing to sample fishes in deep-water sites. In backwaters of the Mississippi River during winter, this technique was non-selective for a wide range of fish species (Sheehan et al. 1990). The total number of species sampled with this technique across sites in Smithland Pool was low relative to Sheehan et al. (1990), with freshwater drum and blue catfish occurring most frequently. To effectively determine if these two species were simply numerically dominant at these sites or if this technique is selective for them, we must compare the catch composition of variable-depth electrofishing with that generated by gill nets and trap nets at several sites A pilot study has been conducted behind chevron dikes in Pool 25 of the upper Mississippi River, where colleagues and I have compared variable depth electrofishing with Missouri trawls and purse seines during December 2002. We found species assemblages similar to those in Smithland Pool. All gears produced generally the same sizes and relative abundances of fish species.

Freshwater drum, channel catfish, and perhaps blue catfish should swim well at moderately low main channel temperatures (2-4°C; Chapter 1), potentially explaining their ubiquitous presence during the entire winter. For freshwater drum, small individuals were present in tributaries in which flow was lower. This apparent size-specific partitioning of habitat may be related to differences in tolerance to differences in flow and temperature between tributaries and the main channel (Chapter 1). It is important to note that our measurements of flow were taken near the surface, although fish were near the bottom. Hence, our estimates of flow may not accurately reflect the flows experienced by the fish. Future work will involve using an acoustic doppler current profiler recently acquired by the Fisheries and Illinois Aquaculture Center at SIUC to explore how flow varies at these bottom sites. We also must determine how flow changes throughout the water column during and after vessels have passed in proximity to these potential overwintering sites (see Executive Summary, Figure 1 for some preliminary findings).

We would expect greater use of the artificial scour areas in the main channel if these sites were used for refuge. Blue catfish appeared to have some association with these sites, although other species were infrequent. Although we might expect main channel areas to be exposed to displacement from barges or high flow, freshwater drum use of these sites was high during both years and only declined by late June, suggesting that these sites are preferred during cold months, perhaps due to enhanced foraging opportunities. Channel catfish use of the main channel and island sites was consistently high during both years. Why these species showed different apparent preferences for these habitats can only draw speculation, but this pattern was consistent between years and likely is related to the species-specific interactions between flow, temperature, and perhaps food availability. Overall abundance of fish declined with increasing temperature. This may be expected if many species using deep-water habitat during winter dispersed to different depths as temperatures increased.

Quantifying the number of species encountered at a site (i.e., richness) is another approach for estimating use. Physical factors at sites did appear to affect general use by species, with tributary and island backwater sites showing the most change. Species richness increased in both island backwater and tributary sites with declining temperatures, suggesting that these areas might provide a refuge for species as temperatures decline. Flow rates at both of these sites were consistently lower than those in the main channel, supporting this view. Interestingly, species richness increased in tributaries with a slight increase in flow in these areas. These flow rates were still much lower than those in the main channel. Thus, the increase in species use with increased tributary flow may be related to an increase in connectivity of these areas with the main channel. Although we would expect fish species use in tributaries to be strongly tied to the low dissolved oxygen concentrations that often occurred at these sites, this did not occur. Fish species richness was only consistently low in tributaries when dissolved oxygen concentrations were less than 5 mg/L.

Body condition (i.e., relative weight) of freshwater drum was positively related with size and did not change during the winter sessions of 2002 and 2003. However, condition did decline by late spring, perhaps because individuals had expended energy for spawning. Other species such as channel catfish, white bass, and crappie had high relative weights during the study period. Relative weight often corresponds well with fat content in fishes. If this holds true for these populations, then these fish were likely consuming sufficient food to offset energetic costs of overwintering. Foraging did occur in freshwater drum, although it was size dependent. Smaller individuals foraged more frequently than large counterparts, perhaps because these individuals (which had lower condition values) required more energy intake to offset higher mass-specific metabolic rates and lower fat reserves.

Size distributions did change during winter in consistent ways during the two sampling years. Small freshwater drum were predominant in distributions during the winter but declined by the late spring/summer sampling. Distributions of blue catfish, the other species for which we have sufficiently abundant size data, changed little during the sampling sessions. Potentially, small freshwater drum are moving from deep water and tributary habitats to forage in other habitats as temperatures increase. A contrasting interpretation would be that small individuals suffered higher mortality by late spring. However, condition of all individuals was high and thus does not support size-dependent winter mortality. All sizes of blue catfish appear to remain at sites that we sampled during winter through late spring/early summer.

Summary

Relative to late spring, fishes were more abundant in relatively rare, tributary or deep-water scour areas adjacent to the main channel when temperatures were < 10^{o}C (expectations are outlined in Chapter 1). Fish assemblages in tributaries did differ from the main channel sites during winter, primarily because species that typically occupy more lentic systems were only present in tributaries (particularly in 2002). High catch rates at deep-water artificial sites and in the main channel during winter suggest that these sites are quite important for some species, including the commercially important blue catfish. During cold months, fish using sites adjacent to or directly in the main channel with low velocity refuges may be subject to displacement by barge traffic. As such, we would expect that survival of species that use these areas will be compromised by navigation. Both winter through spring 2002 and 2003 were characterized by high flow and relatively mild temperatures. Future research must explore how site-specific flow rates, temperatures, and fish use of these areas change as a function of different winter conditions (e.g., a more severe, dry winter) and proximity to navigation traffic (see

Executive Summary).

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Table 2-1. Sites selected for sampling during winter through late spring 2002 in the Smithland Pool of the Ohio River.

Habitat Type	Description
Main Channel	Area extending from shore including the center of the channel.
Island/Backwater	Area between an island and the shore. May be closed at one end of the channel (i.e., creating a flow break).
Artificial Flow Break	Artificial structures such as wing dams and moorings that create relatively deep scour holes; includes lock and dam complexes
Tributaries	Streams that flow into the main channel.

Table 2-2. Sampling sites in the Smithland Pool of the Ohio River during winter through late spring 2002 and 2003.

Habitat Type	Site (#)	Location in Pool	Site Description	Mean Depth (m)	River Mile	Location N	Location W
Artificial	14	Upper	Scour adjacent to J. T. Meyers Lock and Dam	7.6	846	37.47373	87.59593
	15	Upper	Scour behind submerged wingdam on the non-channel side of Wabash Island	7.6	850	37.46600	88.00766
	43	Upper	Scour behind submerged wingdam	7.6	875	37.47103	88.10740
	54	Upper	Scour behind submerged wingdam	9.1	883	37.45419	88.19456
	2	Lower	Scour downstream from an abandoned boat ramp	7.6	902.7	37.36623	88.48194
	61	Lower	Scour behind submerged wingdam	7.6	904.5	37.33731	88.48140
	62	Lower	Scour behind submerged wingdam on the non-channel side of Pryor Island	9.1	905.5	37.32228	88.48333
	66	Lower	Scour behind submerged wingdam	10.7	906.3	37.31522	88.49349
	63	Lower	Scour behind submerged wingdam	10.7	907	37.30203	88.50331
	64	Lower	Scour behind submerged wingdam	9.1	907.3	37.29828	88.50535
	65	Lower	Scour behind submerged wingdam	10.7	907.5	37.29581	88.50651
Island	13	Upper	Non-channel side of the first island upstream of Shawneetown Bar	6.1	855	37.43134	88.05804
	20	Upper	Non-channel side of Cincinnati Island	6.1	860	37.39384	88.09156
	53	Upper	Non-channel side of Cave In Rock Island	6.1	880.5	37.46170	88.15633
	30	Upper	Between Hurricane Island and unnamed island immediately downstream	4.6	889.5	37.43806	88.30481
	25	Lower	Non-channel side of Rondeau Island	6.1	901	37.37595	88.46862
	23	Lower	Non-channel side of Pryor Island	6.1	905	37.31287	88.49214

	11	Lower	Non-channel side of the first Sisters Islands	7.6	909	37.27226	88.50574
Main	70	Upper	Numerous submerged boulders near main channel immediately	7.6	869	37.55687	88.10599
	42	Upper	Scour downstream of a sand bar	7.6	878	37.48793	88.07469
	40	Upper	Sheer rock wall exposed to main channel	9.1	880	37.46892	88.14976
	27	Lower	Numerous submerged boulders near main channel	6.1	894.3	37.40544	88.37815
Tributary	22	Upper	Saline River	7.6	867	37.57049	88.12529
	34	Upper	Big Creek	6.1	889.5	37.44280	88.31506
	29	Lower	Deer Creek	4.6	893	37.39818	88.35518
	28	Lower	Small unnamed tributary	3	893.7	37.39668	88.36796
	35	Lower	Threemile Creek	3.1	896	37.42156	88.39661
	37	Lower	Grand Pierre Creek	6.1	897.6	37.42150	88.42973
	1	Lower	Lusk Creek	6.1	902.5	37.37155	88.48615

Table 2-3. Water quality data for each site of the Smithland Pool of the Ohio River during session 1 (January 2002).

Habitat Type	Site (#)	Temperature (C)	Dissolved oxygen (mg/l)	Secchi (cm)	Flow Rate (m/s)	Conductivity (mS/cm)
Artificial	14	3.87	6.98	53	0	0.526
	15	3.81	7.12	51	*	0.526
	43	*	*	*	*	*
	54	4.36	6.84	77	0.18	0.594
	2	4.32	7.15	79	0.1	0.545
	61	4.23	7.07	69	0.2	0.592
	62	3.98	7.08	65	0	0.574
	66	4.14	7.15	73	0.2	0.59
	63	3.8	7.28	67	0	0.574
	64	3.79	7.26	66	0	0.575
	65	3.79	7.22	67	0	0.575
Island	13	2.58	7.5	39	0.05	0.646
	20	4.29	7.41	46	0.2	0.532
	53	4.49	6.91	63	0	0.587
	30	*	*	*	*	*
	25	4.32	7.12	65	0.2	0.592
	28	3.51	6.4	98	0	0.376
	11	3.7	7.28	64	0	0.573
Main	70	4.62	7.49	60	0.18	0.611
	42	*	*	*	*	*
	40	4.35	7.01	80	0.2	0.629
	27	*	*	*	*	*
Tributary	22	4.53	7.52	63	0	0.651
	34	2.8	5.85	157	0	0.373
	29	3.6	5.7	104	0	0.363
	23	4.19	7.38	59	0.25	0.56
	35	3.48	5.32	83	0	0.378
	37	3.68	5.34	123	0	0.266
	1	3.8	4.92	131	0	0.213

* Not available due to site inaccessibility or equipment failure.

Table 2-4. Water quality data for each site of the Smithland Pool of the Ohio River during session 2 (February through March 2002).

Habitat Type	Site (#)	Temperature (C)	Dissolved oxygen (mg/l)	Secchi (cm)	Flow Rate (m/s)	Conductivity (mS/cm)
Artificial	14	7.72	6.12	45	0.08	0.436
	15	7.59	6.05	46	*	0.435
	43	8.94	5.69	16	0.22	0.498
	54	5.78	6.99	50	0.2	0.492
	2	6.64	6.73	34	0.02	0.499
	61	7.73	6.11	19	0.3	0.488
	62	6.51	6.76	34	0.1	0.446
	66	7.54	6.1	19	0.6	0.5
	63	7.51	6.18	21	0.2	0.5
	64	6.84	6.68	38	0.02	0.458
	65	6.52	6.49	41	0.02	0.458
Island	13	8.81	5.41	14	0.14	0.476
	20	7.47	6.36	31	0.1	0.441
	53	6.12	7.11	41	0.05	0.482
	30	7.82	6.68	48	1.1	0.514
	25	7.64	6.38	18	0.1	0.48
	23	*	*	*	*	*
	11	6.62	6.83	28	0.2	0.45
Main	70	9.75	5.12	18	0.22	0.552
	42	8.85	5.62	16	0.02	0.498
	40	5.39	7.12	32	0.2	0.568
	27	7.51	7.06	35	0.6	0.516
Tributary	22	7.76	5.51	23	0.04	0.654
	34	7.97	5.45	31	0	0.344
	29	8.77	4.64	35	0	0.253
	28	8.62	5.96	33	0	0.31
	35	8.61	5.01	19	0	0.291
	37	7.24	6.23	34	0	0.233
	1	*	*	*	*	*

* Not available due to site inaccessibility or equipment failure.

Table 2-5. Water quality data for each site of the Smithland Pool of the Ohio River during session 3 (June 2002).

Habitat Type	Site (#)	Temperature (C)	Dissolved oxygen (mg/l)	Secchi (cm)	Flow Rate (m/s)	Conductivity (mS/cm)
Artificial	14	23.91	6.71	32	*	0.366
	15	23.7	7.2	28	*	0.362
	43	27.52	*	21	0.03	0.524
	54	22.97	6.52	31	0.08	0.372
	2	24.06	6.15	45	0.02	0.414
	61	24.85	6.16	27	*	0.415
	62	23.86	6.11	42	0.12	0.407
	66	25.07	6.1	47	*	0.417
	63	26.9	4.4	56	0	0.456
	64	23.87	6.14	45	0.06	0.406
	65	23.78	6.34	45	0.38	0.406
Island	13	24.5	7.47	15	*	0.511
	20	29.3	7.85	47	0	0.443
	53	23.18	6.92	31	0.1	0.367
	30	27.46	*	28	0.04	0.484
	25	27.64	*	59	0	0.465
	23	25.03	6.21	41	*	0.417
	11	23.69	6.22	41	0.08	0.405
Main	70	27.91	*	57	*	0.519
	42	29.8	8.99	49	*	0.526
	40	24.2	5.14	15	0.2	0.47
	27	24.7	6.3	40	*	0.41
Tributary	22	*	*	*	*	1.375
	34	22.71	*	42	0	0.369
	29	23.55	1	41	0	0.311
	28	22.96	3.1	46	*	0.28
	35	*	*	*	*	*
	37	24.29	5.67	31	0	0.424
	1	*	*	*	*	0.26

* Not available due to site inaccessibility or equipment failure.

Table 2-6. Mean water quality values across sites during three sampling sessions in Smithland Pool of the Ohio River during winter through late spring 2002.

Sampling Session	Habitat Type	Temperature (C)	Dissolved oxygen (mg/l)	Secchi (cm)	Flow Rate (m/s)	Conductivity (mS/cm)
January	Artificial	4.01	7.12	66.70	0.08	0.57
	Island	3.82	7.10	62.50	0.08	0.55
	Main	4.02	6.18	101.50	0.10	0.45
	Tributary	3.86	6.31	93.86	0.06	0.45
February-March	Artificial	7.25	6.36	31.75	0.17	0.47
	Island	7.37	6.48	32.40	0.32	0.47
	Main	7.88	6.23	25.25	0.26	0.53
	Tributary	8.16	5.47	29.17	0.01	0.35
June	Artificial	24.84	6.18	39.83	0.10	0.42
	Island	25.63	7.12	32.40	0.07	0.44
	Main	26.65	6.81	40.25	0.20	0.48
	Tributary	23.71	4.00	40.20	0.00	0.36

Table 2-7. Water quality data for each site of the Smithland Pool of the Ohio River during session 1 (February 2003).

Habitat Type	Site (#)	Temperature (C)	Dissolved oxygen (mg/l)	Secchi (cm)	Flow Rate (m/s)	Conductivity (mS/cm)
Artificial	14	2.73	13.36	28	0	0.409
	15	*	*	*	*	*
	43	2.69	13.13	29	0.02	0.562
	54	2.65	13	29	0.22	0.459
	2	*	*	*	*	*
	61	*	*	*	*	*
	62	*	*	*	*	*
	66	*	*	*	*	*
	63	*	*	*	*	*
	64	*	*	*	*	*
	65	*	*	*	*	*
Island	13	3.24	14.49	32	0	0.559
	20	2.69	13.18	27	0.2	0.453
	53	2.34	12.99	28	0.1	0.472
	30	2.81	13.39	34	0.08	0.468
	25	2.87	12.73	40	0.12	0.482
	11	3.3	12.4	43	0.1	0.471
Main	70	2.82	12.6	30	0.4	0.577
	42	2.95	13.04	24	*	0.559
	40	2.75	12.78	30	0.5	0.553
	27	2.79	12.75	40	0.2	0.459
Tributary	22	*	*	*	*	*
	34	8.18	9.14	53	0	0.327
	29	7.71	11.06	46	0	0.287
	23	*	*	*	*	*
	28	7.5	11.14	28	0	0.279
	35	*	*	*	*	*
	37	8.17	9.96	67	0	0.32
	1	*	*	*	*	*

* Not available due to site inaccessibility or equipment failure.

Table 2-8 Water quality data for each site of the Smithland Pool of the Ohio River during session 2 (April 2003).

Habitat Type	Site (#)	Temperature (C)	Dissolved oxygen (mg/l)	Secchi (cm)	Flow Rate (m/s)	Conductivity (mS/cm)
Artificial	14	12.43	7.89	30	0	0.291
	15	*	*	*	*	*
	43	*	*	*	*	*
	54	*	*	*	*	*
	2	*	*	*	*	*
	61	*	*	*	*	*
	62	*	*	*	*	*
	66	*	*	*	*	*
	63	*	*	*	*	*
	64	*	*	*	*	*
	65	*	*	*	*	*
Island	13	13.67	8.53	28	0.1	0.347
	20	13.12	8.33	29	0.08	0.303
	53	*	*	*	*	*
	30	*	*	*	*	*
	25	*	*	*	*	*
	23	*	*	*	*	*
	11	*	*	*	*	*
Main	70	13.51	8.67	28	0.28	0.351
	42	*	*	*	*	*
	40	*	*	*	*	*
	27	*	*	*	*	*
Tributary	22	*	*	*	*	*
	34	11.1	7.13	76	0	0.282
	29	11.76	6.61	61	0	0.251
	28	12.58	6.12	64	0	0.32
	35	*	*	*	*	*
	37	12.08	7.67	55	0	0.267
	1	*	*	*	*	*

* Not available due to site inaccessibility or equipment failure.

Table 2-9. Water quality data for each site of the Smithland Pool of the Ohio River during session 3 (June 2003).

Habitat Type	Site (#)	Temperature (C)	Dissolved oxygen (mg/l)	Secchi (cm)	Flow Rate (m/s)	Conductivity (mS/cm)
Artificial	14	18.52	8	28	0.8	0.303
	15	*	*	*	*	*
	43	18.43	7.5	29	0.2	0.432
	54	18.36	7.11	26	0.18	0.312
	2	28.09	7.48	38	0.2	0.336
	61	18.53	5.72	30	0.1	0.334
	62	18.74	5.56	29	0.08	0.334
	66	28.05	8.11	36	0.08	0.324
	63	19.02	5.57	29	0.08	0.336
	64	27.86	8.56	36	0.1	0.327
	65	27.81	7.89	36	0.1	0.33
Island	13	18.97	5.76	26	0.12	0.463
	20	18.86	5.88	25	0.02	0.318
	53	18.34	6.95	28	0.4	0.312
	30	18.44	7.03	24	0.1	0.351
	25	18.48	5.61	33	0.14	0.343
	23	27.8	7.5	36	0.1	0.325
	11	27.77	7.61	32	0.02	0.331
Main	70	18.97	5.9	26	0.1	0.426
	42	29.8	8.99	49	*	0.526
	40	18.49	7.5	28	0.16	0.431
	27	18.4	6.24	35	0.2	0.349
Tributary	22	*	*	*	*	*
	34	17.65	1.83	56	0	0.181
	29	18.6	1.9	96	0	0.155
	28	18.42	2.16	110	0	0.125
	35	*	*	*	*	*
	37	17.15	2.87	72	0	0.126
	1	*	*	*	*	0.26

* Not available due to site inaccessibility or equipment failure.

Table 2-10. Mean water quality values across sites during three sampling sessions in Smithland Pool of the Ohio River during winter through late spring 2003.

Sampling Session	Habitat Type	Temperature (C)	Dissolved oxygen (mg/l)	Secchi (cm)	Flow Rate (m/s)	Conductivity (mS/cm)
February	Artificial	2.69	13.16	28.67	0.08	0.48
	Island	2.88	13.20	34.00	0.10	0.48
	Main	2.83	12.79	31.00	0.37	0.54
	Tributary	7.89	10.33	48.50	0.00	0.30
March-April	Artificial	12.43	7.89	30.00	0.00	0.29
	Island	13.40	8.43	28.50	0.09	0.33
	Main	13.51	8.67	28.00	0.28	0.35
	Tributary	11.88	6.88	64.00	0.00	0.28
June	Artificial	22.34	7.15	31.70	0.19	0.28
	Island	21.24	6.62	29.14	0.13	0.34
	Main	18.56	6.64	29.50	0.17	0.35
	Tributary	17.96	2.19	83.50	0.00	0.41

Table 2-11. Total number of fish caught at each habitat type in the Smithland Pool of the Ohio River during session 1 of 2001-2002 (January 2002).

	Habitat types				
Species	Artificial	Island	Main	Tributary *	Total *
Bigmouth Buffalo	0	1	0	1	2
Blue Catfish	50	8	0	0	58
Bluegill	1	0	0	2	3
Channel Catfish	0	4	0	2	6
Common Carp	0	1	0	1	2
Emerald Shiner	0	10	0	0	10
Flathead Catfish	0	1	0	0	1
Flier	0	0	0	1	1
Freshwater Drum	142	65	33	93	333
Gizzard Shad	5	0	0	2	7
Longear Sunfish	0	0	0	0	0
Black/White Crappie	1	0	0	6	7
Quillback	0	0	0	0	0
Redear Sunfish	0	0	0	1	1
Smallmouth Buffalo	1	0	0	0	1
Spotted Bass	0	0	0	1	1
Warmouth	0	0	0	0	0
White Bass	1	0	0	2	3
Total *	201	90	33	112	436

* Excludes one tributary site with high catch of freshwater drum and catfish.

Table 2-12. Percent species composition at each habitat type in the Smithland Pool of the Ohio River during session 1 of 2001-2002 (January 2002).

	Habitat types				
Species	Artificial	Island	Main	Tributary *	Total *
Bigmouth Buffalo	0.0	1.1	0.0	0.9	0.5
Blue Catfish	24.9	8.9	0.0	0.0	13.3
Bluegill	0.5	0.0	0.0	1.8	0.7
Channel Catfish	0.0	4.4	0.0	1.8	1.4
Common Carp	0.0	1.1	0.0	0.9	0.5
Emerald Shiner	0.0	11.1	0.0	0.0	2.3
Flathead Catfish	0.0	1.1	0.0	0.0	0.2
Flier	0.0	0.0	0.0	0.9	0.2
Freshwater Drum	70.6	72.2	100.0	83.0	76.4
Gizzard Shad	2.5	0.0	0.0	1.8	1.6
Longear Sunfish	0.0	0.0	0.0	0.0	0.0
Black/White Crappie	0.5	0.0	0.0	5.4	1.6
Quillback	0.0	0.0	0.0	0.0	0.0
Redear Sunfish	0.0	0.0	0.0	0.9	0.2
Smallmouth Buffalo	0.5	0.0	0.0	0.0	0.2
Spotted Bass	0.0	0.0	0.0	0.9	0.2
Warmouth	0.0	0.0	0.0	0.0	0.0
White Bass	0.5	0.0	0.0	1.8	0.7

* Excludes one tributary site with high catch of freshwater drum and catfish (N > 500).

Table 2-13. Mean number of fish caught per hour of electrofishing among sites of the Smithland Pool during session 1 of 2001-2002 (January 2002).

	Habitat types			
Species	Artificial	Island	Main	Tributary *
Bigmouth Buffalo	0.00	0.43	0.00	0.40
Blue Catfish	15.00	3.43	0.00	0.00
Bluegill	0.30	0.00	0.00	0.80
Channel Catfish	0.00	1.71	0.00	0.80
Common Carp	0.00	0.43	0.00	0.40
Emerald Shiner	0.00	4.29	0.00	0.00
Flathead Catfish	0.00	0.43	0.00	0.00
Flier	0.00	0.00	0.00	0.40
Freshwater Drum	42.60	27.86	49.50	37.08
Gizzard Shad	1.50	0.00	0.00	0.80
Longear Sunfish	0.00	0.00	0.00	0.00
Black/White Crappie	0.30	0.00	0.00	2.39
Quillback	0.00	0.00	0.00	0.00
Redear Sunfish	0.00	0.00	0.00	0.40
Smallmouth Buffalo	0.30	0.00	0.00	0.00
Spotted Bass	0.00	0.00	0.00	0.40
Warmouth	0.00	0.00	0.00	0.00
White Bass	0.30	0.00	0.00	0.80
Total	60.30	38.57	49.50	44.65
Total Effort (hours)	3.33	2.33	0.67	2.51

* Excludes one tributary site with high catch of freshwater drum and catfish (N > 500).

Table 2-14. Total number of fish caught at each habitat type in the Smithland Pool of the Ohio River during session 2 of 2001-2002 (February through March 2002).

	Habitat types				
Species	Artificial *	Island *	Main	Tributary	Total *
Bigmouth Buffalo	0	0	0	0	0
Blue Catfish	298	11	21	4	334
Bluegill	0	0	0	10	10
Channel Catfish	8	14	6	0	28
Common Carp	1	0	0	1	2
Emerald Shiner	0	0	0	0	0
Flathead Catfish	0	0	0	0	0
Flier	0	0	0	0	0
Freshwater Drum	205	28	237	44	514
Gizzard Shad	10	0	1	6	17
Longear Sunfish	0	0	0	4	4
Black/White Crappie	2	0	0	2	4
Quillback	1	0	0	0	1
Redear Sunfish	0	0	0	0	0
Smallmouth Buffalo	0	1	0	0	1
Spotted Bass	0	0	0	0	0
Warmouth	0	0	0	1	1
White Bass	0	0	0	0	0
Total *	525	54	265	72	916

*Excludes one artificial and one island site due to high catch of freshwater drum and catfish (N > 500).

Table 2-15. Percent species composition at each habitat type in the Smithland Pool of the Ohio River during session 2 of 2001-2002 (February through March 2002).

	Habitat types				
Species	Artificial *	Island *	Main	Tributary	Total *
Bigmouth Buffalo	0.00	0.00	0.00	0.00	0.00
Blue Catfish	56.76	20.37	7.92	5.56	36.46
Bluegill	0.00	0.00	0.00	13.89	1.09
Channel Catfish	1.52	25.93	2.26	0.00	3.06
Common Carp	0.19	0.00	0.00	1.39	0.22
Emerald Shiner	0.00	0.00	0.00	0.00	0.00
Flathead Catfish	0.00	0.00	0.00	0.00	0.00
Flier	0.00	0.00	0.00	0.00	0.00
Freshwater Drum	39.05	51.85	89.43	61.11	56.11
Gizzard Shad	1.90	0.00	0.38	8.33	1.86
Longear Sunfish	0.00	0.00	0.00	5.56	0.44
Black/White Crappie	0.38	0.00	0.00	2.78	0.44
Quillback	0.19	0.00	0.00	0.00	0.11
Redear Sunfish	0.00	0.00	0.00	0.00	0.00
Smallmouth Buffalo	0.00	1.85	0.00	0.00	0.11
Spotted Bass	0.00	0.00	0.00	0.00	0.00
Warmouth	0.00	0.00	0.00	1.39	0.11
White Bass	0.00	0.00	0.00	0.00	0.00

*Excludes one artificial and one island site due to high catch of freshwater drum and catfish (N > 500).

Table 2-16. Mean number of fish caught per hour of electrofishing among sites of the Smithland Pool during session 2 of 2001-2002 (February through March 2002).

	Habitat types			
Species	Artificial *	Island *	Main	Tributary
Bigmouth Buffalo	0.00	0.00	0.00	0.00
Blue Catfish	62.74	4.71	14.00	2.05
Bluegill	0.00	0.00	0.00	5.13
Channel Catfish	1.68	6.00	4.00	0.00
Common Carp	0.21	0.00	0.00	0.51
Emerald Shiner	0.00	0.00	0.00	0.00
Flathead Catfish	0.00	0.00	0.00	0.00
Flier	0.00	0.00	0.00	0.00
Freshwater Drum	43.16	12.00	158.00	22.56
Gizzard Shad	2.11	0.00	0.67	3.08
Longear Sunfish	0.00	0.00	0.00	2.05
Black/White Crappie	0.42	0.00	0.00	1.03
Quillback	0.21	0.00	0.00	0.00
Redear Sunfish	0.00	0.00	0.00	0.00
Smallmouth Buffalo	0.00	0.43	0.00	0.00
Spotted Bass	0.00	0.00	0.00	0.00
Warmouth	0.00	0.00	0.00	0.51
White Bass	0.00	0.00	0.00	0.00
Total	110.53	23.14	176.67	36.92
EF Effort (hrs)	4.75	2.33	1.50	1.95

*Excludes one artificial and one island site due to high catch of freshwater drum and catfish (N > 500).

Table 2-17. Total number of fish caught at each habitat type in the Smithland Pool of the Ohio River during session 3 of 2001-2002 (June 2002).

	Habitat types				
Species	Artificial	Island	Main	Tributary	Total
Bigmouth Buffalo	0	0	0	0	0
Blue Catfish	86	28	5	0	119
Bluegill	0	0	0	2	2
Channel Catfish	4	5	17	0	26
Common Carp	2	0	2	0	4
Emerald Shiner	0	0	0	0	0
Flathead Catfish	3	2	5	0	10
Flier	0	0	0	0	0
Freshwater Drum	22	14	32	0	68
Gizzard Shad	4	0	0	19	23
Longear Sunfish	1	0	0	0	1
Black/White Crappie	0	0	0	0	0
Quillback	1	0	0	0	1
Paddlefish	3	0	0	0	3
Redear Sunfish	0	0	0	0	0
Smallmouth Buffalo	0	0	2	0	2
Spotted Bass	0	0	0	0	0
Warmouth	0	0	0	0	0
White Bass	2	0	1	0	3
TOTAL	128	49	64	21	262

Table 2-18. Percent species composition at each habitat type in the Smithland Pool of the Ohio River during session 3 of 2001-2002 (June 2002).

	Habitat types				
Species	Artificial	Island	Main	Tributary	Total
Bigmouth Buffalo	0.00	0.00	0.00	0.00	0.00
Blue Catfish	67.19	57.14	7.81	0.00	45.42
Bluegill	0.00	0.00	0.00	9.52	0.76
Channel Catfish	3.13	10.20	26.56	0.00	9.92
Common Carp	1.56	0.00	3.13	0.00	1.53
Emerald Shiner	0.00	0.00	0.00	0.00	0.00
Flathead Catfish	2.34	4.08	7.81	0.00	3.82
Flier	0.00	0.00	0.00	0.00	0.00
Freshwater Drum	17.19	28.57	50.00	0.00	25.95
Gizzard Shad	3.13	0.00	0.00	90.48	8.78
Longear Sunfish	0.78	0.00	0.00	0.00	0.38
Black/White Crappie	0.00	0.00	0.00	0.00	0.00
Quillback	0.78	0.00	0.00	0.00	0.38
Paddlefish	2.34	0.00	0.00	0.00	1.15
Redear Sunfish	0.00	0.00	0.00	0.00	0.00
Smallmouth Buffalo	0.00	0.00	3.13	0.00	0.76
Spotted Bass	0.00	0.00	0.00	0.00	0.00
Warmouth	0.00	0.00	0.00	0.00	0.00
White Bass	1.56	0.00	1.56	0.00	1.15

Table 2-19. Mean number of fish caught per hour of electrofishing among sites of the Smithland Pool during session 3 of 2001-2002 (June 2002).

	Habitat types			
Species	Artificial	Island	Main	Tributary
Bigmouth Buffalo	0.00	0.00	0.00	0.00
Blue Catfish	17.20	10.50	2.50	0.00
Bluegill	0.00	0.00	0.00	1.60
Channel Catfish	0.80	1.88	8.50	0.00
Common Carp	0.40	0.00	1.00	0.00
Emerald Shiner	0.00	0.00	0.00	0.00
Flathead Catfish	0.60	0.75	2.50	0.00
Flier	0.00	0.00	0.00	0.00
Freshwater Drum	4.40	5.25	16.00	0.00
Gizzard Shad	0.80	0.00	0.00	15.20
Longear Sunfish	0.20	0.00	0.00	0.00
Black/White Crappie	0.00	0.00	0.00	0.00
Quillback	0.20	0.00	0.00	0.00
Paddlefish	0.60	0.00	0.00	0.00
Redear Sunfish	0.00	0.00	0.00	0.00
Smallmouth Buffalo	0.00	0.00	1.00	0.00
Spotted Bass	0.00	0.00	0.00	0.00
Warmouth	0.00	0.00	0.00	0.00
White Bass	0.40	0.00	0.50	0.00
Total	25.60	18.38	32.00	16.80
EF Effort (hrs)	5.00	2.70	2.00	1.50

Table 2-20. Total combined catch and mean total length (mm) as a function of habitat type in Smithland Pool of the Ohio River during winter through late spring 2002.

	Number in Habitat						
Species	Artificial *	Island *	Main	Tributary *	Total *	Mean TL	SD
Bigmouth Buffalo	0	1	0	1	2	**	**
Blue Catfish	434	47	26	4	511	232.56	126.15
Bluegill	1	0	0	14	15	112.38	43.48
Channel Catfish	12	23	23	2	60	370.72	134.50
Common Carp	3	1	2	2	8	662.00	112.00
Emerald Shiner	0	10	0	0	10	**	**
Flathead Catfish	3	3	5	0	11	474.10	257.10
Flier	0	0	0	1	1	**	**
Freshwater Drum	369	107	302	137	915	212.90	123.36
Gizzard Shad	19	0	1	27	47	226.98	32.43
Longear Sunfish	1	0	0	4	5	136.60	17.85
Black/White Crappie	3	0	0	8	11	216.27	57.79
Quillback	2	0	0	8	10	442.00	80.61
Paddlefish	3	0	0	0	3	711.67	314.26
Redear Sunfish	0	0	0	1	1	**	**
Smallmouth Buffalo	1	1	2	0	4	420.25	143.86
Spotted Bass	0	0	0	1	1	**	**
Warmouth	0	0	0	1	1	131.00	
White Bass	3	0	1	2	6	276.67	113.98
Total	854	193	362	213	1622		

*Excludes sites with high catches of freshwater drum and catfish (N > 500).

**Not available.

Table 2-21. Total number of fish caught at each habitat type in the Smithland Pool of the Ohio River during session 1 of 2002-2003 (February 2003).

	Habitat types				
Species	Artificial	Island	Main	Tributary	Total
Bigmouth Buffalo	0	0	0	0	0
Blue Catfish	61	168	107	3	339
Bighead Carp	0	0	0	0	0
Bluegill	0	0	0	0	0
Channel Catfish	1	9	9	1	20
Common Carp	1	0	0	0	1
Emerald Shiner	0	0	0	0	0
Flathead Catfish	0	0	0	0	0
Flier	0	0	0	0	0
Freshwater Drum	142	131	294	33	600
Gizzard Shad	0	3	0	0	3
Goldeye	0	0	0	19	19
Longear Sunfish	0	1	0	0	1
Mooneye	0	2	2	0	4
Paddlefish	0	0	0	0	0
Black/White Crappie	0	0	0	0	0
Quillback	3	1	0	0	4
Redear Sunfish	0	0	0	0	0
River Carpsucker	5	0	0	0	5
Sauger	1	0	0	0	1
Smallmouth Buffalo	11	0	0	0	22
Spotted Bass	0	0	0	0	0
Shortnose Gar	0	1	0	0	1
Striped Bass	2	1	1	0	4
Warmouth	0	0	0	0	0
White Bass	1	0	0	0	1
Total	228	317	413	56	1025

Table 2-22. Percent species composition at each habitat type in the Smithland Pool of the Ohio River during session 1 of 2002-2003 (February 2003).

	Habitat types				
Species	Artificial	Island	Main	Tributary	Total
Bigmouth Buffalo	0.00	0.00	0.00	0.00	0.00
Blue Catfish	26.80	53.00	25.90	5.40	33.07
Bighead Carp	0.00	0.00	0.00	0.00	0.00
Bluegill	0.00	0.00	0.00	0.00	0.00
Channel Catfish	0.40	2.80	2.20	1.80	1.95
Common Carp	0.40	0.00	0.00	0.00	0.10
Emerald Shiner	0.00	0.00	0.00	0.00	0.00
Flathead Catfish	0.00	0.00	0.00	0.00	0.00
Flier	0.00	0.00	0.00	0.00	0.00
Freshwater Drum	62.30	41.30	71.20	58.90	58.54
Gizzard Shad	0.00	0.90	0.00	0.00	0.29
Goldeye	0.00	0.00	0.00	33.90	1.85
Longear Sunfish	0.00	0.30	0.00	0.00	0.10
Mooneye	0.00	0.60	0.50	0.00	0.39
Paddlefish	0.00	0.00	0.00	0.00	0.00
Black/White Crappie	0.00	0.00	0.00	0.00	0.00
Quillback	1.30	0.30	0.00	0.00	0.39
Redear Sunfish	0.00	0.00	0.00	0.00	0.00
River Carpsucker	2.20	0.00	0.00	0.00	0.49
Sauger	0.40	0.00	0.00	0.00	0.10
Smallmouth Buffalo	4.80	0.00	0.00	0.00	2.15
Spotted Bass	0.00	0.00	0.00	0.00	0.00
Shortnose Gar	0.00	0.30	0.00	0.00	0.10
Striped Bass	0.90	0.30	0.20	0.00	0.39
Warmouth	0.00	0.00	0.00	0.00	0.00
White Bass	0.40	0.00	0.00	0.00	0.10

Table 2-23. Mean number of fish caught per hour of electrofishing among sites of the Smithland Pool during session 1 of 2002-2003 (February 2003).

	Habitat types			
Species	Artificial	Island	Main	Tributary
Bigmouth Buffalo	0.00	0.00	0.00	0.00
Blue Catfish	53.74	126.00	89.20	7.20
Bighead Carp	0.00	0.00	0.00	0.00
Bluegill	0.00	0.00	0.00	0.00
Channel Catfish	3.53	9.00	18.00	2.40
Common Carp	2.40	0.00	0.00	0.00
Emerald Shiner	0.00	0.00	0.00	0.00
Flathead Catfish	0.00	0.00	0.00	0.00
Flier	0.00	0.00	0.00	0.00
Freshwater Drum	153.91	98.25	249.20	23.73
Gizzard Shad	0.00	9.00	0.00	0.00
Goldeye	0.00	0.00	0.00	12.98
Longear Sunfish	0.00	3.00	0.00	0.00
Mooneye	0.00	3.00	8.00	0.00
Paddlefish	0.00	0.00	0.00	0.00
Black/White Crappie	0.00	0.00	0.00	0.00
Quillback	10.59	3.00	0.00	0.00
Redear Sunfish	0.00	0.00	0.00	0.00
River Carpsucker	17.65	0.00	0.00	0.00
Sauger	3.53	0.00	0.00	0.00
Smallmouth Buffalo	38.82	0.00	0.00	0.00
Spotted Bass	0.00	0.00	0.00	0.00
Shortnose Gar	0.00	3.00	0.00	0.00
Striped Bass	7.06	3.00	2.40	0.00
Warmouth	0.00	0.00	0.00	0.00
White Bass	3.53	0.00	0.00	0.00
Totals	59.17	52.83	116.67	13.03

Table 2-24. Total number of fish caught at each habitat type in the Smithland Pool of the Ohio River during session 2 of 2002-2003 (April 2003).

	Habitat types				
Species	Artificial	Island	Main	Tributary	Total
Bigmouth Buffalo	0	0	0	0	0
Blue Catfish	20	1	1	0	22
Bighead Carp	0	0	0	0	0
Bluegill	0	0	0	0	0
Channel Catfish	1	1	1	1	4
Common Carp	0	0	0	0	0
Emerald Shiner	0	0	0	0	0
Flathead Catfish	1	0	1	0	2
Flier	0	0	0	0	0
Freshwater Drum	12	1	3	2	18
Gizzard Shad	0	0	0	0	0
Goldeye	0	0	0	0	0
Longear Sunfish	0	0	0	0	0
Mooneye	0	0	0	0	0
Paddlefish	0	0	0	0	0
Black/White Crappie	0	0	0	0	0
Quillback	0	0	0	0	0
Redear Sunfish	0	0	0	0	0
River Carpsucker	0	0	0	0	0
Sauger	0	0	0	0	0
Smallmouth Buffalo	0	0	0	0	0
Spotted Bass	0	0	0	0	0
Shortnose Gar	0	0	0	0	0
Striped Bass	0	0	0	0	0
Warmouth	0	0	0	0	0
White Bass	0	0	0	0	0
Total	34	3	6	3	46

Table 2-25. Percent species composition at each habitat type in the Smithland Pool of the Ohio River during session 2 of 2002-2003 (April 2003).

	Habitat types				
Species	Artificial	Island	Main	Tributary	Total
Bigmouth Buffalo	0.00	0.00	0.00	0.00	0.00
Blue Catfish	58.80	33.30	16.70	0.00	47.83
Bighead Carp	0.00	0.00	0.00	0.00	0.00
Bluegill	0.00	0.00	0.00	0.00	0.00
Channel Catfish	2.90	33.30	16.70	33.30	8.70
Common Carp	0.00	0.00	0.00	0.00	0.00
Emerald Shiner	0.00	0.00	0.00	0.00	0.00
Flathead Catfish	2.90	0.00	16.70	0.00	4.35
Flier	0.00	0.00	0.00	0.00	0.00
Freshwater Drum	35.30	33.30	50.00	66.70	39.13
Gizzard Shad	0.00	0.00	0.00	0.00	0.00
Goldeye	0.00	0.00	0.00	0.00	0.00
Longear Sunfish	0.00	0.00	0.00	0.00	0.00
Mooneye	0.00	0.00	0.00	0.00	0.00
Paddlefish	0.00	0.00	0.00	0.00	0.00
Black/White Crappie	0.00	0.00	0.00	0.00	0.00
Quillback	0.00	0.00	0.00	0.00	0.00
Redear Sunfish	0.00	0.00	0.00	0.00	0.00
River Carpsucker	0.00	0.00	0.00	0.00	0.00
Sauger	0.00	0.00	0.00	0.00	0.00
Smallmouth Buffalo	0.00	0.00	0.00	0.00	0.00
Spotted Bass	0.00	0.00	0.00	0.00	0.00
Shortnose Gar	0.00	0.00	0.00	0.00	0.00
Striped Bass	0.00	0.00	0.00	0.00	0.00
Warmouth	0.00	0.00	0.00	0.00	0.00
White Bass	0.00	0.00	0.00	0.00	0.00

Table 2-26. Mean number of fish caught per hour of electrofishing among sites of the Smithland Pool during session 2 of 2002-2003 (April 2003).

	Habitat types			
Species	Artificial	Island	Main	Tributary
Bigmouth Buffalo	0.00	0.00	0.00	0.00
Blue Catfish	40.00	2.40	3.00	0.00
Bighead Carp	0.00	0.00	0.00	0.00
Bluegill	0.00	0.00	0.00	0.00
Channel Catfish	2.00	2.40	3.00	4.00
Common Carp	0.00	0.00	0.00	0.00
Emerald Shiner	0.00	0.00	0.00	0.00
Flathead Catfish	2.00	0.00	3.00	0.00
Flier	0.00	0.00	0.00	0.00
Freshwater Drum	24.00	2.40	9.00	3.67
Gizzard Shad	0.00	0.00	0.00	0.00
Goldeye	0.00	0.00	0.00	0.00
Longear Sunfish	0.00	0.00	0.00	0.00
Mooneye	0.00	0.00	0.00	0.00
Paddlefish	0.00	0.00	0.00	0.00
Black/White Crappie	0.00	0.00	0.00	0.00
Quillback	0.00	0.00	0.00	0.00
Redear Sunfish	0.00	0.00	0.00	0.00
River Carpsucker	0.00	0.00	0.00	0.00
Sauger	0.00	0.00	0.00	0.00
Smallmouth Buffalo	0.00	0.00	0.00	0.00
Spotted Bass	0.00	0.00	0.00	0.00
Shortnose Gar	0.00	0.00	0.00	0.00
Striped Bass	0.00	0.00	0.00	0.00
Warmouth	0.00	0.00	0.00	0.00
White Bass	0.00	0.00	0.00	0.00
Total	22.67	1.22	6.00	0.94

Table 2-27. Total number of fish caught at each habitat type in the Smithland Pool of the Ohio River during session 3 of 2002-2003 (June 2003).

	Habitat types				
Species	Artificial	Island	Main	Tributary	Total
Bigmouth Buffalo	0	0	0	0	0
Blue Catfish	82	8	21	5	116
Bighead Carp	0	0	0	0	0
Bluegill	0	0	0	0	0
Channel Catfish	4	1	2	0	7
Common Carp	0	0	3	0	3
Emerald Shiner	0	0	0	0	0
Flathead Catfish	0	0	3	0	3
Flier	0	0	0	0	0
Freshwater Drum	9	3	23	1	36
Gizzard Shad	0	0	0	0	0
Goldeye	1	0	0	0	1
Longear Sunfish	0	0	0	0	0
Mooneye	0	0	0	0	0
Paddlefish	1	0	1	0	2
Black/White Crappie	0	0	0	0	0
Quillback	0	0	0	0	0
Redear Sunfish	0	0	0	0	0
River Carpsucker	1	0	0	0	1
Sauger	0	0	0	0	0
Smallmouth Buffalo	0	0	0	0	0
Spotted Bass	0	0	0	0	0
Shortnose Gar	0	0	0	0	0
Striped Bass	0	0	0	0	0
Warmouth	0	0	0	0	0
White Bass	0	0	0	0	0
Total	98	12	53	6	169

Table 2-28. Percent species composition at each habitat type in the Smithland Pool of the Ohio River during session 3 of 2002-2003 (June 2003).

	Habitat types				
Species	Artificial	Island	Main	Tributary	Total
Bigmouth Buffalo	0.00	0.00	0.00	0.00	0.00
Blue Catfish	83.70	66.70	39.60	83.30	68.64
Bighead Carp	0.00	0.00	0.00	0.00	0.00
Bluegill	0.00	0.00	0.00	0.00	0.00
Channel Catfish	4.10	8.30	3.80	0.00	4.14
Common Carp	0.00	0.00	5.70	0.00	1.78
Emerald Shiner	0.00	0.00	0.00	0.00	0.00
Flathead Catfish	0.00	0.00	5.70	0.00	1.78
Flier	0.00	0.00	0.00	0.00	0.00
Freshwater Drum	9.20	25.00	43.40	16.70	21.30
Gizzard Shad	0.00	0.00	0.00	0.00	0.00
Goldeye	1.00	0.00	0.00	0.00	0.59
Longear Sunfish	0.00	0.00	0.00	0.00	0.00
Mooneye	0.00	0.00	0.00	0.00	0.00
Paddlefish	1.00	0.00	1.90	0.00	1.18
Black/White Crappie	0.00	0.00	0.00	0.00	0.00
Quillback	0.00	0.00	0.00	0.00	0.00
Redear Sunfish	0.00	0.00	0.00	0.00	0.00
River Carpsucker	1.00	0.00	0.00	0.00	0.59
Sauger	0.00	0.00	0.00	0.00	0.00
Smallmouth Buffalo	0.00	0.00	0.00	0.00	0.00
Spotted Bass	0.00	0.00	0.00	0.00	0.00
Shortnose Gar	0.00	0.00	0.00	0.00	0.00
Striped Bass	0.00	0.00	0.00	0.00	0.00
Warmouth	0.00	0.00	0.00	0.00	0.00
White Bass	0.00	0.00	0.00	0.00	0.00

Table 2-29. Mean number of fish caught per hour of electrofishing among sites of the Smithland Pool during session 3 of 2002-2003 (June 2003).

	Habitat types			
Species	Artificial	Island	Main	Tributary
Bigmouth Buffalo	0.00	0.00	0.00	0.00
Blue Catfish	30.00	7.80	21.60	15.00
Bighead Carp	0.00	0.00	0.00	0.00
Bluegill	0.00	0.00	0.00	0.00
Channel Catfish	5.00	3.00	3.00	0.00
Common Carp	0.00	0.00	3.40	0.00
Emerald Shiner	0.00	0.00	0.00	0.00
Flathead Catfish	0.00	0.00	5.20	0.00
Flier	0.00	0.00	0.00	0.00
Freshwater Drum	4.50	4.50	22.13	3.00
Gizzard Shad	0.00	0.00	0.00	0.00
Goldeye	3.00	0.00	0.00	0.00
Longear Sunfish	0.00	0.00	0.00	0.00
Mooneye	0.00	0.00	0.00	0.00
Paddlefish	3.00	0.00	2.00	0.00
Black/White Crappie	0.00	0.00	0.00	0.00
Quillback	0.00	0.00	0.00	0.00
Redear Sunfish	0.00	0.00	0.00	0.00
River Carpsucker	3.00	0.00	0.00	0.00
Sauger	0.00	0.00	0.00	0.00
Smallmouth Buffalo	0.00	0.00	0.00	0.00
Spotted Bass	0.00	0.00	0.00	0.00
Shortnose Gar	0.00	0.00	0.00	0.00
Striped Bass	0.00	0.00	0.00	0.00
Warmouth	0.00	0.00	0.00	0.00
White Bass	0.00	0.00	0.00	0.00
Total	11.70	1.69	14.76	1.20

Table 2-30. Total combined catch and mean total length (mm) as a function of habitat type in Smithland Pool of the Ohio River during winter through late spring 2003.

	Number in Habitat						
Species	Artificial	Island	Main	Tributary	Total	Mean TL	SD
Bigmouth Buffalo	0	0	0	0	0	.	.
Blue Catfish	493	196	208	8	905	224.29	115.54
Bighead Carp	0	1	0	0	1	880.00	.
Bluegill	0	0	0	0	0	.	.
Channel Catfish	6	18	20	2	46	334.24	115.69
Common Carp	1	0	5	0	6	649.17	37.93
Emerald Shiner	0	0	0	0	0	.	.
Flathead Catfish	1	0	4	0	5	582.00	191.84
Flier	0	0	0	0	0	.	.
Freshwater Drum	197	209	377	36	819	239.96	88.90
Gizzard Shad	3	3	1	19	26	171.38	78.56
Goldeye	0	3	0	0	3	202.33	73.82
Longear Sunfish	0	1	0	0	1	114.00	.
Mooneye	0	2	2	0	4	207.00	62.78
Paddlefish	1	0	1	0	2	630.00	155.56
Black/White Crappie	0	0	1	0	1	224.00	.
Quillback	3	1	0	0	4	215.75	69.08
Redear Sunfish	0	0	0	0	0	.	.
River Carpsucker	7	0	1	0	8	323.75	110.50
Sauger	1	0	0	0	1	246.00	.
Smallmouth Buffalo	11	0	1	0	12	486.83	57.31
Spotted Bass	0	0	0	0	0	.	.
Shortnose Gar	0	1	0	0	1	168.00	.
Striped Bass	0	0	1	0	0	194.00	.
Warmouth	0	0	0	0	4	198.50	32.26
White Bass	1	0	0	0	1	337.00	.

Figure 2-1. Sites within Smithland Pool of the Ohio River during winter through spring 2002 and 2003.

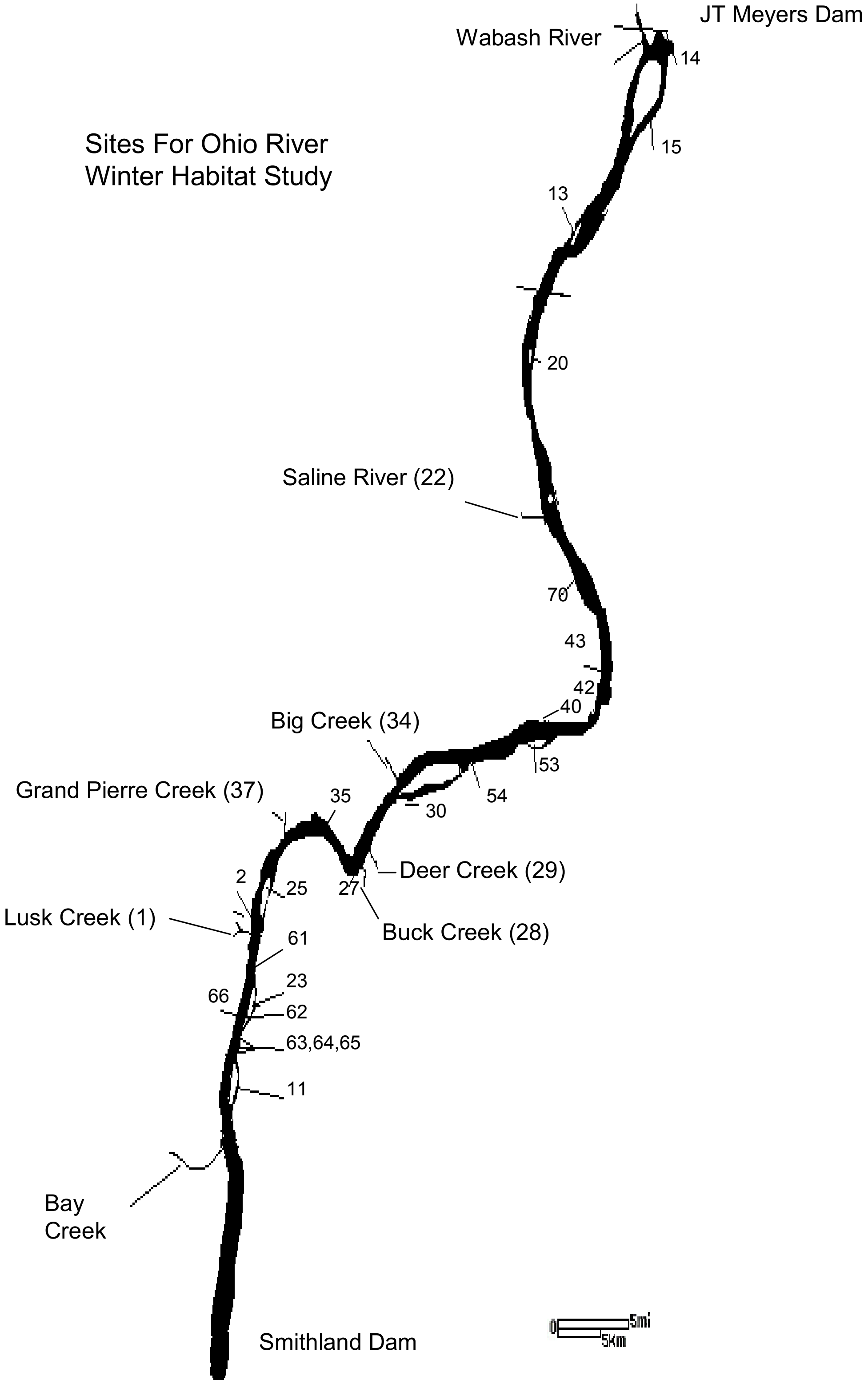


Figure 2-2. Daily discharge (ft^3/s; dashed line) and gage height (ft; solid line) during winter through spring 2002 and 2003 at a gauging station below Smithland Pool, Ohio River (USGS Metropolis, IL). Sampling could only occur during periods of low or normal flow.

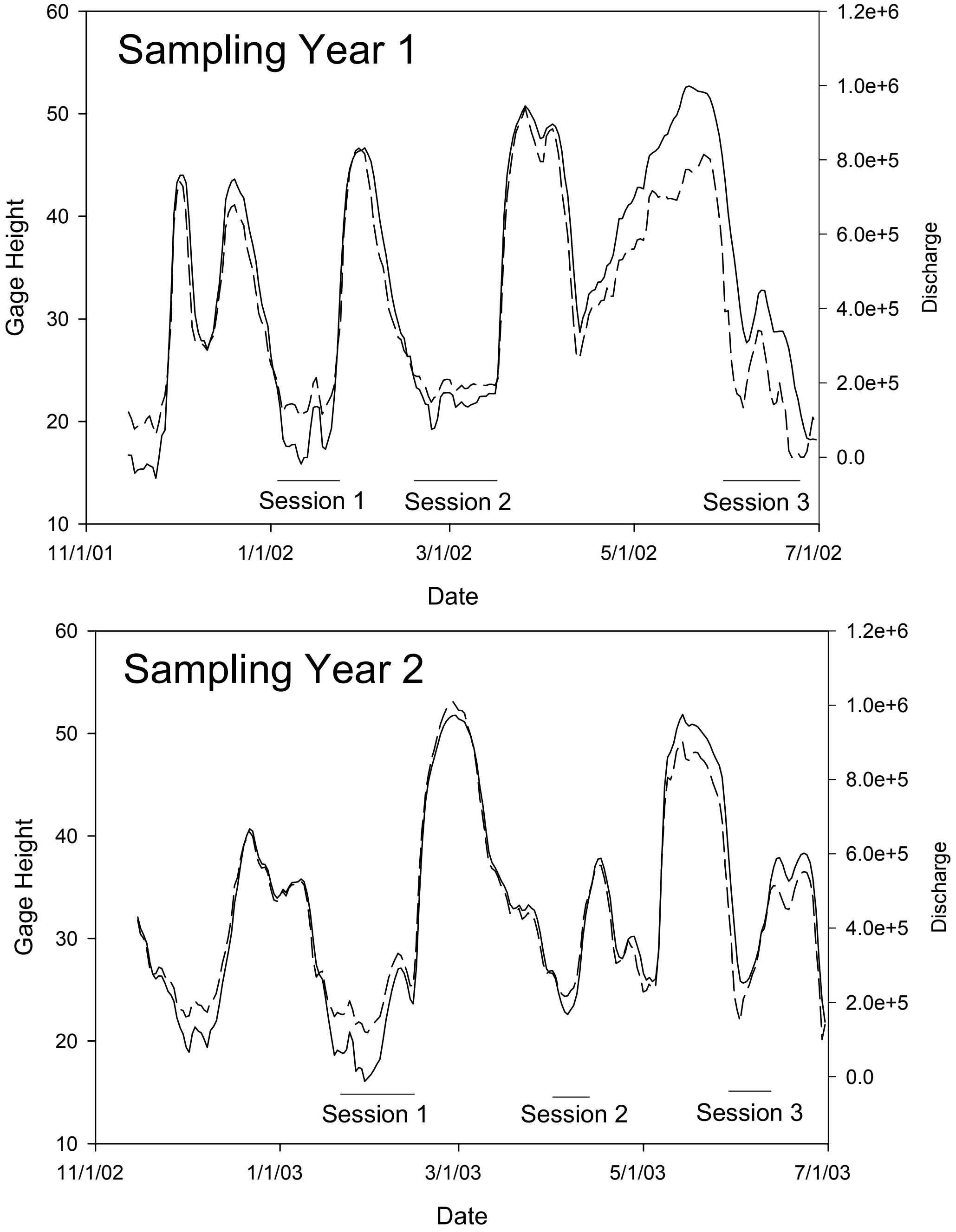


Figure 2-3. Water temperatures of the lower Ohio River during winter through spring 2002 and 2003. Bottom temperatures derive from the bottom of Smithland Pool. Bars above and below the trend line represent maximum and minimum daily temperatures. Surface temperatures derive from the Shawnee Fossil Power Plant below Smithland Dam. Lines on the bottom of each panel show sampling sessions.

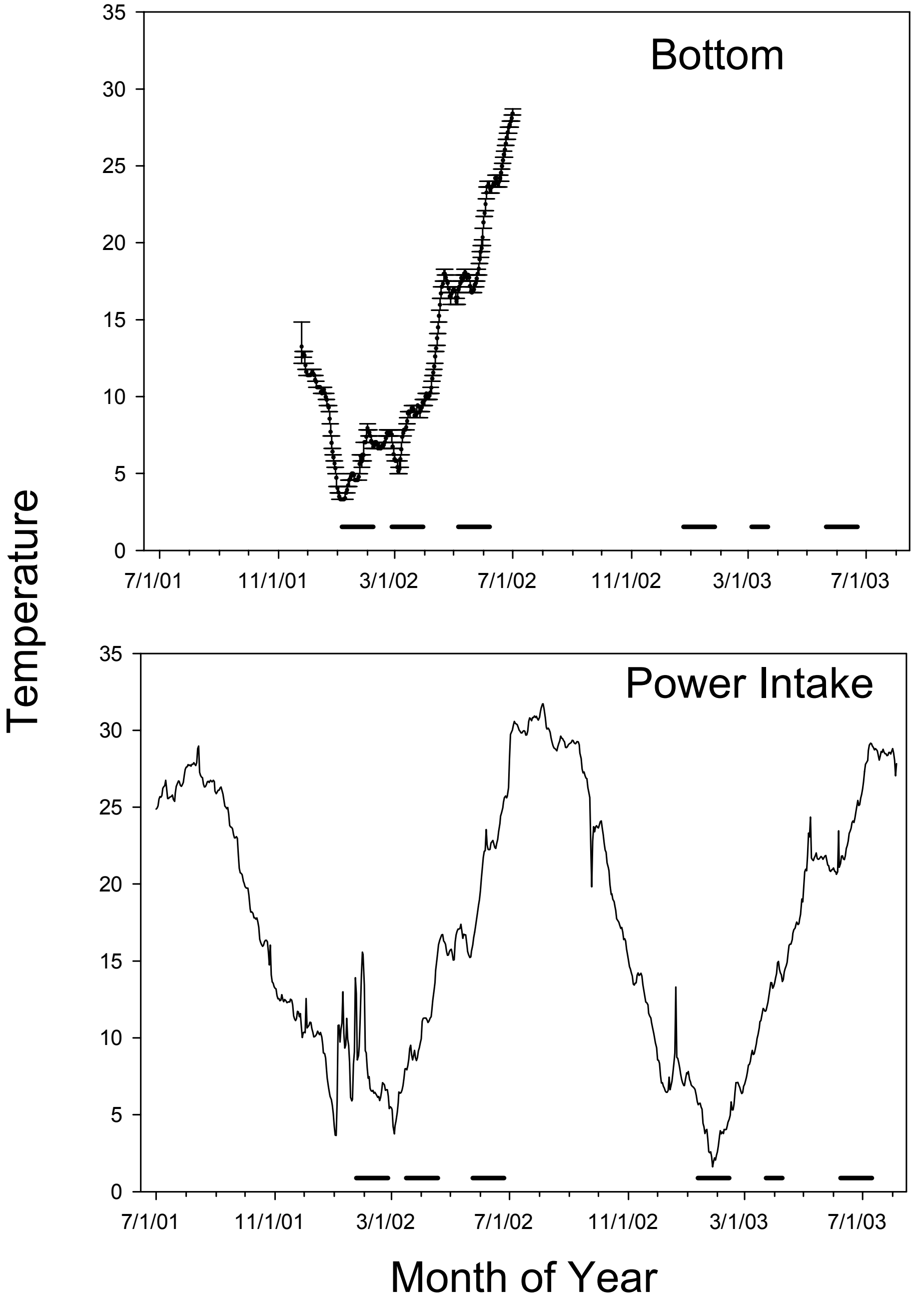


Figure 2-4. Results of a principle components analysis exploring how secchi depth, dissolved oxygen concentration, specific conductance, flow velocity, and temperature varied among sites in Smithland Pool, Ohio River during the winter 2002 and 2003 sampling sessions. The letter in each symbol represents artificial, island, tributary, or main. Note that low and > designations are relative only, often representing slight differences in quantities.

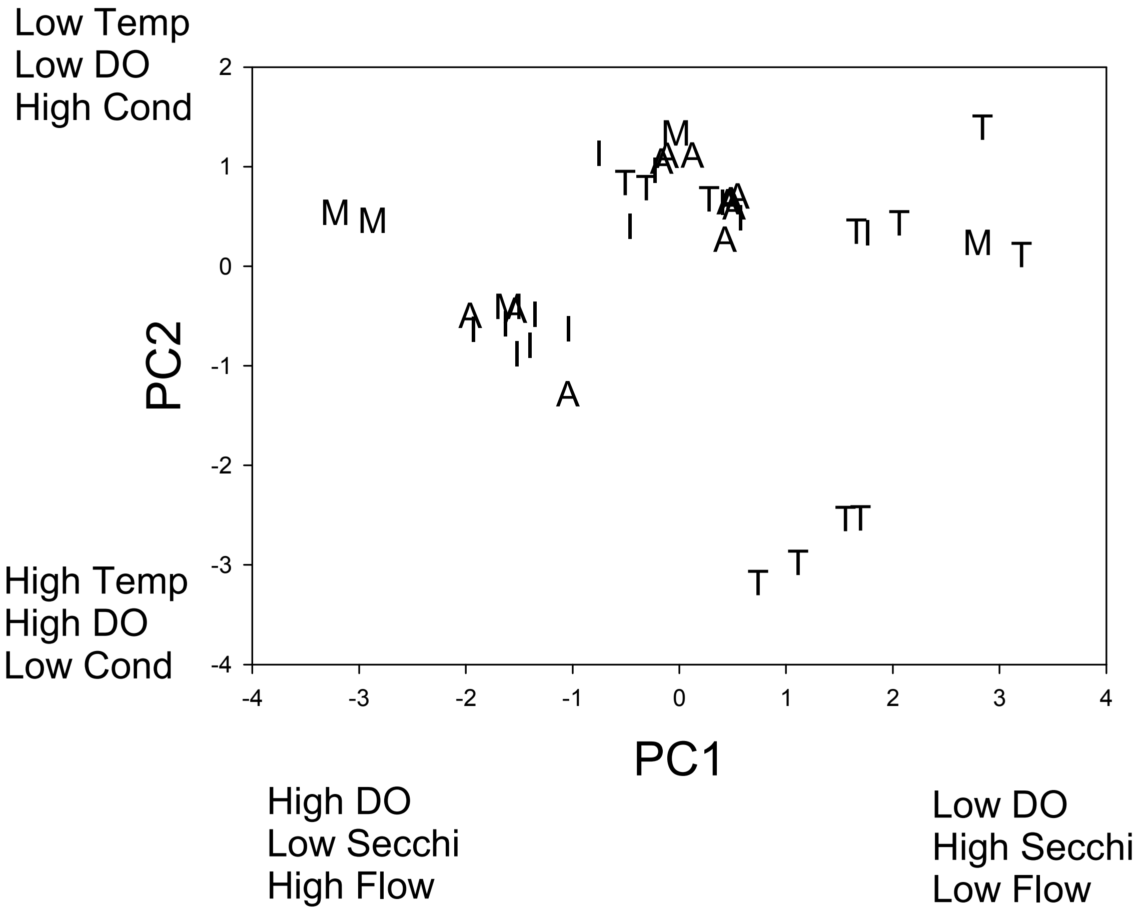


Figure 2-5. Mean number of freshwater drum, channel catfish, and blue catfish captured per hour with variable depth electrofishing in artificial, island, main, and tributary sites in Smithland Pool, Ohio River during winter through late spring 2002 and 2003. Statistics are results of a two way ANOVA exploring the effects of sampling session (Date) and habitat type (Habitat) on fish abundance.

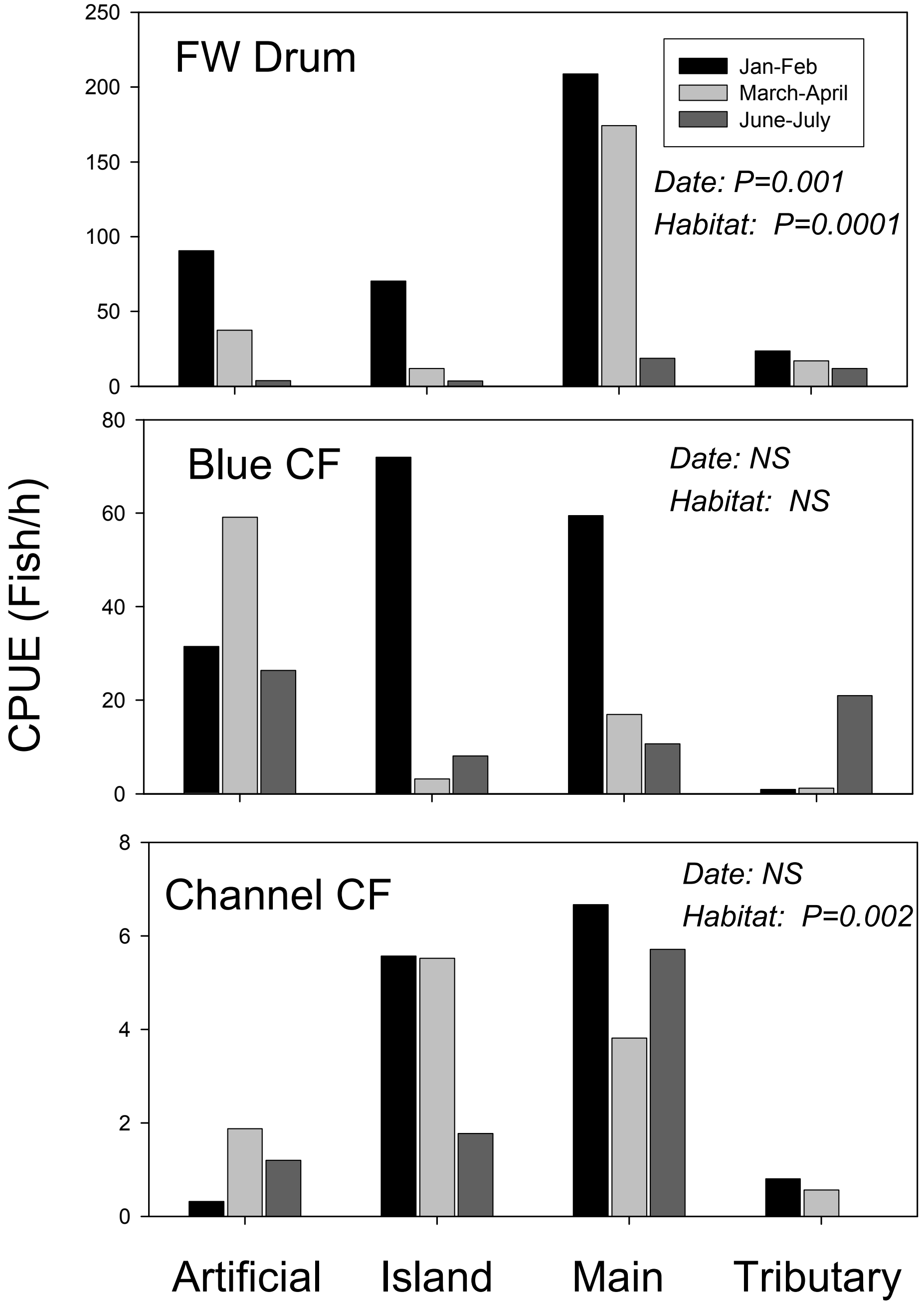


Figure 2-6. Results of principle components analysis for fish species assemblage structure as a function of habitat type (artificial, island, main channel, and tributary) and sampling session during winter through late spring 2002 in Smithland Pool, Ohio River. Relative abundances of all species sampled were included in the analysis (see Table XX). Major loadings were for species found in tributaries. Note that sites either in or adjacent to the main channel contained low numbers of these species. The arrows show that tributary assemblages became more similar to those in other sites by June. A similar pattern did not arise during winter 2003.

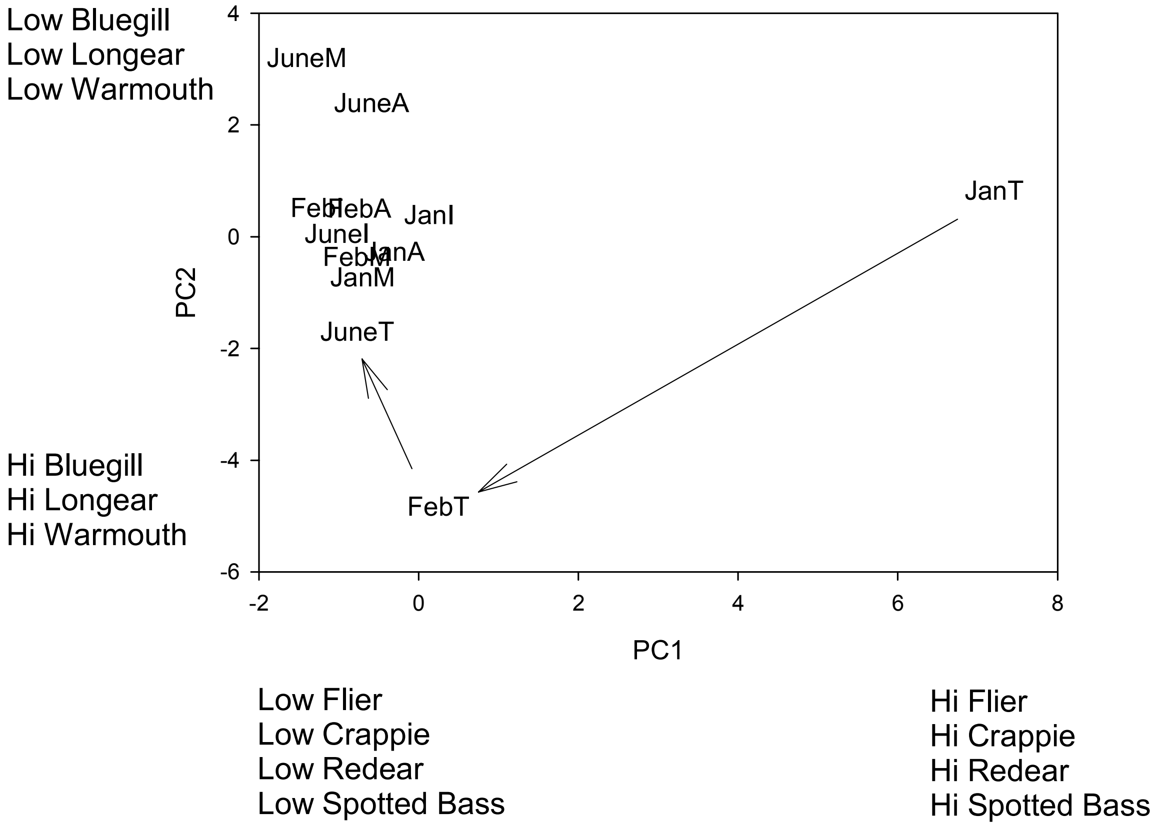


Figure 2-7. Results of non-metric multidimensional scaling ordination for Smithland Pool during winter 2002. Abundances (CPE) of the three fish species and habitat-specific water quality were quantified at each site. Water quality had little effect on the ordination. Conversely, freshwater drum were associated with main channel sites, blue catfish with artificial sites, and channel catfish with island sites. No structure was detected in the 2003 data set.

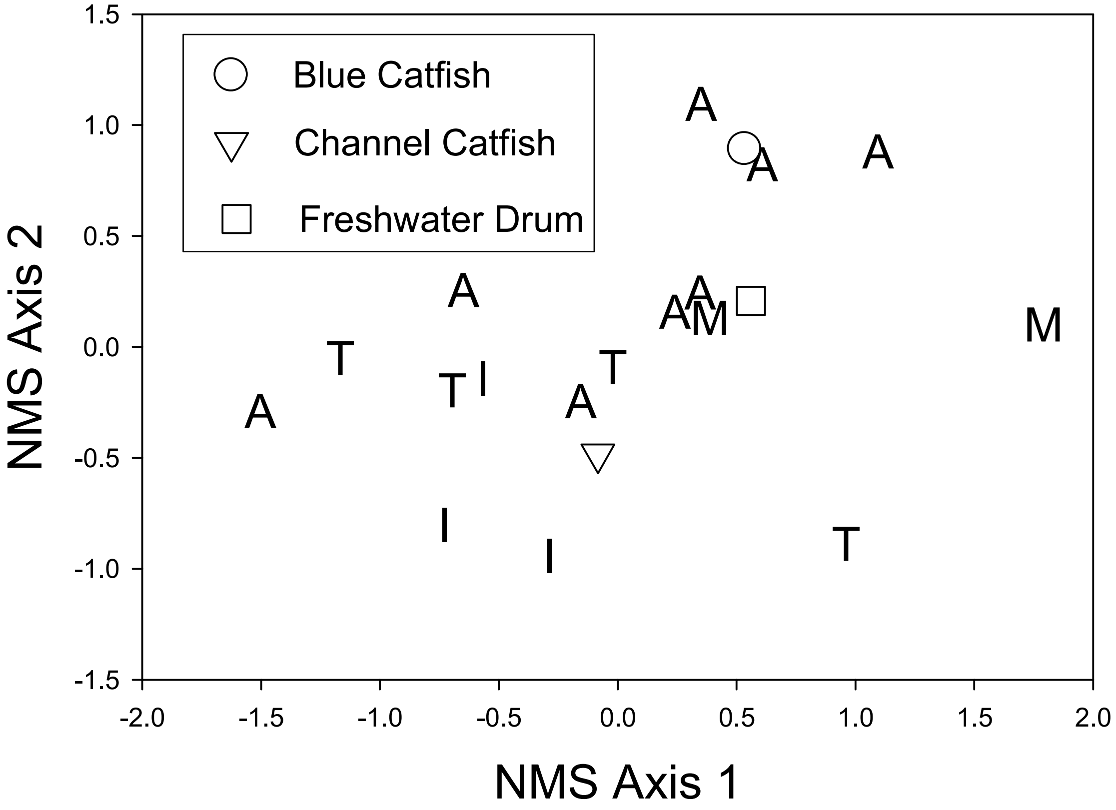


Figure 2-8. Mean total length (mm) of freshwater drum, channel catfish, and blue catfish in artificial, island, main, and tributary sites during winter through late spring 2002 and 2003 in Smithland Pool, Ohio River. An ANOVA for freshwater drum revealed that fish in tributary sites were smaller than at other sites.

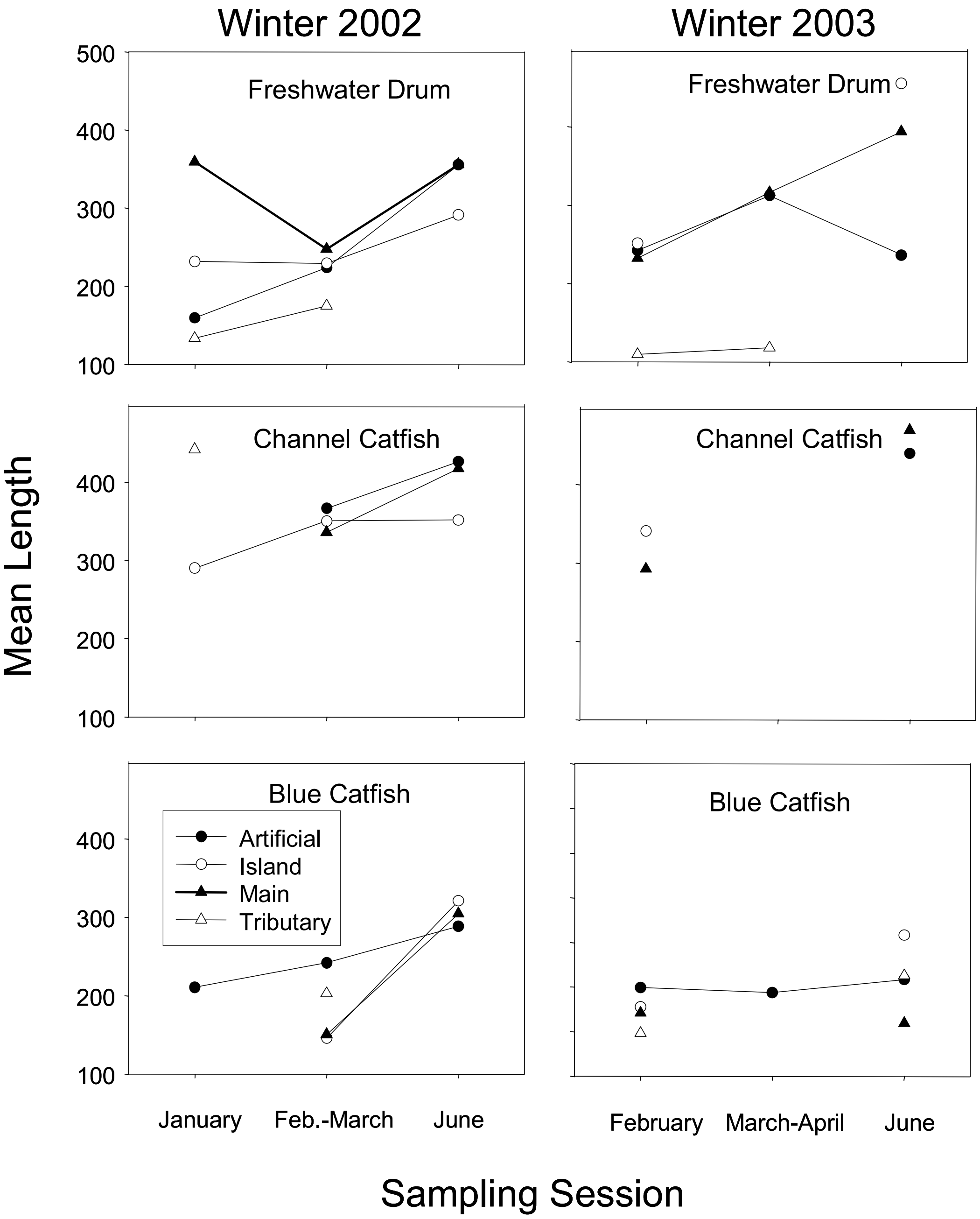


Figure 2-9. Number of species during winter through spring 2002 and 2003 as a function of temperature in Smithland Pool, Ohio River.

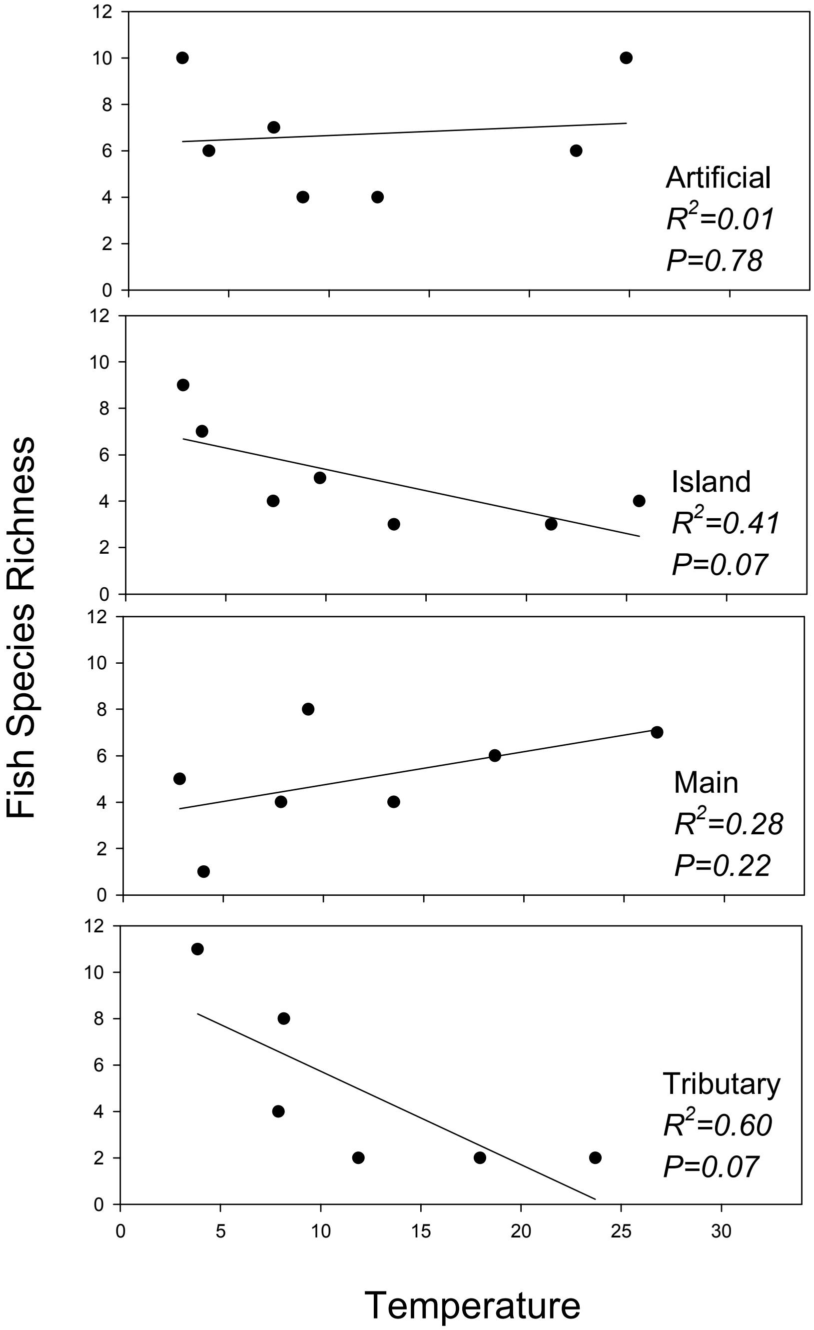


Figure 2-10. Number of species during winter through spring 2002 and 2003 as a function of dissolved oxygen concentration (mg/L) in Smithland Pool, Ohio River.

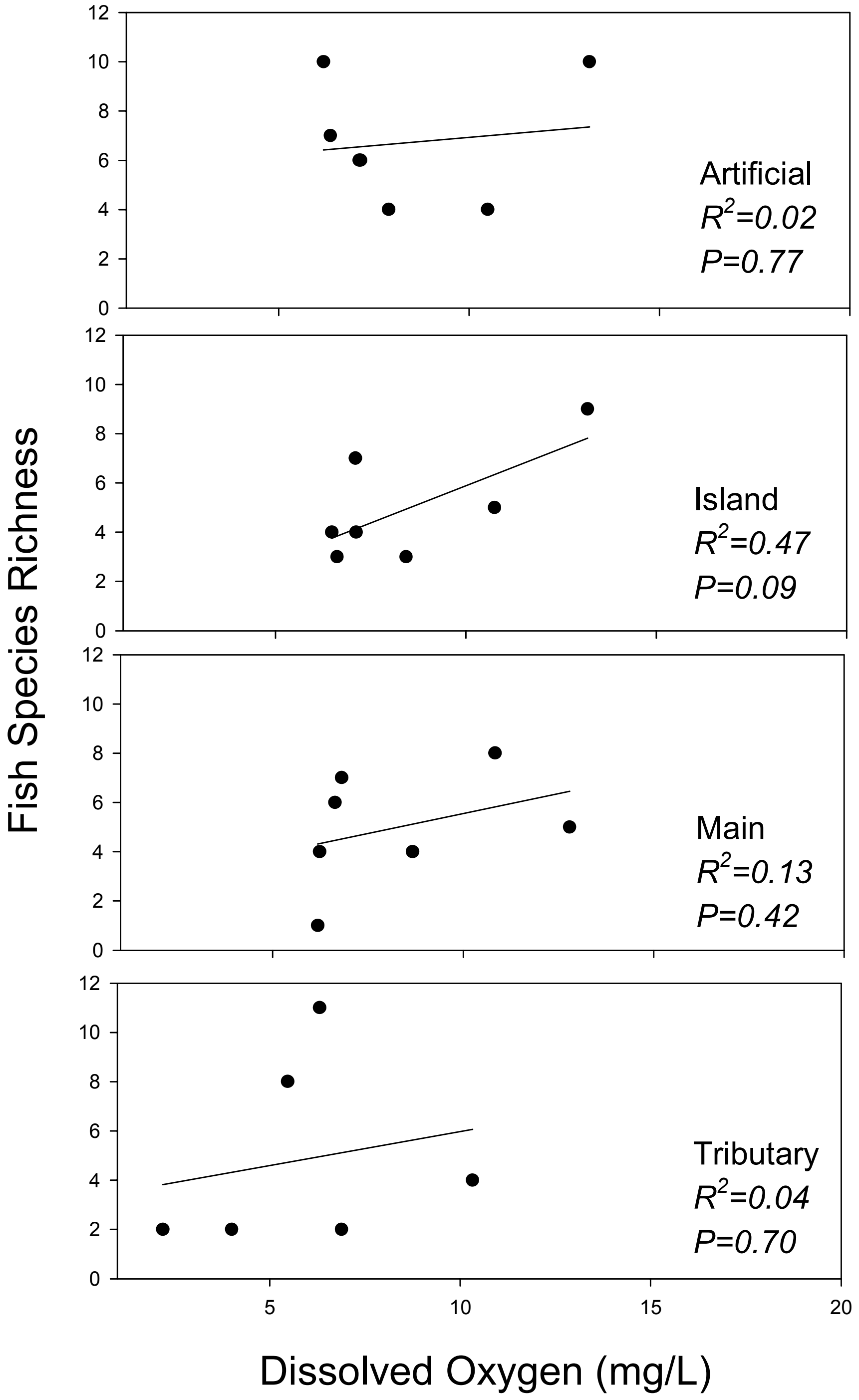


Figure 2-11. Number of species during winter through spring 2002 and 2003 as a function of flow (m/s) in Smithland Pool, Ohio River.

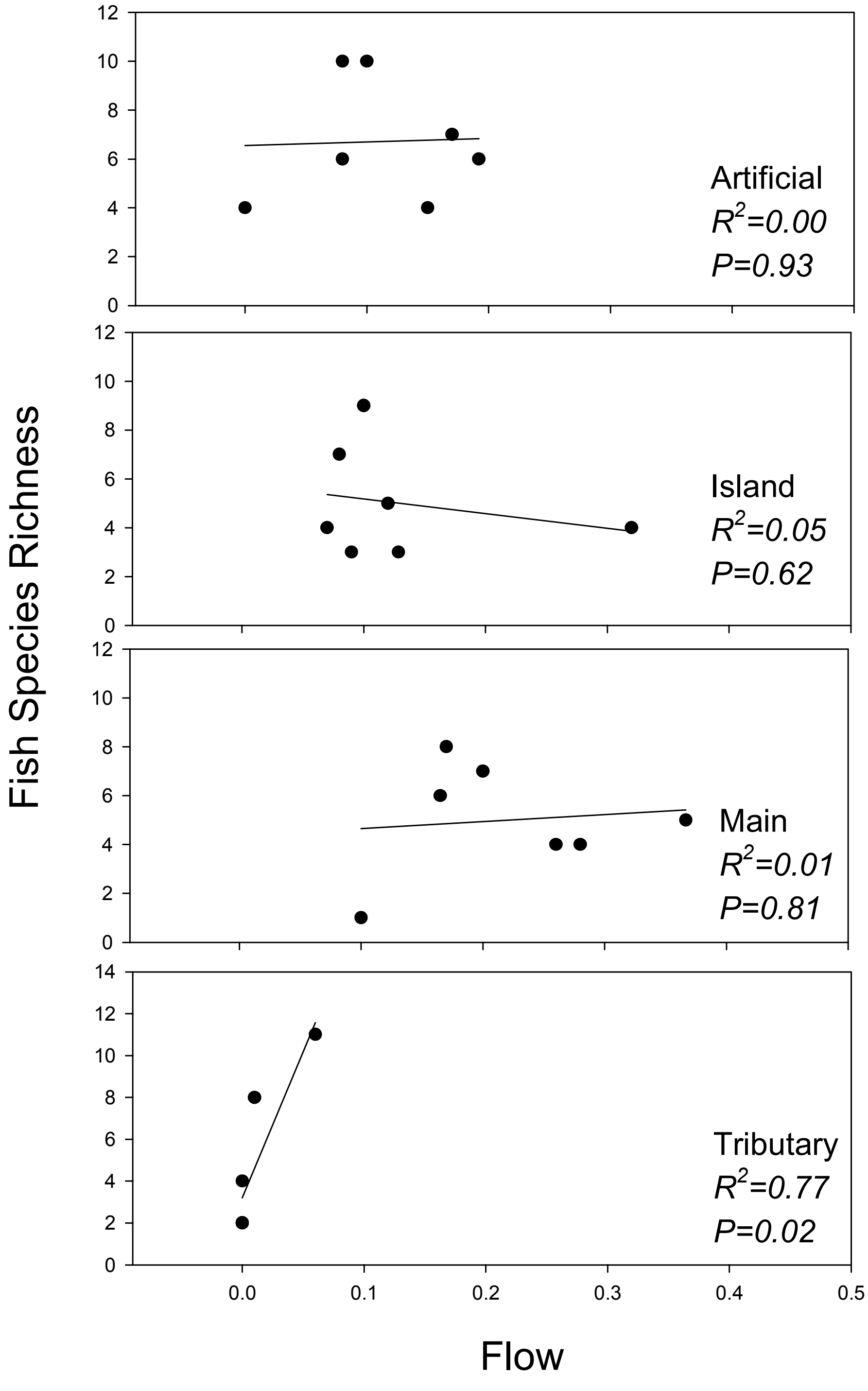


Figure 2-12. Length at age for freshwater drum, channel catfish, crappie, and white bass in Smithland Pool, Ohio River during winter through late spring 2002 (solid symbols) and 2003 (open symbols).

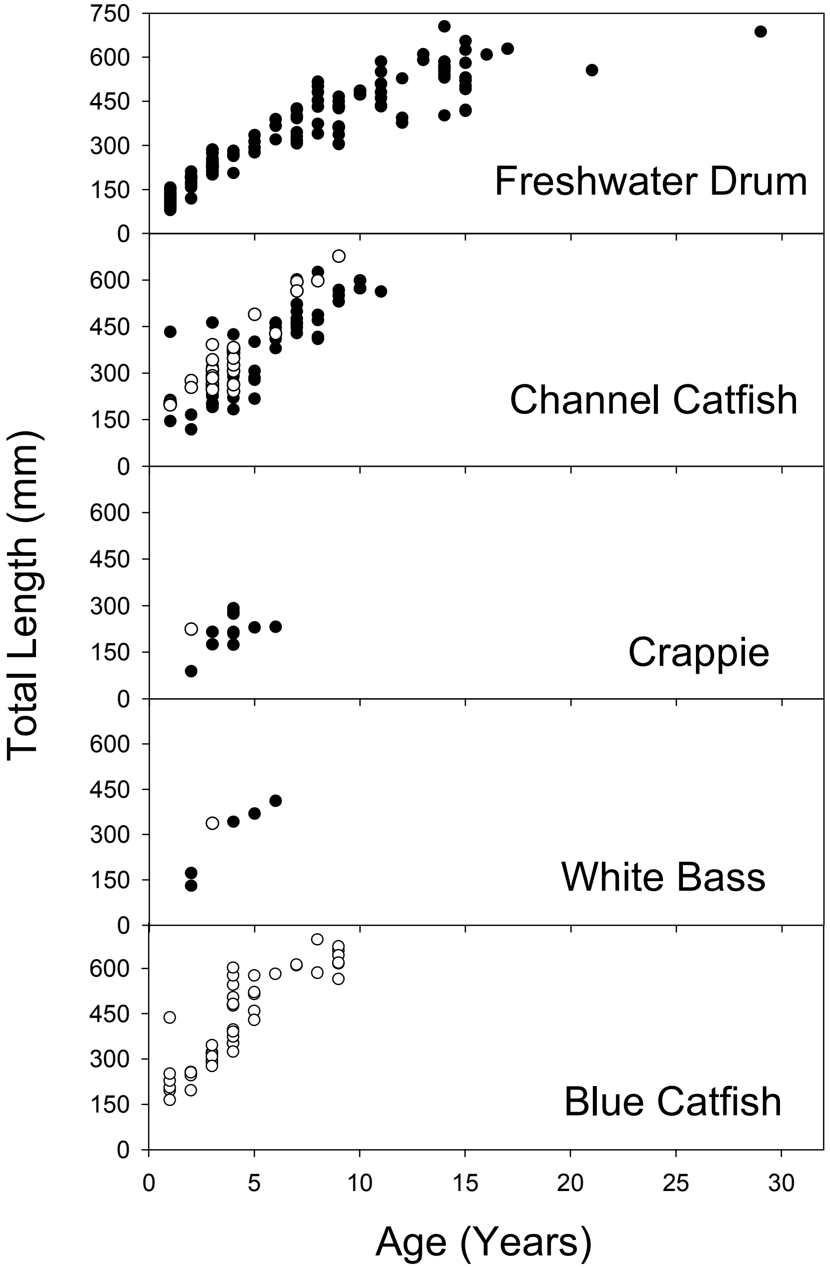


Figure 2-13. Length frequency distribution for freshwater drum in Smithland Pool, Ohio River during winter through spring 2002.

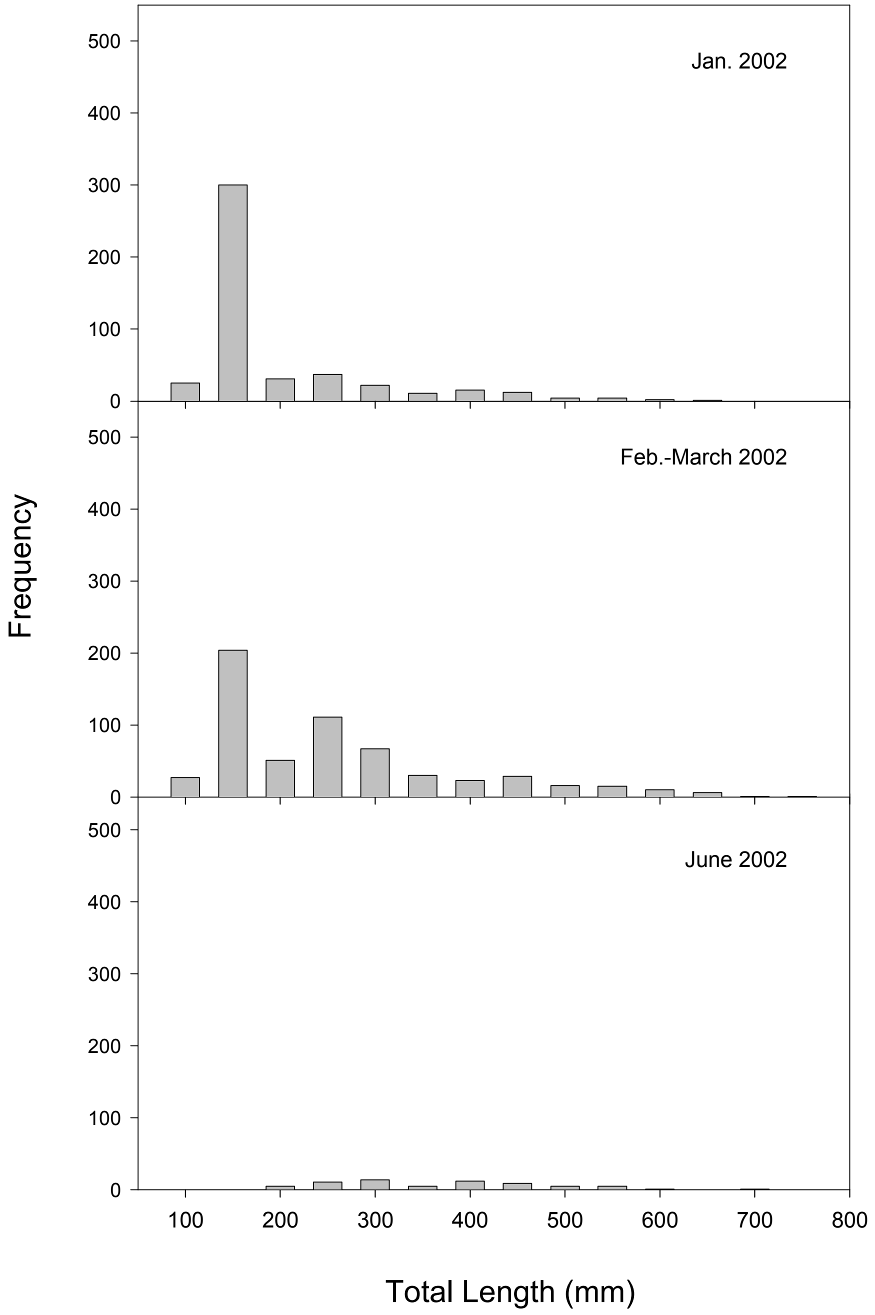


Figure 2-14. Length frequency distribution for freshwater drum in Smithland Pool, Ohio River during winter through spring 2003.

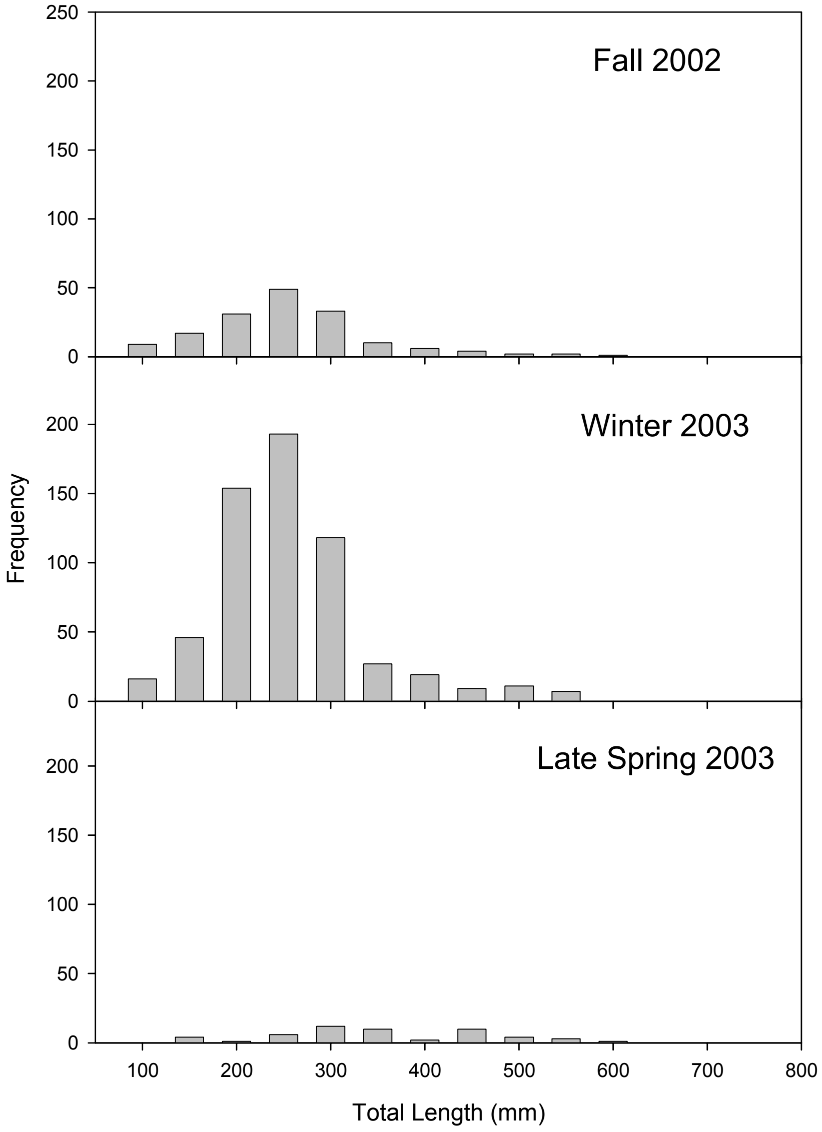


Figure 2-15. Relative weights (Wr) of freshwater drum sampled during three periods in Smithland Pool, Ohio River during winter 2002.

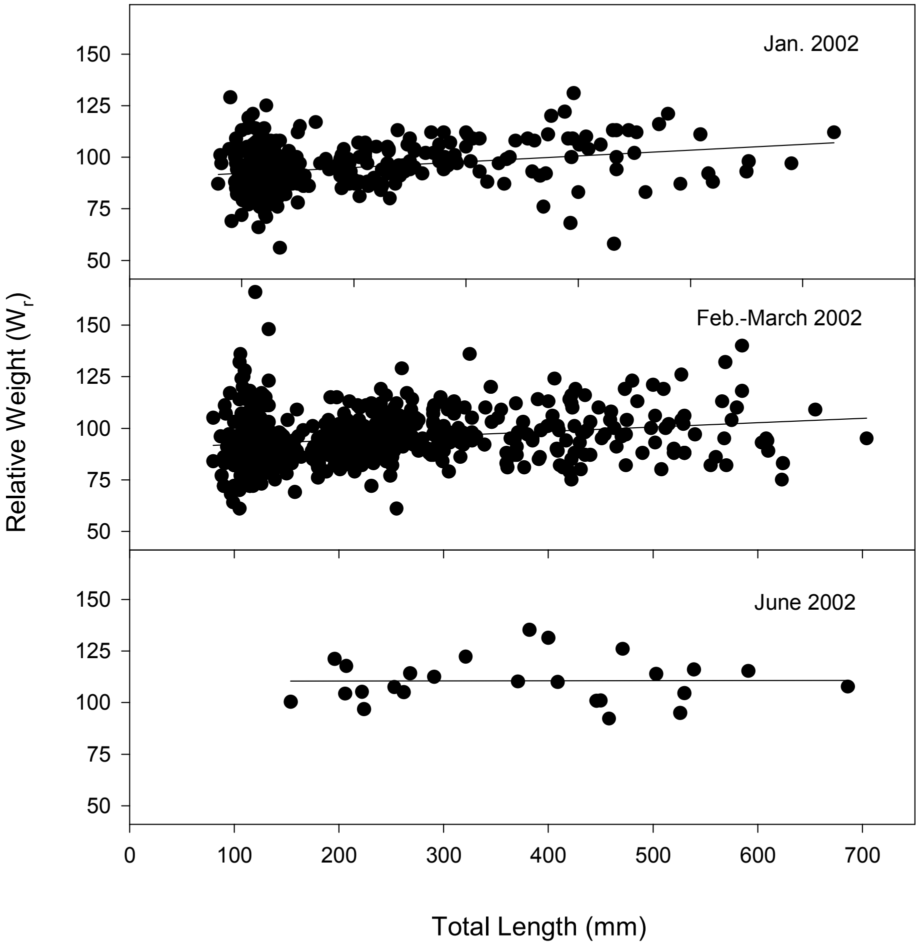


Figure 2-16. Relative weights (Wr) of freshwater drum sampled during four periods in Smithland Pool, Ohio River during winter 2003.

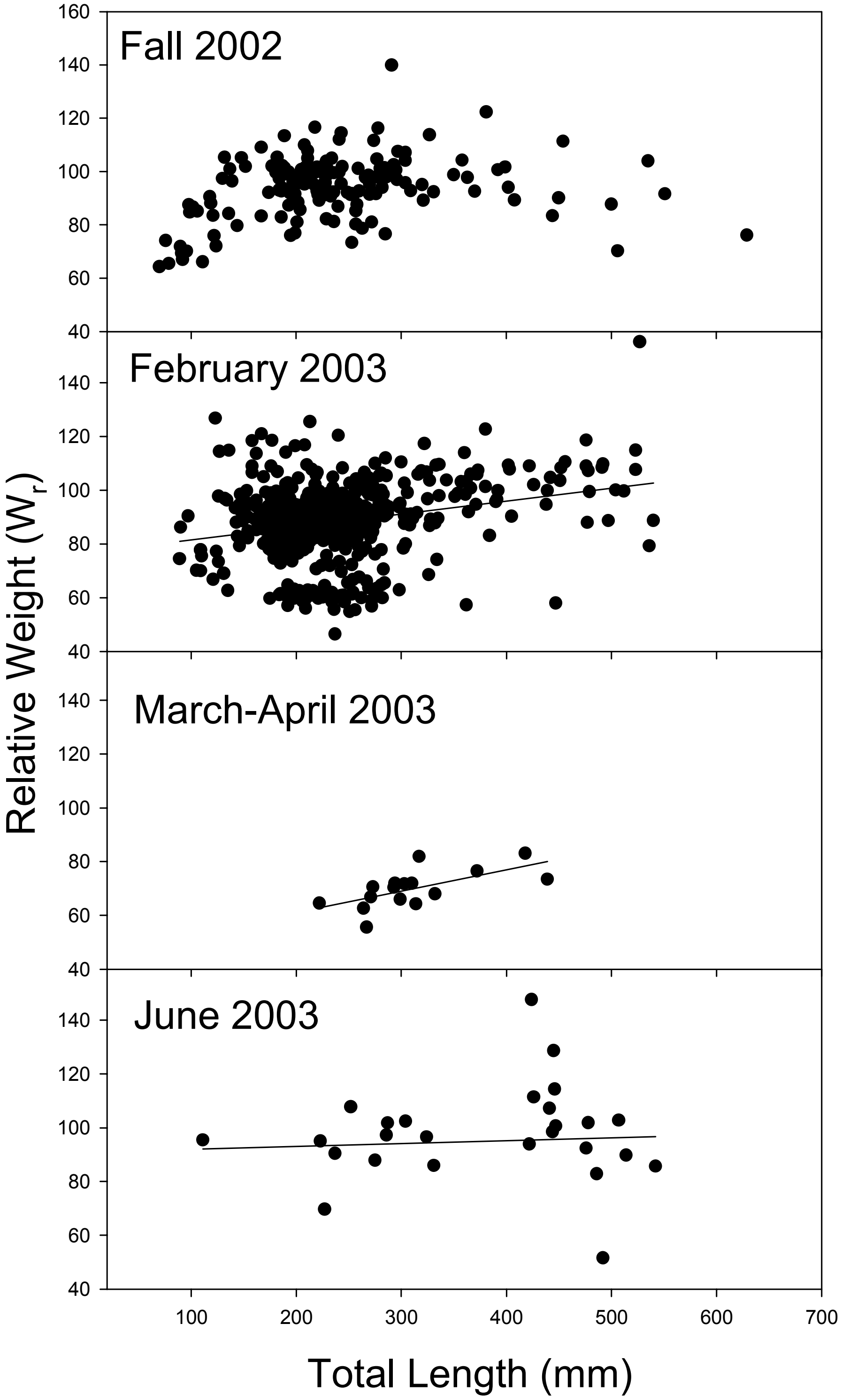


Figure 2-17. Proportion of freshwater drum with empty stomachs as a function of 50 mm length class during the first two sampling sessions of winter 2002 in Smithland Pool, Ohio River. Each length class is comprised of 3-8 individuals.

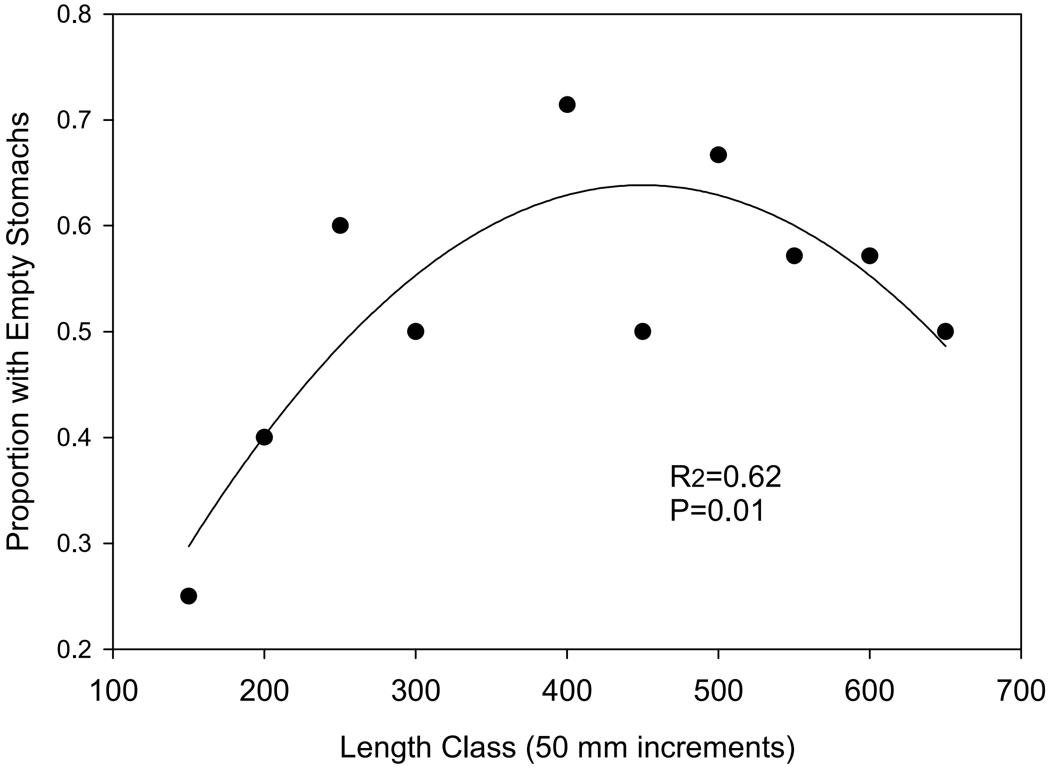


Figure 2-18. Length frequency distribution for channel catfish in the Smithland Pool of the Ohio River during winter through late spring 2002.

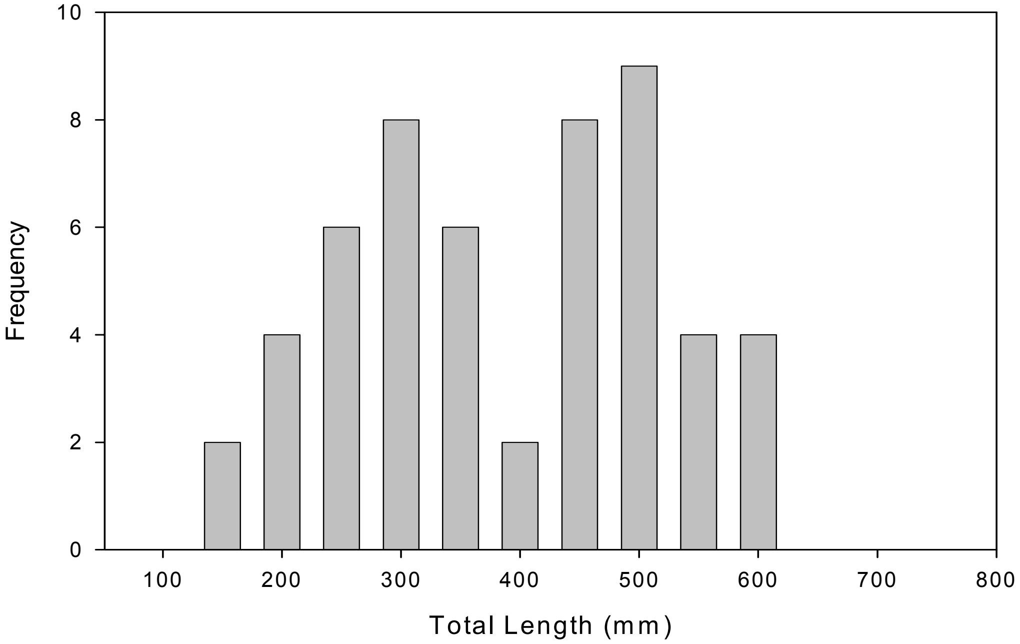


Figure 2-19. Length frequency distribution for channel catfish in the Smithland Pool of the Ohio River during winter through late spring 2003.

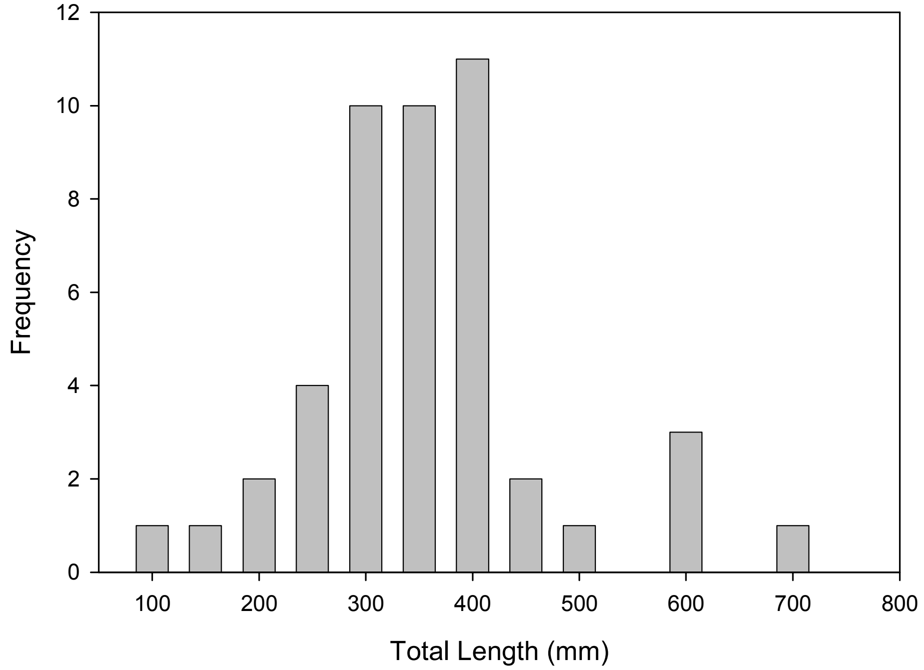


Figure 2-20. Relative weight (Wr) as a function of total length of channel catfish during winter through late spring 2002 in Smithland Pool, Ohio River.

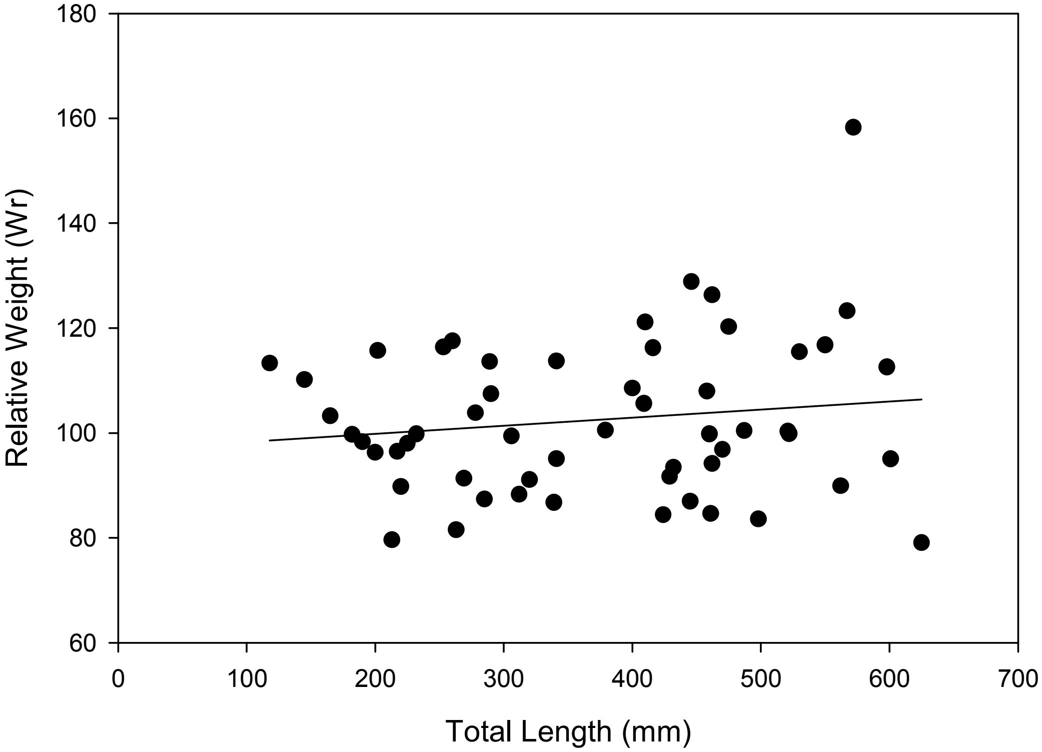


Figure 2-21. Relative weight (Wr) as a function of total length of channel catfish during fall 2002 through late spring 2003 in Smithland Pool, Ohio River.

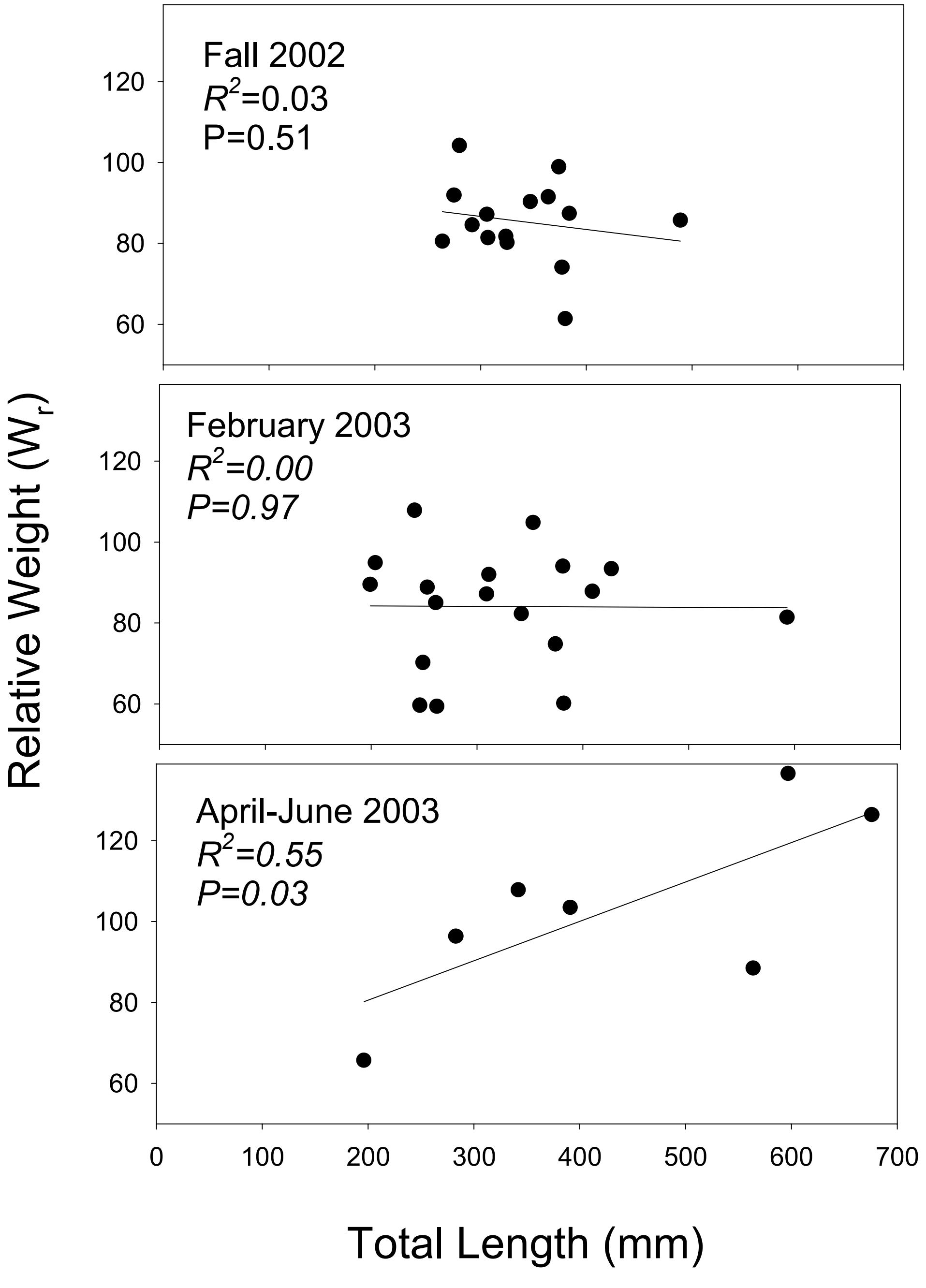


Figure 2-22. Length frequency distribution for blue catfish in the Smithland Pool of the Ohio River during winter through late spring 2002.

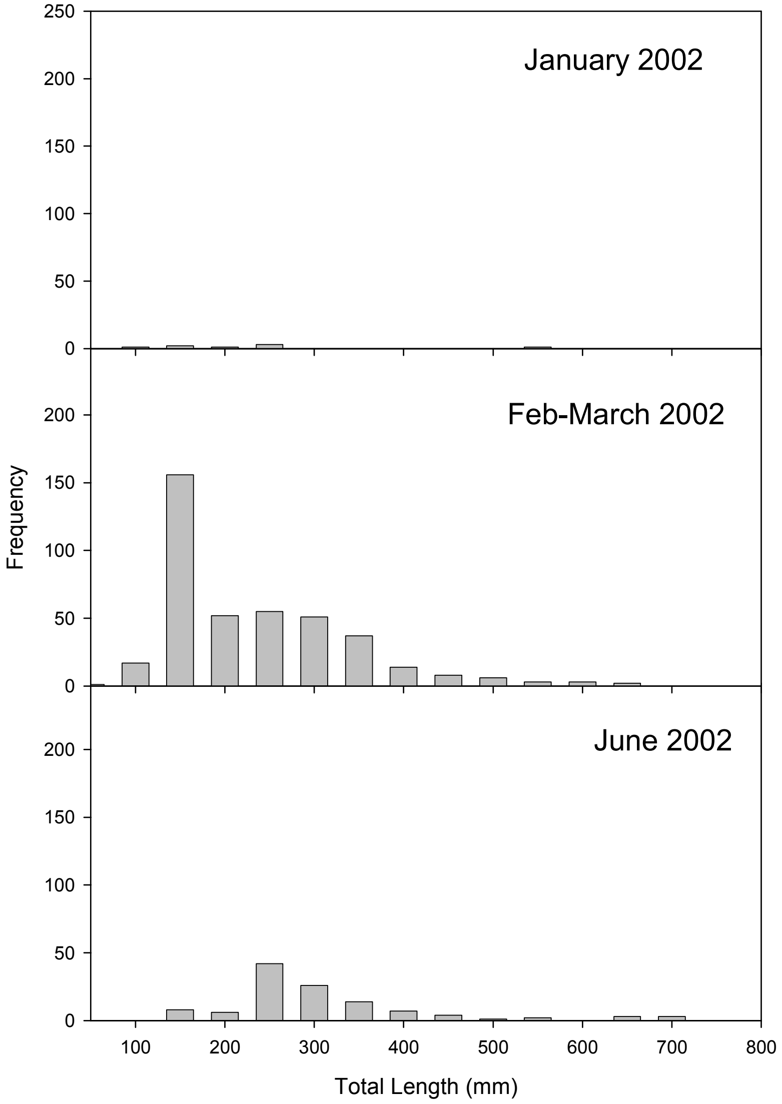


Figure 2-23. Length frequency distribution for blue catfish in the Smithland Pool of the Ohio River during winter through late spring 2003.

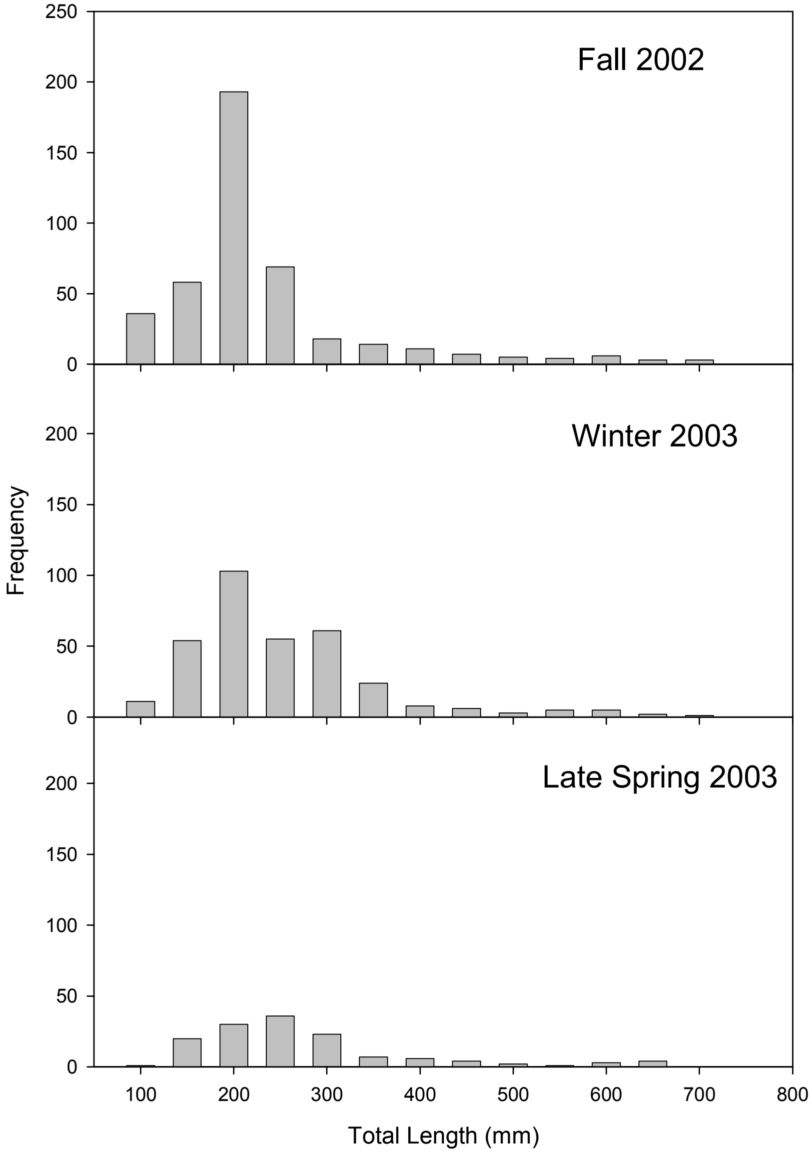


Figure 2-24. Blue catfish lengths versus weights during winter 2002. An analysis of covariance (ANCOVA) revealed that intercepts of lines differed among dates, with the lowest intercept occurring during the June 2002 sampling period.

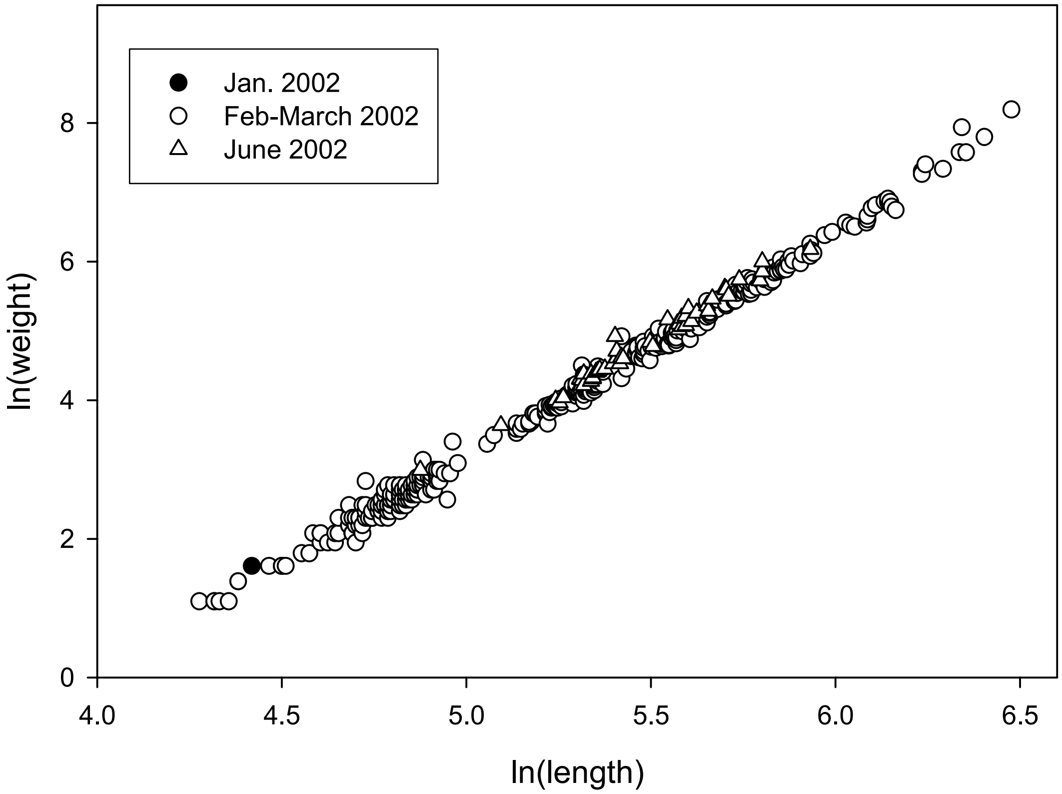
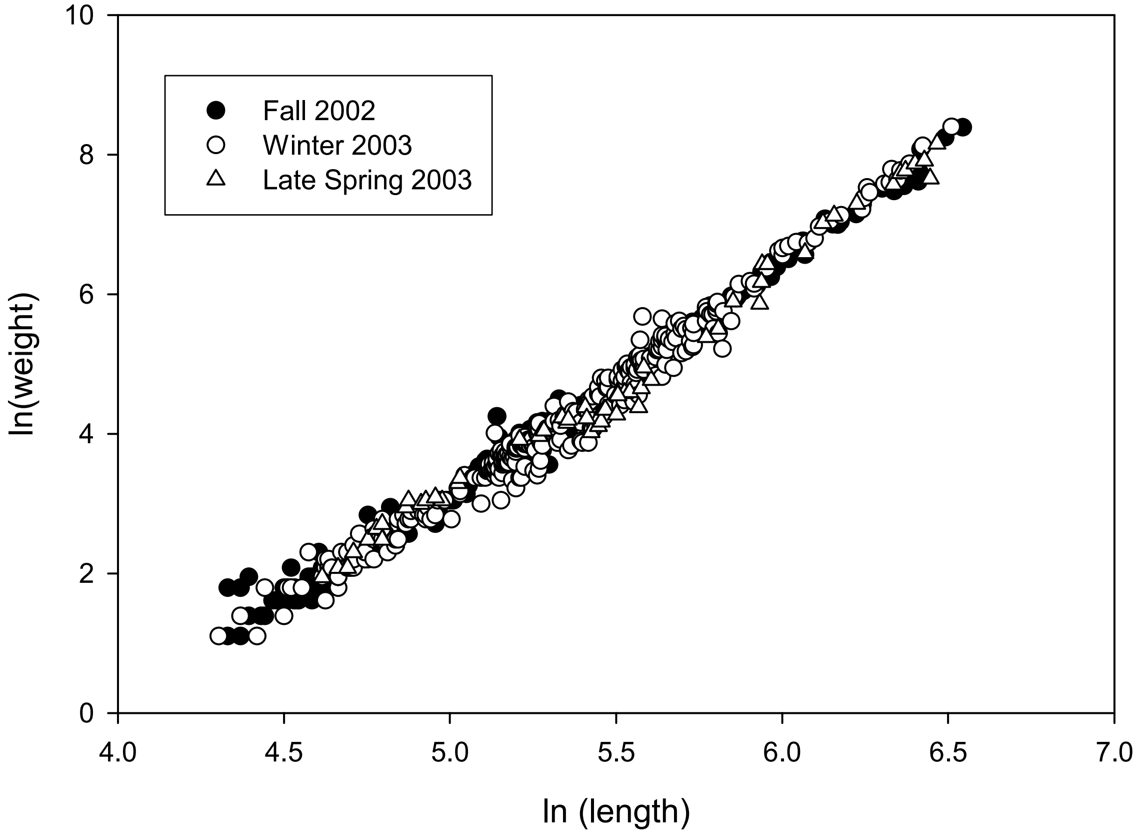


Figure 2-25. Blue catfish lengths versus weights during fall 2002 through winter 2003. An analysis of covariance (ANCOVA) revealed that intercepts of lines differed among dates, with the lowest intercept occurring during the fall 2002 sampling period.



Chapter 3 – Belleville Pool Field Sampling 2001-2003

Stuart Welsh, Kyle J. Hartman, and Ben Lenz, West Virginia University

INTRODUCTION

Fishes enter a torpor-like state in winter (Crawshaw 1984) where metabolic rates and consequently, respiration and activity rates are low (Carlson 1992, Cunjak 1996, Bodensteiner and Lewis 1992). The inability of a fish to expend energy in cold temperatures makes them susceptible to adverse physiochemical conditions, such as low dissolved oxygen concentrations and strong current velocities (Cunjak 1996). Mortality rates of fishes can be high during low water temperatures in winter (Bodensteiner and Lewis 1992, Lyons 1997); however, fishes select refuge habitats to survive winter (Johnson et al. 1998). Given the link between winter temperature and fish mortality, fishery managers need to locate and protect winter refuge habitats.

Despite early calls for wintertime fish research (Hubbs and Trautman 1935), little is known about winter habitat preferences of fishes in temperate river systems (Hubbs and Trautman 1935, Nielsen et al. 1986, Sheehan et al. 1994). Sheehan et al. (1994) and Garvey et al. (2002; Chapter 1) reviewed the literature on species tolerance to velocity and temperature in large rivers, and reported low tolerance to high velocities at temperatures below 4 ºC. Species should partition habitat during winter largely as a function of their relative tolerance to winter temperatures, flow velocity, and minimum dissolved oxygen concentration (Johnson et al. 1998). In our study on Belleville Pool, macrohabitats of the Ohio River provide habitat-specific combinations of these three important factors. We identified five main habitat types (Table 3-1, see Vallazza et al.

1994 and Cray 1999 for similar delineations). Based on research cited herein and in Sheehan et al. (1994) and Garvey et al. (2002; Chapter 1), backwaters, island habitats, tributary confluences, and deep hole habitats provide winter refuges for riverine fishes.

Objectives

Our objective was to (1) determine species/habitat associations among main channel, tributary mouth, backwater, head of island, tail of island, and deep hole habitats during winter in Belleville Pool, Ohio River. A secondary objective was to determine abiotic habitat characteristics associated with fish habitat use. This research was conducted as partial fulfillment of a Master's degree (see completed thesis, Appendix 1).

LITERATURE REVIEW

Winter habitats of fishes in large rivers

Physiochemical tolerance limits influence range distributions and habitat use. Within the range of a species, seasonal variations in physiochemical factors are often extreme, such as cold winter conditions in temperate climates. During seasonal extremes, animals select refuge habitats where physiochemical factors are unlikely to exceed tolerance limits. In large temperate river systems, extremely low water temperatures during winter coupled with high flows increase mortality rates of fishes (Bodensteiner and Lewis 1992, Lyons 1997). Low levels of dissolved oxygen also increase mortality of fishes, and occur typically during ice-cover of backwater areas. Many fishes forage infrequently during cold winter extremes, and select refuges that minimize energy depletion. Fishes often increase fat-reserves before winter; hence, reducing mortality associated with energy depletion. However, energy reserves may not suffice given long winters or energy expenditures due to disturbance, such as variation in river flows or boat traffic (Nielsen et al. 1986).

Temperature and flow

During winter, riverine fishes select habitats with relatively high temperatures and low flows. Riverine fishes overwinter in velocity shelters (Logsdon 1993, Bodensteiner and Lewis 1994, Johnson et al. 1998) and areas with warmer temperatures and lower flows than mainstem river sections, such as off-channel coves, marinas, embayments and industrial warm-water outflows (Raibley et al. 1997, Sheehan et al. 1994, Knights et al. 1995, Gent et al. 1995). Also, backwater areas with relatively warmer temperatures and lower flows provide winter habitats (Bodensteiner and Lewis 1992, Raibley et al. 1997, Sheehan and Rasmussen 1999).

Sheehan et al (1990) examined temperature and flow requirements for several fishes common in the Ohio River, such as gizzard shad (*Dorosoma cepedianum)*, channel catfish (*Ictalurus punctatus*), and freshwater drum (*Aplodinotus grunniens*). Gizzard shad, channel catfish, and freshwater drum occupy relatively low velocity areas during winter (Heese and Newcomb 1982, Newcomb 1989, Sheehan et al 1990, Bodensteiner and Lewis 1994, Logsdon 1993). Gizzard shad are vulnerable to winter die-offs during low water temperatures (Miller 1960). Garvey (2002; Chapter 1) reviewed over 300 articles on the winter ecology of riverine fishes and reported temperature preferences of $ 4 °C for many species in large rivers, such as green sunfish (*Lepomis cyanellus*), bluegill (*Lepomis macrochirus*), and freshwater drum. Some species, such as channel catfish, black crappie (*Pomoxis nigromaculatus*), and walleye (*Stizostedion vitreum*), can maintain swimming abilities at temperatures < 4 °C (Sheehan et al. 1990). Temperature and flow preferences during winter, and swimming abilities during low temperatures are unknown for most riverine fishes.

Dissolved oxygen

Abiotic factors other than water temperature and flow velocity likely influence the suitability of winter habitats. Backwater areas can become anoxic and unsuitable as overwintering areas (Bodensteiner and Lewis 1992, Knights et al. 1995, Johnson et al. 1998). Low DO levels can result in fish die-offs when backwater areas become isolated from the main channel during low water levels in winter (Raibley et al. 1997). In the West Virginia section of the Ohio River, dissolved oxygen is reduced by water pollution near cities, but normally remains above critical levels (Pearson and Krumholz 1984).

Gear Use and Comparisons

Passive gears, such as hoop nets, gill nets, traps (Hubert 1996) and active gears , such as electrofishers and trawls (Hayes et al. 1996) are used to sample fishes in large rivers. Gear use should reflect seasonal variation in fish behavior. For example, passive gears may be ineffective for inactive fishes during winter. Bottom trawling in large rivers is complicated by benthic debris, whereas electrofishing near the surface fails to sample benthic areas. Most fishes are inactive and benthic during winter, so active and benthic-oriented gears are logical choices, such as a variable-depth AC electrofisher (Newcomb 1989). Regardless of gear type and seasonal affects, detection probabilities and sampling efficiency are low for most riverine fishes (Thompson et al. 1998).

Sampling Efficiency

Sampling efficiency, the percent of the population captured by sampling, is difficult to quantify. Sampling efficiency of a gear type can be examined by sampling with other gears or toxicants. Few gears, however, provide a 100% probability of detecting all individuals within an area of an open system, such as a single habitat type within a large river. Results from gear comparisons are often not definitive. For example, one could interpret low captures from two gears as evidence for low fish abundance or one could argue that both gears sample inefficiently.

Conductivity, flow velocity, water temperature, and biological factors affect electrofishing efficiency. Low conductivity decreases electrofishing efficiency (Kolz et al. 1998). High flow velocity moves fishes away from netters and reduces capture success. Additionally, species have variable vulnerability to electrofishing because of morphological, physiological, and behavioral differences (Kolz et al. 1998). Small fishes are less vulnerable to electrofishing (Reynolds 1996).

Electrofishing gears and configurations, such as AC versus DC and electrode position, also influence sampling efficiency. In variable-depth AC electrofishers, the electrical field occurs between electrodes rather than between boat and electrodes as in traditional DC electrofishers. If electrodes from variable-depth AC boats are near the river bottom, then the gear becomes specific to bottom habitat (because of electrode placement), so fishes in the water column are less vulnerable. In contrast, DC electrofishing boats typically deploy electrodes near the surface, and are ineffective at sampling benthic areas in deep habitats.

METHODS

Study area description

The Belleville Pool of the Ohio River, created by Belleville Lock and Dam (rkm 328.1), is bound upstream by Willow Island Lock and Dam (rkm 260.2). The 67.9 km pool averages 404.5 m wide, 7.3 m deep, and comprises 2850 ha of surface area (ORSANCO 1994). The deepest section of the pool (15 m) lies directly upstream of Belleville Lock and Dam. A navigation channel (2.7 m deep) is maintained for commercial barge traffic by the United States Army Corps of Engineers (USACE) (ORSANCO 1994). Two other large rivers, the Muskingum River in Ohio, and the Little Kanawha River in West Virginia are navigable tributaries of the Ohio River.

The riparian zone is a mixture of hardwood forests, urban and industrial frameworks, and agricultural settings. Most large floodplains near Belleville Pool are heavily urbanized. The two largest population centers along Belleville Pool are Parkersburg, WV (confluence of the Little Kanawha and Ohio rivers) and Marietta, OH (junction of Muskingum and Ohio rivers). Riparian areas unaffected by human settlement are steep forested hillsides that restrict lateral flow away from the mainstem Ohio River.

Habitat type classifications

We classified habitat types as main channel, deep hole, backwater, island head, island tail, tributary, wing dam, and embayment. Vallazza et al. (1994) and Cray (1999) discussed similar habitats, and our classification scheme (see Table 3-1) is further described below. Main channel habitats are used as commercial navigation routes, and typically have shallow near-shore areas and deeper mid-channel sections. Deep hole habitats are deep areas created by dredging or natural scour within main channel or backwater areas. Backwater, island head, and island tail habitats are associated with islands. Backwater habitats are not typically used for barge navigation and occur between an island and the mainland. Seven backwater areas (associated with seven islands) occur within the Belleville Pool. Habitats near the upstream and downstream ends of each island are island head and island tail habitats, respectively. Embayment habitats are shallow bay-like areas connected to the main channel by tributary or artificial channel. Wing dams (and other artificial flow barriers) create near-shore habitats with low water velocities.

Selection and description of study sites

Initially, we selected six main channel sites, six tributary confluences, six backwater areas, six head of islands, six tail of islands, and three deep hole sites (Figure 3-1; see coordinates in Table 3-2). Main channel and tributary sites were selected randomly within Belleville Pool and stratified relative to their abundance in the upper and lower half. We added two main channel sites, three tributary sites, three deep hole sites, one wing dam (artificial) site, and an embayment (Figure 3-1; Table 3-2). Depths of main channel and backwater sites ranged from 3 to 9 m, and included near-shore mid-channel transects. Tributary habitats were 2 to 9 m deep, and included near-shore areas and deeper scour holes. Depths of deep hole habitats ranged from 7 to 14 m, and those of island head and tail habitats ranged from 2 to 6 m. Island size differed among Newberry (0.4 km long), Blennerhasset (6.4 km long), Neal (2.4 km long), Halfway (1.6 km long), Muskingum (3.2 km long) and Marietta (4.8 km long), but sample areas within backwater, head, and tail habitats were similar among islands. Depths, flows, and water quality of each habitat type are presented with results.

Sampling methodology

Abiotic data

At each sample site, we used a YSI 6820 meter or a Hydrolab Surveyor 4 to measure specific conductivity, dissolved oxygen (DO), pH, salinity, and temperature depth profiles at 1m intervals. Turbidity was estimated with secchi disk (near surface), and a YSI 6820 meter along 1 m depth profiles during the December 2002 and January 2003 sample sessions. We measured flow velocity with a Marsh-McBirney Flowmate 2000 at the surface (depths < 1.5 m) or at 2 m.

Bottom contour and depth profiles for each transect at each site were recorded by sonar during peddle time. Tidbit dataloggers recorded water temperatures every 30 minutes at three main-channel (RM180, RM196, and near head of Marietta Island) and three back-channel (Blennerhasset, Newberry, and Neal Islands) sites during February 2002 through March 2003. Presence/absence of large woody debris was recorded for each site.

Fish sampling

Fishes were sampled with a variable-depth AC electrofishing boat for depths of 2-10 meters (Grunwald 1983, Newcomb 1989). Our boat is an 18 ft flat-bottom (7 ft wide) aluminum jon boat with a 5 kilowatt Honda 3-phase AC generator. Three electrodes (2 m sections of 1.25 inch diameter corrugated conduit) are attached to 14-gauge 3-strand pre-insulated solid wire. The wire from the three electrodes connects to an electrical junction box, which is wired to the generator. A ground wire connects the boat and generator. Amp output is turned off by the generator's on/off switch or by a safety footswitch (controlled by the boat operator). If needed, we reduce amp output by taping the electrodes, i.e., amps decrease when the electrode surface is covered with electrical tape.

The amp output is monitored by inline amp gauges and/or clip-on amp gauges. Output is generally above 7 amps, and typically 9-10 amps.

Electrodes were weighted and lowered to the river bottom off a boom on the bow. We attempted to get the electrodes near bottom without making contact. One, two, or three transects were electrofished in the direction of the river current lasting up to10-minutes (peddle time) for each sampling location. During peddle time with the bow upstream, we allowed the boat to drift with the river current. This maintained electrodes near the river bottom, but caused longer transects during higher flows. In backwater and main channel habitats, the three transects represented shallow, intermediate, and deep water areas and were sampled near each shore and in mid-channel. Peddle time and number of transects varied with habitat availability. Often, we sampled two transects within the small areas of island head and island tail habitats, or one transect within scour holes of tributary habitats. During or after peddle time, researchers in a chase boat or the electrofishing boat netted fishes from the water surface.

Fish data

Fishes were captured, identified to species, measured (nearest millimeter total length, TL), and weighed. Weights for large fishes (over 1kg) were taken to the nearest 25g with a Pesola spring scale (5 kg maximum). Smaller fishes (less than 1 kg) were weighed to the nearest 1g with a Homs spring dial scale (1kg maximum). Channel catfish, black crappie, white crappie (*Pomoxis annularis*), hybrid striped bass (*Morone saxatilis x Morone chrysops*) and freshwater drum were weighed and frozen for removal of spines or otoliths. Ages of channel catfish were determined with sections of pectoral spines, whereas ages of other species were based on otoliths. We used at least two observers for age estimation.

Data management procedures

We archived copies of field notes, lab data, and electronic data files and recorded metadata for electronic data files. Data, stored primarily in Excel spreadsheets, were checked for accuracy after transfer from field notes.

Statistical methods

Site occupancy rates

Abundance or presence/absence estimates are often biased (underestimated) unless adjusted with detection probabilities (MacKenzie and Kendall 2002). We used occupancy rate models (a method that incorporates detection probabilities) to estimate the proportion of sites occupied by freshwater drum and channel catfish using presence/absence data (MacKenzie et al. 2002). Specifically, we used Program MARK to estimate maximum likelihoods of two parameters: the probability of detection (p) and the proportion of sites occupied by a species (ψ). The proportion of sites occupied by a species could be estimated as the fraction of sites with species detections over the total number of sites. For example, if freshwater drum were collected in 10 of 20 tributary habitats, then one estimate of ψ is 10/20 or 0.5. This estimate, however, is biased (low) if the probability of detection is less than 1 (nondetection may not equal absence). Detection probabilities can be estimated with data from multiple visits to each site, and used to adjust ψ. If a species was detected on the second sample occasion, but not on the first and third occasions, then the likelihood of ψ given detection probabilities (p) for site *i* would be as follows:

$$L(\psi, p) = \psi_i(1 - p_{i1})p_{i2}(1 - p_{i3})$$

The likelihood for a capture history of three occasions without detection at site k would be as follows:

$$L(\psi, p) = \psi_k \prod_{t=1}^{3}(1 - p_{kt}) + (1 - \psi_k)$$

Selection of occupancy rate models followed an information-theoretic approach based on Kullback-Leibler information and likelihood theory (Burnham and Anderson 1998). A set of candidate models for estimates of p and ψ were selected before analysis. Biologically-reasonable hypotheses were used to develop the set of candidate models and were examined under a multiple working hypotheses framework (Chamberlin 1965). We modeled parameter ψ as unique for each habitat type or constant across habitat types, with notation as ψ(habitat) and ψ(.), respectively. Detection probabilities were modeled as (1) unique for each site, (2) constant across sites, (3) with time as a covariate, or (4) with abiotic covariates of conductivity, depth, DO, temperature, or velocity. Additional models with interaction terms were not considered given our sparse (many zeros) data set.

Candidate models were fit to the data using Program MARK, and selected based on a second order adjustment to Akaike's information criterion (AICc; Burnham and Anderson 1998), where

$\mathrm{AIC_c} = -2\log\left(L(\hat{\theta})\right) + 2K + \frac{2\mathrm{K}(\mathrm{K}+1)}{(\mathrm{n}-\mathrm{K}-1)}$, and n = sample size, K = number of model parameters. The model likelihoods were determined by comparing Akaike model weights (as described below). The AICc values were rescaled as simple differences, where $\Delta_{\mathrm{i}} = \mathrm{AICc_{i}} - \mathrm{minAICc}$. Then the likelihood of model *i*, given the data, is $L(M_i|\underline{x}) = \exp(-\tfrac{1}{2}\Delta_i)$, and normalized to sum to 1, as $w_i = \frac{\exp(-\frac{1}{2}\Delta_i)}{\sum_{r=1}^{R}\exp(-\frac{1}{2}\Delta_i)}$. The w_i values can be interpreted as probabilities, where the relative likelihood of model i versus model j is w_i/w_j. For example, given weights of 0.9 for model i and 0.1 for model j, then the model i is nine times more likely than model j.

We estimated p and ψ as a weighted average across all models, where weight is a function of model fit (Burnham and Anderson 1998; Buckland et al. 1997). Model averaging eliminates the need to select the single best model, allowing the uncertainty of model selection to be incorporated into the variance of parameter estimates (Burnham and Anderson 1998).

Multivariate descriptive and exploratory analysis

Following occupancy rate estimation, we used canonical correspondence analysis (CCA) to explore relationships between species and abiotic variables. Canonical correspondence analysis is a constrained ordination approach, and allows concurrent analysis of species abundance, site, and environmental (abiotic) data (ter Braak 1995). A square root transformation of abundance data minimized affects of a few high abundance values (McGarigal et al. 2000). We conducted CCAs using an Excel macro with data from February - April 2002 and December 2002 – March 2003, separately (macro obtained from Eric Smith, Virginia Polytechnic Institute and State University).

Sampling efficiency

Sampling efficiency, the percent of the population captured by sampling, is important in studies of animal abundance. Poor sampling efficiency will provide low (biased) estimates of abundance. Sampling efficiency of a gear type is difficult to quantify, but can be examined by sampling with other gears or toxicants. Few gears, however, provide 100% detection probabilities for all individuals or all species within open systems, such as macrohabitats of large rivers. Researchers at Southern Illinois University (SIU, Garvey et al. 2002, Chapter 2) conducted a companion study on winter habitat used by fishes in Smithland Pool, and we compared sampling efficiencies of the SIU and WVU boats. Additionally, we compared sonar, gill nets, DC electrofishing, and multiple pass removals with data collected by AC gear.

We attempted to corroborate abundance data from February 2002 – March 2003 with concurrent electrofishing and sonar surveys. We used sonar images to estimate fish abundance prior to electrofishing and to assess gear efficiency. A stern-mounted sonar device recorded fish abundance along with bottom contour profiles of each transect. Electrofishing was conducted by moving the boat backward, and the recorded sonar image was captured immediately preceding the passage of the bow-mounted electrofishing electrodes.

We used experimental gill nets at 11 sites and a Smith-Root DC electrofishing boat at one site for comparison with the variable-depth AC electrofishing boat. Gill nets were five panels (8 by 32 feet) with 3 to 12 inch stretched mesh. Anchored gill nets (a passive method) will likely be unsuccessful at capturing inactive fishes during winter. The use of gill nets will not provide an estimate of our electrofishing gear efficiency, but it may indicate species-specific vulnerabilities to gear types. For example, species captured with gill nets and not with electrofishing would support gear-specific differences. Comparing abundance data collected by DC electrofishing (with electrical field near the water surface) and variable-depth AC electrofishing boat (with electrical field near river bottom) also has limitations, and is restricted to relatively shallow habitats. In December 2002, we compared DC and AC electrofishing boats at the Blennerhasset Island tail.

We conducted multiple-pass removal samples at Bull Creek (January 2003 and March 2003) and main channel RM 165 (March 2003). We examined the relationship between fish size and estimates of detection probabilities. Although fishes were free to move in and out of the sample area, we believe low water temperatures and short time periods (approximately 10 minutes) between electrofishing passes minimized fish movements. Detection probabilities were estimated using the closed capture option in Program MARK, where four models were fit to the three-pass removal data. Among-species differences in detection probabilities were not important to our analysis, so we combined species to increase sample size, and separated fishes into two size groups (<300mm, >300mm). Standard removal models (Otis et al. 1978; White et al. 1982), and models reflecting fish size were selected with AIC and information theoretic methods as described above. Detection probabilities from the three-pass sample were parameterized as (1) equal among sample occasions and between size groups, (2) equal among sample occasions with unequal size groups, (3) equal for second and third sample occasions with equal size groups, and (4) equal for second and third sample occasions with unequal size groups. Analyses of two-pass samples were restricted to the first two models (listed above).

RESULTS

Effort and Sample dates

First sample phase (February, March, and April of 2002)

Thirty-seven sites were sampled during February, March, and April of 2002, including nine tributary confluences, six backwater areas, six head of islands, six tail of islands, seven main channel sites, and three deep main channel sites (Table 3-2). Sites were sampled from one to four times across four sample sessions (session 1, February 16 – 22; session 2, March 9 – 25; session 3, April 4 – 7; session 4, April 14 - 15). Based on higher temperatures, session 4 was not representative of winter conditions.

Second sample phase (December 2002, January 2003, March 2003)

During December 2002, January 2003, and March 2003, we sampled six tributary confluences, six backwater areas, six head of islands, six tail of islands, six main channel sites, and six deep main channel sites (Table 3-2). Sites were sampled from one to three times across the three sample sessions (session 1, December 12-17; session 2, January 10 – 19; session 3, March 1 – 17). Samples during March were interrupted by high flows and occurred during March 1 – 2 and March 16 – 17). We added a shallow embayment site (Little Sand Creek) in December 2002, and a wing dam, main channel, and deep hole sites in January 2003 (Table 3-2). Mean depths of sample transects (estimated with 50 randomly-selected depth measurements) were lowest for head and tail island habitats and highest for deep hole habitats (Table 3-3).

Abiotic data

Abiotic data are summarized in Table 3-4. Water temperatures (Celsius) ranged from 4.4 to 5.5, 5.5 to 7.7, 8.7 to 11.2, and 11.5 to 15.2 during our first, second, third, and fourth sampling sessions of 2002, and from 1.9 to 5.1 in December 2002, 0.4 to 3.6 in January 2003, and 1.95 to 11.24 in March 2003. The high temperature in March (11.24 C) was from the embayment habitat, whereas all other habitats had water temperatures below 6.4 C. Temperatures measured along 1 m depth profiles differed typically less than one degree Celsius (see Welsh et al. 2003 for specific profiles). Tidbit dataloggers recorded similar water temperatures among three main-channel and three back-channel sites during February 2002 through March 2003 (Table 3-5; Figure 3-2, 3-3). Turbidity ranged from 2.4 to 214 (NTU) in December 2002, 1.2 to 75.1 in January 2003, and 17.9 to 119.9 in March 2003, whereas secchi disk readings ranged from 0.15 to 2.15 m in December 2002, 0.33 to 1.6 m in January 2003, and 0.16 to 0.78 in March 2003. Turbidity and secchi readings were not taken during the February – April 2002 sample sessions because of equipment failure and oversight. Dissolved oxygen (mg/L) ranged from 13 to 13.9, 7.3 to 9.3, 6.6 to 12.5, and 9.9 to 12.3 during our first, second, third, and fourth sampling sessions in 2002. Dissolved oxygen ranged from 6.5 to 9.5 in December 2002, 12.1 to 14.6 in January 2003, and 11.07 to 13.79 in March 2003. Specific conductivity (uS/cm) ranged from 285 to 496, 244 to 408, 89 to 434, and 136 to 597 during the first, second, third, and fourth sampling sessions of 2002, and from 153 to 570 in December 2002, 321 to 520 in January 2003, and 185 to 545 in March 2003.

Flow velocity (m/s) at the surface (depths < 1.5 meters) or at 2 meters depth ranged from 0.04 to 0.38, 0 to 1.0, 0 to 1.1, and 0 to 1.15 during our first, second, third, and fourth sampling sessions of 2002, and from 0.0 to 1.0 in December 2002, 0.0 to 0.84 in January 2003, and 0 to 1.25 in March 2003. River stages at Marietta depict high flows during our sample periods (Figure 3-4). Instream structures (i.e. logs near water surface) were present within sampling transects of tributaries (Lee Creek, Little Hocking River), backwaters (Halfway, Marietta, Neal, Newberry), Island heads (Marietta, Newberry), Island tails (Blennerhasset, Marietta, Muskingum), and main channels (river miles 165, 180, 192, 194).

Fish habitat use

Species composition (both years)

We sampled 515 transects and captured 28 species with a variable-depth AC electrofisher during February 2002 through March 2003 (Table 3-6). Relative numbers of common species were similar to those from previous lock rotenone samples between RM 100 – 200 (Pearson and Krumholz 1984); freshwater drum and channel catfish were most abundant. Seventeen species were captured with a DC electrofisher from Little Sand Creek embayment. Thirty-two species were captured (based on all gears) during February 2002 through March 2003.

Species composition by habitat type and sample event

During the first phase (February – April 2002), we sampled 248 transects and captured 15 species (Table 3-7; see Welsh et al. for specific catch data). No fishes were detected at 194 transects. Channel catfish, freshwater drum, and gizzard shad were most abundant. We captured 119 channel catfish during February – April 2002, and percentages by habitat type were as follows: 63% tributary, 14% backwater, 5% island head, 2% island tail, 16% main channel, and 0% deep hole. Percentages of freshwater drum (N=174) by habitat type were as follows: 90% tributary, 2% backwater, 2% island head, 0% island tail, 6% main channel, and 0% deep hole. Tributary habitats had highest species abundances and the highest species richness, including gizzard shad, mooneye (*Hiodon tergisus*), common carp (*Cyprinus carpio*), emerald shiner (*Notropis atherinoides*), spottail shiner (*Notropis hudsonius*), highfin carpsucker (*Carpiodes velifer*), river carpsucker (*Carpiodes carpio*), quillback (*Carpiodes cyprinus*), channel catfish, orangespotted sunfish (*Lepomis humilis*), bluegill, white bass (*Morone chrysops*), walleye, and freshwater drum. The number of fishes collected in tributary confluences made up 83% of all individuals collected. No fishes were collected from the three deep hole sites.

During the second sample phase, fishes were not detected with variable-depth AC sampling at 71 of 88 transects in December 2002, 68 of 88 transects in January 2003, and 58 of 91 transects in March 2003. Although this seems to be a high rate of nondetection or species absence, it is consistent with samples from early 2002. Total species captured was similar between sample phases with 15 species captured in early 2002 and 23 species captured during December 2002-March 2003. Species presence in backwater and main channel habitats during December 2002 through March 2003 exceeded that from early 2002 samples. In an embayment habitat (Little Sand Creek, December 2002 through March 2003), we sampled 17 species (890 individuals) from two near-shore transects with a Smith-Root DC electrofishing boat. This included nine species not captured with our AC gear during December 2002 – March 2003 (bowfin, *Amia calva*; spotted sucker, *Minytrema melanops*; western mosquitofish, *Gambusia affinis*; white crappie; green sunfish; pumpkinseed, *Lepomis gibbosus;* warmouth, *Lepomis gulosus*; orangespotted sunfish; and bluegill). With these species, a total of 32 species was sampled during December 2002 through March 2003. The two near-shore transects in the embayment were shallow (< 1 m depth) with LWD, and could not be sampled with our variable-depth

AC electrofishing boat. We sampled one transect in the embayment (away from shore with 2 m depth) with the variable-depth AC electrofishing boat and captured one freshwater drum.

We captured 83 channel catfish during December 2002 through March 2003, and percentages by habitat type were 16% (tributary), 31% (backwater), 0% (island head), 0% (island tail), 52% (main channel), and 1% (deep hole). Percentages of freshwater drum (N=296) by habitat type were 37% (tributary), 7% (backwater), 0% (island head), 0.3% (island tail), 50% (main channel), 1% (deep hole), 2% (embayment), and 2% (wing dam). The highest species richness (N = 11) was taken from the embayment habitat in December 2002. Tributary habitats contained the highest species richness (N=13) in January 2003. Most species of tributary habitats in January came from one site, Bull Creek, whereas the embayment habitat was not sampled in January due to ice-cover. During March 2003, 16 and 10 species were sampled from embayment and tributary habitats, respectively. Although no species were collected from deep hole sites during February – April 2002, we captured three species (channel catfish, spotted bass, and freshwater drum) from a deep hole site near Marietta Island in December 2002.

Species composition by gear type

The primary gear was variable-depth AC electrofishing (515 transects; 28 species), whereas DC electrofishing (9 transects) and gillnets (11 sets) were used infrequently. Results from DC electrofishing at the Blennerhasset Island tail (December 2002) and gill nets (11 sites) were compared to variable-depth AC gear (summarized below), whereas DC electrofishing in the embayment was used to sample a unique habitat (nearshore embayment; inaccessible to the AC gear). We fished the Little Sand Creek embayment three times (during December 2002 and March 2003) with the DC electrofishing boat and captured 17 species. Nine of these species were not captured with AC gear during December through March 2003.

Size distribution, length-weight comparison, and ages

Size distributions of abundant species were depicted for both field seasons (combined and separate; Figures 3-5 through 3-7). The range of lengths and presence of multiple length frequency modes indicate several year classes within samples. However, we captured primarily adults (except for Little Sand Creek embayment), but juvenile freshwater drum were captured in tributary, backwater, main channel, and embayment habitats. In general, size distributions by gear, month, or habitat were inhibited by small sample sizes. Data from the embayment habitat (DC gear), however, are presented separately for orangespotted sunfish, bluegill, and white crappie (Figure 3-8; see Appendix 1, Lenz 2003).

Age-length relationships were examined for channel catfish, white bass, white crappie, and freshwater drum (Figures 3-9 through 3-12). Lenz (2003) reported von Bertalanffy growth models of channel catfish, white bass, and freshwater drum (Appendix 1). Mean lengths (variances and sample sizes in parentheses) of white crappie (ages 1 through 4) were 7.6 (1.08, 18), 13.8 (2.44, 25), 19.4 (5.28, 9), 28.4 (1.6, 10) cm, respectively. Mean lengths of white bass (ages 1 through 4) were 11.2 (NA, 1), 18.8 (3.36, 16), 27.8 (0.84, 10), 30.4 (1.3, 5) cm, respectively. Mean lengths (cm) of channel catfish (ages 0 through 9) were as follows: 12.4 (NA, 1), 23.8 (9.7, 5), 24.8 (39.7, 11), 35.6 (19.4, 48), 38.4 (40.7, 13), 45.6 (37.8, 23), 50.5 (55.5, 6), 54 (6.0, 6), 53 (NA, 1), 62

(32.0, 2). The oldest freshwater drum was estimated at 22 years (77 cm TL); ages 0 to 14 had mean lengths of 5.5 (0.5, 2), 8 (1.61, 60), 17.3 (8.2, 40), 23.8 (2.5, 50), 28.6 (5.59, 47), 31.6 (5.43, 20), 37.9 (8.1, 12), 45.0 (27.6, 6), 44.8 (63.6, 5), 48.7 (5.9, 8), 49 (32.0, 2), 48 (36.0, 5), 54.7 (21.2, 7), 58.7 (37.3, 3), 61.0 (8.0, 2). High variances, in part, reflect uncertainty from small sample sizes.

Relative abundance (CPUE)

With data combined for February 2002 through March 2003, CPUE (fish/hour) was highest for gizzard shad (10.6), freshwater drum (9.9), channel catfish (4.2), bluegill (3.4), emerald shiner (3.0), white crappie (1.5), smallmouth buffalo (1.4), orangespotted sunfish (1.0), and white bass (0.96) (Tables 3-8, 3-9, 3-10). The CPUE estimates for gizzard shad, emerald shiner, white crappie, and sunfish were largely influenced by catches within the Little Sand Creek embayment. The estimates for smallmouth buffalo and white bass were influenced by a single sample at a wing dam.

When separated by habitat types and sample events (excluding the embayment), CPUE was generally highest for tributaries (see Tables 26-34 in Welsh et al. 2003). During December 2002 and January 2003, however, CPUE for channel catfish and freshwater drum (the two species with highest abundances) increased in backwater and main channel habitats. A single sample from a wing dam habitat provided highest CPUE (fish/hour) estimates for carp (5.2), black buffalo (5.2), smallmouth buffalo (90.0), white bass (5.2), and freshwater drum (52.6).

Results of occupancy rate modeling

Site occupancy rate models were used to estimate detection probabilities (*p*) and the proportion of sites occupied (ψ) by freshwater drum in tributary, backwater, and main channel habitats. Models with depth, flow, and constant detection probabilities received highest weights for freshwater drum (Table 3-11). Model-averaged estimates of ψ were highest for tributaries during February through early April 2002, but were highest for main channel habitats during December 2002 through March 2003 (Table 3-12). Habitat specific parameters for ψ were unestimable for other species because of sparse data.

Results of multivariate exploratory analysis

Relationships among species abundances and environmental variables (flow, temperature, conductivity, depth, and turbidity) were depicted in CCA triplots (Figures 3-13, 3-14). For data from February 2002 through April 2002, the relationship among low flows, tributaries, and abundance of freshwater drum were emphasized along the axis of flow. To a lesser extent, channel catfish were also associated with areas of low flow velocities. Similarly, flow was the major axis and tributary habitats were associated with low flows from December 2002 through March 2003; flow, temperature, and conductivity depicted similar gradients. Higher flows, temperatures, and conductivities in main channel and backwater areas, however, were associated with the two species of highest abundance (freshwater drum and channel catfish) during December 2002 through March 2003. No relationship occurred among species, habitat types, and turbidity. Depth was associated with deep hole habitats, but not with species.

Sample efficiency

Sonar images were used to assess gear efficiency by comparison of the number of fishes viewed by sonar and the number of fishes collected at each site. We did not find a relationship between the number of fishes viewed by sonar and the number of fishes collected at each site during both seasons. During the 2002 season, the two methods were consistent during 91 transect samples, where no fishes were viewed on sonar and no fishes were collected (this includes the three deep main channel sites). Also, the number of fishes viewed on sonar equaled the number of fishes collected during six transects. However, 44 transects had a higher number of fishes viewed on sonar than collected, whereas the number of fishes collected exceeded the number of fishes viewed on sonar at 28 sample locations. Similarly, during the 2003 season, the two methods were consistent (no fishes collected or viewed) during 125 transect samples. The number of fishes viewed on sonar equaled the number of fishes collected during seven transects. Forty-three transects had a higher number of fishes viewed than collected, whereas the number of fishes collected exceeded the number of fishes viewed at 34 sample locations.

Other methods to assess sampling efficiency included comparison of the WVU variable-depth AC electrofishing boat with (1) a similar boat used by SIU, (2) a Smith-Root DC electrofishing boat, and (3) anchored gillnets. The variable-depth AC electrofishing boats of SIU and WVU are similar in construction and sampled with similar efficiency during comparison. Eleven gill nets were fished during the December 2002 through March 2003 sample sessions (Table 3-13). Three gill nets were set overnight at Bull Creek (tributary habitat), Marietta Island head, and river mile 167 (main channel) in December and were fished for a combined total of 76.85 hours. In January, three gill nets were fished during the daytime at Neal Island head, tail, and backwater sites for a combined total of 14 hours. During March 2003, three gill nets were fished (Lee Creek, Hocking River, and Newberry Island tail) for 16.75 hours, collectively. Seven of the 11 gill net sets caught no fish, yielding the same results as the AC electrofishing efforts. The gill net at Bull Creek caught three fishes (two sauger and a shorthead redhorse) and none were captured with AC gear. At Neal Island backwater, the AC gear produced four fishes (three channel catfish and a freshwater drum) and the gill net caught one (a mooneye). In March, two carp were captured with a gill net at Lee Creek, whereas six freshwater drum and one gizzard shad were captured with AC gear.

In December 2002, DC and AC electrofishing boats were compared at the Blennerhasset Island tail and the embayment. We captured four fishes (a freshwater drum, two mooneye, and a sauger) from three transects sampled with the variable-depth AC electrofishing boat at the Blennerhasset Island tail in December 2002. We repeated the transects with a Smith-Root DC electrofishing boat and captured a silver chub (*Macrhybopsis storeriana*) and a smallmouth buffalo.

A three-pass removal sample at Bull Creek during January 2003 provided another look at sampling efficiency for the variable-depth AC gear. We captured 57, 6, and 1 fishes over 300 mm TL during three passes, respectively. Fishes under 300 mm TL from the three passes were 39, 31, and 1, respectively. The best approximating model parameterized detection probabilities as equal for second and third sample occasions with unequal size groups. The detection probability (with SE and 95% CI in parentheses) of small fishes (< 300 mm TL) for the first pass was 0.55 (0.06, 0.43 to 0.66), whereas the combined estimate for the second and third passes was 0.97 (0.03, 0.81 to 1.0). Detection probabilities of large fishes (> 300 mm TL) for the first and subsequent passes were 0.89 (0.04, 0.79 to 0.95) and 0.88 (0.12, 0.46 to 0.98), respectively. Two-pass removals at Bull Creek (March 2003) and main channel RM 165 (March 2003) yielded 28 and 4, and 34 and 11 individuals, respectively. We were unable to model data from Bull Creek (March 2003) due to small sample size; however, detection probability for fishes >300 mm TL (p = 0.85, 95%CI = 0.62 to 0.95) exceeded that for smaller fishes (p = 0.69, 95%CI = 0.36 to 0.88) from the best approximating model for RM 165.

DISCUSSION

Species/habitat associations

Canonical correspondence analysis and abundance estimates depicted low-velocity tributary habitats with highest abundances and richness of fishes during our February 2002 through March 2003 sample sessions. The proportion of tributary sites occupied by species was consistently higher than that of Island head, Island tail, and deep hole habitats. We believe that fishes used tributary habitats because of low velocities. Average surface velocity (m/s) for tributary confluences (0.10) was lower than those of backwater (0.58), island head (0.57), island tail (0.30), main channel (0.56), and deep hole (0.65) habitats. Carlson (1992) and Braaten and Guy (1999) also reported low-velocity tributary confluences as important winter refuges. During the December 2002 sample, water temperatures were consistently between 3 and 5 ºC for all habitats. In January 2003, all tributary habitats were below 3 ºC, except for Bull Creek (3.2 ºC) and Sugar Camp Run (3.2 ºC) which had highest estimates of abundance and richness. Although other unmeasured variables may explain fish use of tributary habitats during winter, we believe that low velocities are important, except when water temperatures fall below 3 ºC.

Backwater and main channel habitats were similar in many physiochemical measurements, including flow velocity, temperature, and depth. In some large rivers, backwater areas have warmer water temperatures and provide a shelter from current velocity during winter (Bodensteiner and Lewis 1992, Johnson et al. 1998, Raibley et al. 1997, Sheehan and Rasmussen 1999). The backwaters in the upper Ohio River valley are not characteristic of other large river backwaters that are slow-moving isolated sloughs. Our sample efforts did not find high abundance or diverse fish assemblages in backwater and main channel habitats, except when water temperatures in low-velocity tributary habitats were below 4 ºC. Our data indicate that many large river fishes trade low-velocity habitats for relatively high-velocity areas when water temperatures of low-velocity areas drop below 4 ºC. During our coldest sampling events (December 2002 and January 2003), the abundances of several species increased in backwater or main channel habitats, such as gizzard shad, mooneye, carp, smallmouth buffalo, channel catfish, and freshwater drum (as supported by occupancy rate models). Fishes in backwater and main channel habitats were primarily captured in near-shore transects, and taken rarely from mid-channel transects. Consequently, estimates of occupancy rates in island backwaters and main channels were decreased by low catches in mid-channel transects.

Few embayments occur within Belleville Pool, but our data from Little Sand Creek embayment support their importance as winter refuge habitats. We captured high abundances of juvenile sunfish (bluegill, green, orangespotted, pumpkinseed, and warmouth), juvenile white crappie, and juvenile gizzard shad in the low-velocity embayment habitat. Additionally, three juvenile freshwater drum were captured in the embayment habitat. Within other habitats, we captured mostly adult fishes (possibly from size selectivity of electrofishing gear). Juvenile fishes suffer higher mortality than adults at critically low water temperatures (Post et al. 1998, Wright et al. 1999, Fullerton et al. 2000, Jackson and Noble 2000, Bodensteiner and Lewis 1994); consequently, our sampling gear (if selectivity is an issue) missed an important component of winter fish/habitat relations, i.e., winter habitats of juvenile fishes. Our finding of juvenile fishes in a low-velocity habitat is consistent with other literature (Bodensteiner and Lewis 1992, Braaten and Guy 1999); however, we did capture juvenile freshwater drum in relatively high-velocity backwater and main channel habitats.

Dissolved oxygen, conductivity, and turbidity were not associated with differential habitat use among habitat types. Although dissolved oxygen concentrations may decline in some backwater areas during winter (Gent et al. 1995, Knights et al. 1995), data herein and those from Pearson and Krumholz (1984) indicate that DO remains relatively high in Belleville Pool. It is unlikely that DO influenced fish presence during our study, given similar and high DO values among habitat types and sample events. Similarly, the range of conductivity during our sample periods did not likely influence fish presence. Conductivity, however, is known to affect electrofishing efficiency, and its importance to estimates of detection probabilities of freshwater drum is discussed under sampling efficiency. Analyses did not support turbidity (based on secchi and NTU measurements) as an influence on habitats used by fishes.

Sample efficiency and gear selectivity

Our efforts with variable-depth AC electrofishing produced primarily freshwater drum and channel catfish. In a companion study in the lower Ohio River (Smithland Pool) during winter 2001/2002, the catch was predominantly blue catfish (*Ictalurus furcatus*) and freshwater drum (Garvey et al. 2002; Chapter 2). Sheehan et al. (1990)

used variable-depth AC electrofishing gear to capture a diversity of species, and Newcomb (1989) predominantly captured channel catfish, common carp, freshwater drum, river carpsucker, and goldeye (*Hiodon alosoides*) using variable depth AC electrofishing gear. Deepwater electrofishing gear targets fish species on or near the river bottom, and this likely explains the relatively high numbers of catfish and freshwater drum; however, we did capture 28 species with our AC gear.

A comparison of our sonar images with the number of fishes collected indicated that the gear was often inefficient at capturing all fishes (when fishes were present); however, this is probably true for most gear types. The sonar method has limitations, in part, because sample area of sonar (with 36 degree cone) differs with water depth, and rarely equals the sample area of the electrofisher. Also, interpreters of sonar graphs can overlook fishes near the river bottom or count images of logs or other objects. Data from gill nets and DC electrofishing did not support poor sampling efficiency of the variable-depth AC electrofishing boat. However, this type of gear comparison has limitations, given that gill nets and DC electrofishing may have poor sampling efficiency. Sampling efficiency for the DC electrofishing boat was high at near-shore areas within the embayment habitat; however, the AC electrofishing gear could not access this near-shore shallow habitat. Possibly, shallow near-shore areas within the six habitat types provide important over-winter habitats, but were not sampled during our study.

Estimates of detection probabilities may be useful in assessing sample efficiency. Detection probabilities in site occupancy models, however, are defined as the probability that a species is detected, and not as the probability that a gear type detects a species. However, conductivity and flow models of detection probabilities received low weights; hence, the data did not support an association with sampling efficiency, conductivity, and water velocity.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Based on data from six habitats (backwater, island head, island tail, main channel, and tributary), fishes primarily used low-velocity habitats at tributary mouths during winter conditions. Consequently, the importance of habitats at tributary confluences should be emphasized within management plans. Some species, however, used areas with higher velocities and relatively warmer temperatures during periods when low-velocity tributary habitats were below 4 ºC. Embayment and wing dam habitats had relatively high abundances and species richness, but were underrepresented in our study (because of inaccessibility or unavailability). Although one embayment and one wing dam were evaluated during our study, we believe that these habitats are important winter refuges, and if possible, should be emphasized in management and future studies on winter habitats used by fishes in the Ohio River. Additionally, future studies during winter should evaluate near-shore areas of all habitat types, which may provide insights into habitats used by juvenile fishes. Additionally, studies need to address impacts of habitat disturbances on fish survival during winter, including high flow events and barge traffic.

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Table 3-1. Description of macrohabitats within Belleville Pool, Ohio River.

Habitat type	Description
Main Channel	Area extending from shore including the center of the channel.
Backwater	Area between an island and the shore without barge traffic.
Island head	Area adjacent to the upstream end of an island.
Island tail	Area adjacent to the downstream end of an island.
Tributary	Area encompassing a tributary mouth and its connection to the main channel.
Embayment	A shallow bay-like area connected to the main channel.
Artificial wing dam	A near-shore area of low velocity created by an artificial barrier.
Deep hole	Dredged or natural scour areas within the main channel or back channel.

Table 3-2. Site locations and sample dates of habitat types within Belleville Pool, Ohio River.

			Month/Date					
Site, by habitat type	Latitude	Longitude	2002 Feb	2002 Mar	2002 Apr	2002 Dec	2003 Jan	2003 Mar
Tributary								
1) Bull Cr.	39.20.19.5	81.22.13.8		25	6, 15	12	11	2
2) Duck Cr.	39.24.17.8	81.25.38.1		9, 24	6, 15	12	11	2
3) Lee Cr.	39.09.00.5	81.44.28.5	16, 22		4, 7	15	18	1
4) Little Hocking R.	39.15.46.7	81.41.38.5	17		5, 7	16	13	17
5) Little Kanawha R.	39.15.51.1	81.34.04.9		15	5, 14	16	19	16
6) Hocking R.	39.11.02.9	81.45.15.6	16, 22		4, 7	15	18	1
Backwater								
1) Blennerhasset	39.16.14.1	81.38.45.3		14	5, 14	16	19	17
2) Halfway	39.21.11.8	81.32.46.6		24	6, 15	17	10	16
3) Neal	39.18.29.9	81.33.19.8		15	6, 14	17	10	16
4) Newberry	39.13.12.4	81.41.32.0	17		5, 7	15	18	1
5) Marietta	39.23.41.6	81.25.18.4		25	6, 15	13	12	2
6) Muskingum	39.21.44.7	81.30.37.4		24	6, 15	17	19	16
Island head/tail								
1) Blennerhasset head	39.16.10.2	81.35.40.9		14	5, 14	16	19	17
2) Blennerhasset tail	39.16.29.3	81.39.38.0		14	5, 14	16	19	17
3) Halfway head	39.21.23.6	81.32.20.3		24	6, 15	17	10	16
4) Halfway tail	39.20.55.0	81.32.59.5		24	6, 15	17	10	16
5) Neal head	39.18.51.1	81.33.31.9		15	6, 14	17	10	16
6) Neal tail	39.17.43.7	81.33.44.5		24	5, 14	17	10	16
7) Newberry head	39.13.16.7	81.41.32.8	17		5, 7	16	18	1
8) Newberry tail	39.13.13.0	81.41.41.2	17	11	5, 7	15	18	1
9) Marietta head	39.23.03.8	81.24.30.6			6, 15	12	12	2
10) Marietta tail	39.24.31.2	81.26.48.3		9, 25	6, 15	12	12	2
11) Muskingum head	39.22.36.5	81.29.36.3		24	6, 15	17	19	16
12) Muskingum tail	39.21.34.3	81.31.25.3		24	6, 15	13	10	16
Main Channel								
1) River Mile 165	39.20.23.8	81.22.12.7		25	6, 15	12	12	2
2) River Mile 167	39.21.51.0	81.23.54.4		25	6, 15	12	12	2
3) River Mile 180	39.20.07.0	81.33.18.3		24	6.15	17	10	16
4) River Mile 184	39.16.31.2	81.33.56.6		24	6, 14	17	19	16
5) River Mile 192	39.15.38.3	81.41.29.1		14	5, 7	16	13	17
6) River Mile 194	39.13.38.4	81.41.21.0		14	5, 7	16	18	1
Deep Hole								
1) River Mile 170 #1	39.23.38.2	81.25.08.3		25	6,15	13	11	2
2) River Mile 170 #2	39.23.42.9	81.25.15.3				13	11	2
2) River Mile 180	39.19.56.6	81.33.27.7		24	6,15	17	10	16
3) River Mile 198	39.11.13.9	81.44.34.4	22	14	7	15	18	1

Table 3-2. Continued.

			Month/Date					
	Latitude	Longitude	2002 Feb	2002 Mar	2002 Apr	2002 Dec	2003 Jan	2003 Mar
<u>Extra</u>								
1) Moore's Run	39.22.40.4	81.29.51.4		24				
2) Williams 2-Mile Cr.	39.23.15.0	81.28.46.8		24				
3) Sugarcamp Run	39.21.39.0	81.24.06.0		24			11	
4) River Mile 176	39.21.45.0	81.31.11.4			6			
5) Embayment	39.13.57.0	81.41.10.8				15		1, 17
6) Wing Dam	39.22.16.1	81.24.04.8					11	
7) shoreline below Lee Cr.	39.08.54.0	81.44.29.4					9	
8) River Mile 170 DH #3	39.23.49.1	81.25.24.0					11	2
9) River Mile 170 DH #4	39.24.10.0	81.25.52.5					11	2

Table 3-3. Mean depths of transects with standard deviations, SD, (based on randomly-selected depths from each transect).

Site, by habitat	Transect	Mean depth (m)	SD
Tributary			
Bull Cr.	1	3.53	1.07
Duck Cr.	1	4.7	1.32
Hocking R.	1	6.87	0.78
	2	7.56	1.5
	3	6.95	0.74
Lee Cr.	1	5.04	1.43
	2	3.91	1.43
L. Hocking R.	1	3.85	1.26
L. Kanawha R.	1	8.69	0.66
	2	9.04	0.35
	3	9.06	0.46
Backwater			
Blennerhasset Is.	1	5.12	0.49
	2	8.94	0.25
	3	3.2	0.62
Halfway Is.	1	4.58	1.03
	2	6.36	0.23
	3	5.16	0.5
Neal Is.	1	5.84	0.47
	2	7.51	0.17
	3	5.2	0.47
Newberry Is.	1	7.26	0.43
	2	6.44	0.35
	3	3.48	0.54
Marietta Is.	1	4.54	0.48
	2	5.17	0.49
	3	3.31	0.59
Muskingum Is.	1	4.64	0.52
	2	5.16	0.49
	3	4.42	0.6

Table 3-3. Continued.

Island Head			
Blennerhasset Is.	1	2.77	0.44
	2	2.71	0.4
	3	2.06	0.21
Halfway Is.	1	2.51	0.42
	2	2.72	0.36
Neal Is.	1	4.52	0.43
	2	2.57	0.36
	3	2.74	0.36
Newberry Is.	1	2.66	0.35
	2	2.81	0.36
	3	2.02	0.3
Marietta Is.	1	2.85	0.37
	2	2.1	0.26
	3	2.83	0.48
Muskingum Is.	1	2.88	0.42
	2	2.87	0.43
	3	3.73	0.47
Island Tail			
Blennerhasset Is.	1	2.5	0.25
	2	2.08	0.28
	3	2.98	0.34
Halfway Is.	1	2.93	0.41
	2	3.02	0.43
Neal Is.	1	3.28	0.41
	2	3.4	0.44
	3	2.12	0.23
Newberry Is.	1	2.01	0.35
	2	2.11	0.25
Marietta Is.	1	2.05	0.29
	2	2.96	0.32
	3	2.03	0.31
Muskingum Is.	1	2.96	0.24
	2	3	0.29
	3	2.95	0.26

Table 3-3. Continued.

Main Channel			
River Mile 165	1	4	0.39
	2	7.64	0.3
	3	3.92	0.48
River Mile 167	1	5.19	0.38
	2	6.28	0.37
	3	8.75	0.53
River Mile 180	1	4.8	0.47
	2	9	0.61
	3	6.75	0.74
River Mile 184	1	7.4	0.54
	2	9.5	0.51
	3	7.47	0.41
River Mile 192	1	3.92	0.43
	2	7.98	0.48
	3	3.17	0.6
River Mile 194	1	3.85	0.55
	2	9.56	0.48
	3	3.77	0.43
Deep hole			
River Mile 170 #1	1	8.66	0.65
River Mile 170 #2	1	8.83	0.45
River Mile 170 #3	1	7.96	0.76
River Mile 170 #4	1	7.75	0.5
River Mile 180	1	10.51	0.47
River Mile 198	1	13.19	1.15

Table 3-4. Habitat data by site and habitat type for sample sessions from February 2002 through March 2003 in Belleville Pool, Ohio River (* indicates data not available). Dissolved oxygen (DO), pH, specific conductivity, and turbidity are average values from 1 m depth profiles.

Site	Habitat	Date	Temp (C)	DO (mg/L)	pH	sp. Cond. uS/cm	Flow (m/s)	Turb. (NTU)	Secchi (m)
Lee Cr.	tributary	2/16/2002	4.65	13.45	7.38	295	0.07	*	*
Lee Cr.	tributary	2/22/2002	5.36	13.12	7.8	354.3	*	*	*
Lee Cr.	tributary	4/4/2002	9.02	7.86	7.2	250.9	0	*	*
Lee Cr.	tributary	4/7/2002	8.84	9.86	7.26	251.7	0.15	*	*
Lee Cr.	tributary	12/15/2002	4.51	6.63	6.8	317.4	0.10	160.8	0.2
Lee Cr.	tributary	1/18/2003	1.44	13.81	7.5	427.4	0.03	17.5	0.94
Lee Cr.	tributary	3/1/2003	1.98	11.66	6.7	214.5	0.01	37	0.53
Hocking R.	tributary	2/16/2002	4.56	13.04	7.6	467.8	0.05	*	*
Hocking R.	tributary	2/22/2002	5.03	13.43	7.62	495.9	*	*	*
Hocking R.	tributary	4/4/2002	10.97	6.6	7.45	421.5	0.06	*	*
Hocking R.	tributary	4/7/2002	9.06	8.97	7.49	434.2	0.1	*	*
Hocking R.	tributary	12/15/2002	3.41	6.48	6.7	437.0	0.20	167.6	0.15
Hocking R.	tributary	1/18/2003	0.86	13.06	7.40	508.1	0.00	8.5	0.72
Hocking R.	tributary	3/1/2003	2.86	11.39	6.7	387.3	0.29	27	0.51
L. Hocking R.	tributary	2/17/2002	4.6	13.64	7.49	337.5	0.04	*	*
L. Hocking R.	tributary	4/5/2002	9.59	10.05	7.34	287.1	0.05	*	*
L. Hocking R.	tributary	4/7/2002	9.07	12.5	7.31	319.2	0.08	*	*
L. Hocking R.	tributary	12/16/2002	4.05	*	7.3	311.8	0.06	42.7	0.3
L. Hocking R.	tributary	1/13/2003	2.52	13.71	7.6	432.3	0.04	26.3	0.52
L. Hocking R.	tributary	3/17/2003	6.54	12.43	7.4	400.4	0.00	94	0.19
L. Kanawha R.	tributary	3/15/2002	7.58	8.19	7.42	283	0.05	*	*
L. Kanawha R.	tributary	4/5/2002	10.15	9.65	7.08	89.3	0.1	*	*
L. Kanawha R.	tributary	4/14/2002	13.07	10.56	7.19	200.4	0.14	*	*
L. Kanawha R.	tributary	12/16/2002	5.03	*	7.2	171.3	0.35	63.9	0.34
L. Kanawha R.	tributary	1/19/2003	0.83	14.13	7.8	327.3	0.06	9.3	1.61
L. Kanawha R.	tributary	3/16/2003	6.35	11.36	7.4	315.8	0.15	25	0.78
Bull Cr.	tributary	3/25/2002	7.53	8.21	7.32	292.6	0.03	*	*
Bull Cr.	tributary	4/6/2002	8.9	10.09	7.2	241.9	0.21	*	*
Bull Cr.	tributary	4/15/2002	12.85	9.59	7.28	217.1	0	*	*
Bull Cr.	tributary	12/12/2002	3.04	7.64	8.0	366.8	0.03	7.8	1.54
Bull Cr.	tributary	1/11/2003	3.24	13.55	7.2	397.0	0.23	69.4	0.33
Bull Cr.	tributary	3/2/2003	2.67	12.60	7.5	306.0	0.05	101	0.24
Duck Cr.	tributary	3/9/2002	6.64	8.97	7.42	389.6	0	*	*
Duck Cr.	tributary	3/24/2002	6.82	7.98	7.37	355.1	0	*	*
Duck Cr.	tributary	4/6/2002	8.94	10.12	7.25	244.4	0.72	*	*
Duck Cr.	tributary	4/15/2002	16.3	7.79	7.52	597.3	0.09	*	*
Duck Cr.	tributary	12/12/2002	4.39	7.45	7.1	414.8	0.03	3.3	0.22
Duck Cr.	tributary	1/11/2003	2.68	13.86	7.2	430.7	0.00	43.6	0.43
Duck Cr.	tributary	3/2/2003	3.88	11.38	7.1	499.6	0.28	93	0.24
Moore's Run	tributary	3/24/2002	6.28	8.15	7.43	324.1	0	*	*
Sugarcamp Run	tributary	3/24/2002	7.42	8.04	7.26	325.2	0.34	*	*
Sugarcamp Run	tributary	1/12/2003	3.23	13.55	7.4	402.8	0.05	51	0.32
Williams Two-Mile Cr.	tributary	3/24/2002	5.57	7.31	7	244.1	0	*	*

Table 3-4. Continued.

Site	Habitat	Date	Temp (C)	DO (mg/L)	pH	sp. Cond. uS/cm	Flow (m/s)	Turb. (NTU)	Secchi (m)
Newberry	island tail	3/11/2002	5.93	7.86	7.5	359.7	0.19	*	*
Newberry	island tail	4/5/2002	8.71	10.78	7.44	253.4	0.32	*	*
Newberry	island tail	4/7/2002	8.76	10.11	7.26	254.3	0.32	*	*
Newberry	island tail	12/15/2002	4.66	9.57	6.6	316.0	0.20	133.0	0.18
Newberry	island tail	1/18/2003	1.51	13.40	7.52	433.7	0.10	6.1	1.31
Newberry	island tail	3/1/2003	2.23	12.78	6.9	356.3	0.29	113	0.29
Newberry	island head	3/11/2002	8.71	7.73	7.5	356.8	0.21	*	*
Newberry	island head	4/5/2002	8.75	10.56	7.44	252.6	0.41	*	*
Newberry	island head	4/7/2002	8.75	12.19	7.29	252.4	0.41	*	*
Newberry	island head	12/15/2002	4.73	7.44	6.7	293.9	1.00	175.3	0.118
Newberry	island head	1/18/2003	1.51	13.12	7.52	433.0	0.19	6.1	1.31
Newberry	island head	3/1/2003	2.20	12.96	7.0	365.3	0.49	105	0.49
Blennerhasset	island tail	3/14/2002	7.45	9.33	7.96	403.9	0.04	*	*
Blennerhasset	island tail	4/5/2002	8.96	10.75	7.13	255	0.3	*	*
Blennerhasset	island tail	4/14/2002	11.95	11.89	7.34	310.9	0.08	*	*
Blennerhasset	island tail	12/16/2002	3.57	*	7.3	488.0	0.21	49.2	0.49
Blennerhasset	island tail	1/19/2003	1.21	12.15	7.6	456.3	0.06	12.5	1.02
Blennerhasset	island tail	3/17/2003	5.31	13.63	7.6	475.0	0.37	66	0.32
Blennerhasset	island head	3/14/2002	7.61	9.19	7.94	408.2	0.2	*	*
Blennerhasset	island head	4/5/2002	8.96	10.49	7.12	245.3	0.48	*	*
Blennerhasset	island head	4/14/2002	12.03	11.64	7.46	317.6	0.42	*	*
Blennerhasset	island head	12/16/2002	3.59	*	7.3	463.0	0.60	48.8	0.31
Blennerhasset	island head	1/19/2003	1.23	13.60	7.8	459.7	0.18	7.5	1.31
Blennerhasset	island head	3/17/2003	5.39	13.78	7.7	471.5	0.82	74	0.22
Neal	island tail	3/24/2002	7.14	8.05	7.18	332.3	0.27	*	*
Neal	island tail	4/5/2002	8.98	10.38	7.23	247	0.68	*	*
Neal	island tail	4/14/2002	11.6	11.7	7.43	272.1	0.09	*	*
Neal	island tail	12/17/2002	3.72	*	7.2	420.3	0.00	60.0	0.35
Neal	island tail	1/10/2003	3.54	13.50	7.2	405.0	0.12	60	0.46
Neal	island tail	3/16/2003	4.85	12.66	7.2	461.5	0.56	43	0.26
Neal	island head	3/24/2002	7.26	8.1	7.18	329.3	0.45	*	*
Neal	island head	4/5/2002	8.98	10.43	7.22	249.2	0.98	*	*
Neal	island head	4/14/2002	11.54	11.85	7.36	274.3	0.65	*	*
Neal	island head	12/17/2002	3.61	*	7.2	423.0	0.66	80.3	0.32
Neal	island head	1/10/2003	3.56	13.48	7.1	406.0	0.62	44.7	0.44
Neal	island head	3/16/2003	4.82	13.17	7.2	466.8	0.98	43	0.24
Halfway	island tail	3/24/2002	7.46	8.31	7.47	404.9	0.3	*	*
Halfway	island tail	4/6/2002	9.62	10.22	7.57	371.8	0.16	*	*
Halfway	island tail	4/15/2002	14.48	9.04	7.62	432.3	0.43	*	*
Halfway	island tail	12/17/2002	3.66	*	7.1	538.0	0.26	39.9	0.42
Halfway	island tail	1/10/2003	3.29	13.48	7.1	506.0	0.23	38.6	0.49
Halfway	island tail	3/16/2003	4.98	12.84	7.3	532.0	0.34	139	0.18
Halfway	island head	3/24/2002	7.49	8.23	7.57	403.6	0.48	*	*
Halfway	island head	4/6/2002	9.57	10.21	7.6	373	0.83	*	*
Halfway	island head	4/15/2002	14.47	9.12	7.61	369.2	0.56	*	*
Halfway	island head	12/17/2002	3.66	*	7.3	540.0	0.57	43.4	0.42
Halfway	island head	1/10/2003	3.28	13.37	7.2	507.5	0.50	36.4	0.42
Halfway	island head	3/16/2003	5.09	12.73	7.5	539.7	0.82	134	0.18

Table 3-4. Continued.

Site	Habitat	Date	Temp (C)	DO (mg/L)	pH	sp Cond. uS/cm	Flow (m/s)	Turb. (NTU)	Secchi (m)
Muskingum	island tail	3/24/2002	7.51	8.04	7.24	338.4	0.65	*	*
Muskingum	island tail	4/6/2002	8.92	10.66	7.05	246.3	0.76	*	*
Muskingum	island tail	4/15/2002	11.92	9.85	7.44	284	0	*	*
Muskingum	island tail	12/13/2002	4.47	8.47	7.2	443.0	0.23	6.5	1.35
Muskingum	island tail	1/10/2003	3.59	13.49	7.3	407.0	0.21	45.6	0.41
Muskingum	island tail	3/16/2003	5.01	13.17	7.4	480.0	0.18	38	0.42
Muskingum	island head	3/24/2002	7.51	8.12	7.24	335.2	1.02	*	*
Muskingum	island head	4/6/2002	8.91	10.58	7.08	246.2	0.86	*	*
Muskingum	island head	4/15/2002	11.58	10.35	7.32	264.2	0.96	*	*
Muskingum	island head	12/17/2002	3.56	*	7.2	427.0	0.84	66.8	0.36
Muskingum	island head	1/19/2003	1.23	13.52	7.8	457.0	0.15	10.8	1.25
Muskingum	island head	3/16/2003	4.97	13.20	7.5	483.3	1.13	42	*
Marietta	island tail	3/25/2002	7.31	8.25	7.27	288.3	0.26	*	*
Marietta	island tail	4/6/2002	9.04	10.38	7.2	241	0.38	*	*
Marietta	island tail	4/15/2002	11.71	10.9	7.45	267.3	0.73	*	*
Marietta	island tail	12/12/2002	4.81	7.38	7.2	400.0	0.10	3.1	1.5
Marietta	island tail	1/12/2003	3.15	13.89	7.3	397.0	0.04	32.8	0.42
Marietta	island tail	3/2/2003	2.31	13.00	7.4	366.0	0.57	114	0.24
Marietta	island head	3/25/2002	7.3	8.32	7.27	286.5	0.46	*	*
Marietta	island head	4/6/2002	8.89	10.41	7.22	242.6	0.54	*	*
Marietta	island head	4/15/2002	11.88	10.7	7.35	268.8	0.86	*	*
Marietta	island head	12/12/2002	4.59	7.24	7.2	400.0	0.16	3.2	2.01
Marietta	island head	1/12/2003	3.10	13.49	7.3	395.0	0.43	31.2	0.49
Marietta	island head	3/2/2003	2.31	13.34	7.4	365.0	0.60	114	0.24
River Mile 194	main channel	3/14/2002	7.44	9.07	7.8	393.4	0.13	*	*
River Mile 194	main channel	4/5/2002	8.7	10.56	7.44	252.6	0.41	*	*
River Mile 194	main channel	4/7/2002	8.8	12.33	7.25	243.6	0.55	*	*
River Mile 194	main channel	12/16/2002	3.70	*	7.2	523.0	0.60	36.8	0.2
River Mile 194	main channel	1/18/2003	1.23	12.05	7.56	434.3	0.05	10.9	1.14
River Mile 194	main channel	3/1/2003	2.38	12.62	7.0	366.2	0.22	93	0.2
River Mile 192	main channel	3/14/2002	7.24	9.07	7.8	393.4	0.13	*	*
River Mile 192	main channel	4/5/2002	8.7	10.49	7.44	253.2	0.4	*	*
River Mile 192	main channel	4/7/2002	8.84	12.29	7.24	256.4	0.69	*	*
River Mile 192	main channel	12/16/2002	3.70	*	7.2	523.0	0.60	36.8	0.2
River Mile 192	main channel	1/13/2003	2.63	13.90	7.5	462.4	0.33	28.3	0.52
River Mile 192	main channel	3/17/2003	5.30	13.26	7.5	492.6	0.70	110	0.16
River Mile 184	main channel	3/24/2002	7.28	8.25	7.28	335	0.42	*	*
River Mile 184	main channel	4/6/2002	8.98	10.38	7.23	247	0.95	*	*
River Mile 184	main channel	4/14/2002	11.5	11.65	7.38	267.7	0.53	*	*
River Mile 184	main channel	12/17/2002	3.75	*	6.9	496.8	0.81	41.6	0.32
River Mile 184	main channel	1/19/2003	1.49	13.76	7.7	471.0	0.13	11.2	1.26
River Mile 184	main channel	3/16/2003	4.74	12.60	7.3	494.3	1.25	83	0.26
River Mile 180	main channel	3/24/2002	7.27	8.07	7.27	333.7	0.48	*	*
River Mile 180	main channel	4/6/2002	8.98	10.32	7.3	249.9	1.13	*	*
River Mile 180	main channel	4/15/2002	11.66	8.07	7.27	333.7	0.48	*	*
River Mile 180	main channel	12/17/2002	3.66	*	7.0	421.9	0.78	75.3	0.31
River Mile 180	main channel	1/10/2003	3.58	13.45	7.4	404.5	0.84	41.7	*
River Mile 180	main channel	3/16/2003	4.85	12.87	7.3	498.0	1.00	91	0.22
River Mile 176	main channel	4/6/2002	9.35	10.18	7.49	363.2	0.79	*	*

Table 3-4. Continued.

Site	Habitat	Date	Temp (C)	DO (mg/L)	pH	sp. Cond. uS/cm	Flow (m/s)	Turb. (NTU)	Secchi (m)
River Mile 167	main channel	3/25/2002	7.3	8.25	7.27	288.3	0.46	*	*
River Mile 167	main channel	4/6/2002	9.02	10.43	7.18	244.7	0.63	*	*
River Mile 167	main channel	4/15/2002	12	10.3	7.26	273.5	1.15	*	*
River Mile 167	main channel	12/12/2002	4.62	7.18	7.2	399.0	0.23	3	2
River Mile 167	main channel	1/12/2003	3.21	13.56	7.4	401.0	0.43	32.1	0.54
River Mile 167	main channel	3/2/2003	3.92	10.37	7.3	400.0	0.21	18	0.18
River Mile 165	main channel	3/25/2002	7.3	8.22	7.27	288.3	0.45	*	*
River Mile 165	main channel	4/6/2002	8.98	10.35	7.25	246.8	0.79	*	*
River Mile 165	main channel	4/15/2002	12	10.29	7.26	272.5	1.11	*	*
River Mile 165	main channel	12/12/2002	4.60	7.34	7.3	398.0	0.23	3.3	1.85
River Mile 165	main channel	1/12/2003	3.10	13.58	7.9	397.2	0.39	3.6	0.42
River Mile 165	main channel	3/2/2003	2.42	12.86	7.3	361.3	0.37	111	0.2
River Mile 198	deep hole	2/22/2002	5.42	13.64	7.55	373	*	*	*
River Mile 198	deep hole	3/14/2002	7.24	9.07	7.8	393.4	*	*	*
River Mile 198	deep hole	4/7/2002	8.83	12.25	7.24	258.3	*	*	*
River Mile 198	deep hole	12/15/2002	3.70	*	7.2	523.0	0.60	36.8	0.2
River Mile 198	deep hole	1/18/2003	1.55	12.48	7.6	431.1	0.15	11.3	1.1
River Mile 198	deep hole	3/1/2003	2.32	12.44	7.0	349.7	0.35	97	0.18
River Mile 180	deep hole	3/24/2002	7.26	8.07	7.27	333.7	0.48	*	*
River Mile 180	deep hole	4/6/2002	8.98	10.32	7.3	249.9	1.13	*	*
River Mile 180	deep hole	4/15/2002	11.66	8.07	7.27	333.7	0.48	*	*
River Mile 180	deep hole	12/17/2002	3.66	*	7.0	421.9	0.78	75.3	0.31
River Mile 180	deep hole	1/10/2003	3.58	13.45	7.4	404.5	0.84	41.7	*
River Mile 180	deep hole	3/16/2003	4.85	12.87	7.3	498.0	1.00	91	0.22
River Mile 170 #1	deep hole	3/25/2002	7.3	8.32	7.27	286.5	0.39	*	*
River Mile 170 #1	deep hole	4/6/2002	8.99	10.3	7.17	244.4	0.92	*	*
River Mile 170 #1	deep hole	4/15/2002	11.87	10.7	7.35	268.8	0.82	*	*
River Mile 170 #1	deep hole	12/13/2002	4.49	8.38	7.3	371.8	0.43	4.5	*
River Mile 170 #1	deep hole	1/11/2003	3.23	13.71	7.5	398.0	0.64	39.9	0.42
River Mile 170 #1	deep hole	3/2/2003	2.31	12.87	7.2	363.0	0.60	116	0.21
River Mile 170 #2	deep hole	12/13/2002	4.49	8.38	7.3	371.8	0.43	4.5	*
River Mile 170 #2	deep hole	1/11/2003	3.23	13.71	7.5	398.0	0.64	39.9	0.42
River Mile 170 #2	deep hole	3/2/2003	2.31	12.87	7.2	363.0	0.60	116	0.21
River Mile 170 #3	deep hole	12/13/2002	4.49	8.38	7.3	371.8	0.43	4	*
River Mile 170 #3	deep hole	1/11/2003	3.23	13.71	7.5	398.0	0.64	40	0.42
River Mile 170 #3	deep hole	3/2/2003	2.32	13.22	7.2	363.3	0.61	121	0.25
River Mile 170 #4	deep hole	12/13/2002	4.49	8.38	7.3	371.8	0.43	4	*
River Mile 170 #4	deep hole	1/11/2003	3.23	13.71	7.5	398.0	0.64	40	0.42
River Mile 170 #4	deep hole	3/2/2003	2.32	13.22	7.2	363.3	0.61	121	0.25
Newberry	backwater	3/11/2002	4.4	7.74	7.5	356.2	0.2	*	*
Newberry	backwater	4/5/2002	8.7	10.78	7.44	253.4	0.32	*	*
Newberry	backwater	4/7/2002	8.74	10.07	7.26	243.6	0.67	*	*
Newberry	backwater	12/15/2002	4.73	7.44	6.7	293.9	1.00	175.3	0.18
Newberry	backwater	1/18/2003	1.57	13.00	7.52	432.6	0.06	11	1.36
Newberry	backwater	3/1/2003	2.31	12.68	6.8	345.0	0.59	99	0.22
Blennerhasset	backwater	3/14/2002	7.1	9.14	7.78	366.5	0.14	*	*
Blennerhasset	backwater	4/5/2002	8.96	10.75	7.13	255	0.44	*	*
Blennerhasset	backwater	4/14/2002	11.86	11.3	7.44	288.5	0.33	*	*
Blennerhasset	backwater	12/16/2002	3.59	*	7.3	463.0	0.60	48.8	0.29

Table 3-4. Continued.

Site	Habitat	Date	Temp (C)	DO (mg/L)	pH	sp. Cond. uS/cm	Flow (m/s)	Turb. (NTU)	Secchi (m)
Blennerhasset	backwater	1/19/2003	1.18	13.35	7.8	453.3	0.16	11.7	1.1
Blennerhasset	backwater	3/17/2003	5.18	13.68	7.5	463.4	0.69	56	0.32
Neal	backwater	3/15/2002	7.42	9.13	7.56	382.3	0.18	*	*
Neal	backwater	4/6/2002	8.98	10.38	7.23	247	0.93	*	*
Neal	backwater	4/14/2002	11.46	11.83	7.42	260.8	0.63	*	*
Neal	backwater	12/17/2002	3.66	*	7.2	419.0	0.66	72.8	0.34
Neal	backwater	1/10/2003	3.54	13.49	7.3	404.2	0.59	44.9	0.45
Neal	backwater	3/16/2003	4.81	12.94	7.2	459.1	0.64	39	0.39
Halfway	backwater	3/24/2002	7.49	8.23	7.57	403.6	0.42	*	*
Halfway	backwater	4/6/2002	9.81	10.28	7.57	381.9	0.77	*	*
Halfway	backwater	4/15/2002	14.47	9.04	7.62	432.3	0.76	*	*
Halfway	backwater	12/17/2002	4.54	*	7.2	568.3	0.50	36.3	0.41
Halfway	backwater	1/10/2003	4.03	13.42	7.1	539.0	0.49	36	0.48
Halfway	backwater	3/16/2003	5.13	12.70	7.3	534.7	0.60	136	0.18
Muskingum	backwater	3/24/2002	7.5	8.04	7.24	338.4	0.92	*	*
Muskingum	backwater	4/6/2002	8.91	10.58	7.08	246.2	0.76	*	*
Muskingum	backwater	4/15/2002	11.58	10.35	7.32	264.2	0.82	*	*
Muskingum	backwater	12/17/2002	3.71	*	7.1	425.0	0.81	70.1	0.36
Muskingum	backwater	1/19/2003	1.18	13.36	7.8	453.7	0.18	10.8	1.22
Muskingum	backwater	3/16/2003	4.99	13.18	7.3	476.8	0.95	37	*
Marietta	backwater	3/25/2002	7.3	8.32	7.27	286.5	0.39	*	*
Marietta	backwater	4/6/2002	8.99	10.3	7.17	244.4	0.92	*	*
Marietta	backwater	4/15/2002	11.87	10.7	7.35	268.8	0.82	*	*
Marietta	backwater	12/13/2002	4.49	8.38	7.3	371.8	0.43	4.5	*
Marietta	backwater	1/11/2003	3.23	13.71	7.6	398.0	0.64	39.9	0.42
Marietta	backwater	3/2/2003	2.37	13.06	7.2	360.2	0.62	116	0.24
L. Sandy Cr.	embayment	12/15/2002	4.08	7.41	6.9	257.3	0.00	65.8	*
L. Sandy Cr.	embayment	3/1/2003	2.95	11.16	7.3	257.0	0	55.00	0.39
L. Sandy Cr.	embayment	3/17/2003	11.24	11.75	7.7	350.0	0	84.00	0.25
Wing Dam	artificial	1/11/2003	3.26	14.61	7.2	400.7	0.10	50	37

Table 3-5. Sites of temperature loggers in Belleville Pool, Ohio River, during 2002 and 2003. Loggers at river mile 196 and Neal Island were not recovered in 2003.

Site Location	Habitat	Water column placement
Blennerhasset Is.	Backwater	Bottom
Newberry Is.	Backwater	Bottom
Neal Is.	Backwater	Bottom
River Mile 196	Main channel	Near surface
River Mile 184	Main channel	Near surface
Marietta Is. Head	Main channel	Near surface

Table 3-6. Total number of fishes caught at each habitat type in the Belleville Pool, Ohio River, during sample sessions from February 2002 – March 2003.

Species	Island Head	Island Tail	Back water	Main	Tributary	Deep hole	Wing Dam	Embay-ment	Total
Black Buffalo	0	0	0	0	0	0	1	0	1
Black Crappie	0	0	0	0	1	0	0	2	3
Bluegill	0	0	0	0	1	0	0	164	165
Bowfin	0	0	0	0	0	0	0	1	1
Channel Catfish	6	2	43	62	88	1	0	0	202
Common Carp	0	1	3	2	6	0	1	3	16
Emerald Shiner	0	0	0	0	7	0	2	137	146
Flathead Catfish	0	0	0	1	0	0	0	0	1
Freshwater Drum	3	3	26	157	270	3	7	6	475
Gizzard Shad	0	0	2	13	60	0	1	430	506
Golden Redhorse	0	0	0	0	1	0	0	0	1
Green Sunfish	0	0	0	0	0	0	0	7	7
Highfin Carpsucker	0	0	0	0	4	0	0	0	4
Hybrid Striped Bass	0	0	0	6	14	0	0	0	20
Largemouth Bass	0	0	0	1	0	0	0	3	4
Mooneye	0	5	7	4	2	0	0	0	18
Mosquitofish	0	0	0	0	0	0	0	1	1
Ohio Lamprey	0	0	1	0	0	0	0	0	1
Orangespotted Sunfish	0	0	0	0	1	0	0	49	50
Pumpkinseed	0	0	0	0	0	0	0	5	5
Quillback	0	0	0	0	4	0	0	0	4
River Carpsucker	0	0	2	2	21	0	1	4	30
Rock Bass	0	0	1	0	0	0	0	0	1
Sauger	0	1	0	0	2	0	0	0	3
Shorthead Redhorse	0	0	0	1	0	0	1	0	2
Silver Chub	0	4	4	6	0	0	0	0	14
Smallmouth Buffalo	0	2	10	12	30	0	12	1	67
Spottail Shiner	0	0	0	0	1	0	0	0	1
Spotted Bass	0	0	0	0	0	2	0	0	2
Spotted Sucker	0	0	0	0	0	0	0	2	2
Walleye	0	0	0	0	3	0	0	0	3
Warmouth	0	0	0	0	0	0	0	5	5
White Bass	1	0	3	4	37	0	1	0	46
White Crappie	0	0	0	1	0	0	0	70	71
Total	10	18	102	272	553	6	27	890	1878

Table 3-7. Total number of fishes caught at each habitat type in the Belleville Pool, Ohio River, during sample sessions from February – April 2002.

	Island		Back			Deep	
Species	Head	Tail	water	Main	Tributary	hole	Total
Bluegill	0	0	0	0	1	0	1
Channel Catfish	6	2	17	19	75	0	119
Common Carp	0	0	0	0	4	0	4
Emerald Shiner	0	0	0	0	7	0	7
Flathead Catfish	0	0	0	1	0	0	1
Freshwater Drum	3	2	4	10	160	0	179
Gizzard Shad	0	0	0	1	57	0	58
Highfin Carpsucker	0	0	0	0	2	0	2
Mooneye	0	3	1	1	2	0	7
Orangespotted Sunfish	0	0	0	0	1	0	1
Quillback	0	0	0	0	2	0	2
River Carpsucker	0	0	0	0	15	0	15
Spottail Shiner	0	0	0	0	1	0	1
Walleye	0	0	0	0	2	0	2
White Bass	0	0	0	0	4	0	4
Total	9	7	22	32	333	0	403

Table 3-8. Fish caught per hour (CPUE) within each habitat type in the Belleville Pool, Ohio River, during February 2002 through March 2003.

	Habitat types								
	Island		Back	Main		Deep	Wing	Embay-	
Species	Head	Tail	water	channel	Trib	hole	dam	ment	Total
Black Buffalo	0	0	0	0	0	0	7.52	0.00	0.02
Black Crappie	0	0	0	0	0.16	0	0	1.36	0.06
Bluegill	0	0	0	0	0.16496	0	0	111.87	3.44
Bowfin	0	0	0	0	0	0	0	0.68	0.02
Channel Catfish	1.80	0	3.45	3.44	14.52	0.48	0	0.00	4.21
Common Carp	0	0.23	0.24	0.11	0.99	0	7.52	2.05	0.33
Emerald Shiner	0	0	0	0	1.15	0	15.04	93.45	3.05
Flathead Catfish	0	0	0	0	0	0	0	0.00	0.02
Freshwater Drum	0.90	0.69	2.08	8.71	44.54	1.43	52.63	4.09	9.91
Gizzard Shad	0	0	0.16	0.72	9.90	0	8	293.32	10.56
Golden Redhorse	0	0	0	0	0.16496	0	0	0.00	0.02
Green Sunfish	0	0	0	0	0	0	0	4.77	0.15
Highfin Carpsucker	0	0	0	0	0.66	0	0	0.00	0.08
Hybrid Striped Bass	0	0	0	0.33	2	0	0	0.00	0.42
Largemouth Bass	0	0.00	0.00	0.06	0	0	0	2.05	0.08
Mooneye	0	1.15	0.56	0.22	0.33	0	0	0.00	0.38
Mosquitofish	0	0	0	0	0	0	0	0.68	0.02
Ohio Lamprey	0	0	0.08	0	0	0	0	0.00	0.02
Orangespotted Sunfish	0	0	0	0	0	0	0	33.42	1.04
Pumpkinseed	0	0	0	0	0	0	0	3.41	0.10
Quillback	0	0	0	0	0.66	0	0	0.00	0.08
River Carpsucker	0	0	0.16	0.11	3	0	8	2.73	0.63
Rock Bass	0	0	0.08	0	0	0	0	0.00	0.02
Sauger	0	0	0	0	0.33	0	0	0.00	0.06
Shorthead Redhorse	0	0	0	0.06	0	0	8	0.00	0.04
Silver Chub	0	0.92	0.32	0.33	0	0	0	0.00	0.29
Smallmouth Buffalo	0	0.46	0.80	0.67	4.95	0	90	0.68	1.40
Spottail Shiner	0	0	0	0	0.16	0	0	0.00	0.02
Spotted Bass	0	0	0	0	0	0.95	0	0.00	0.04
Spotted Sucker	0	0	0	0	0	0	0	1.36	0.04
Walleye	0	0	0	0	0.49	0	0	0.00	0.06
Warmouth	0	0	0	0	0	0	0	3.41	0.10
White Bass	0.30	0	0.24	0.22	6.10	0	7.52	0.00	0.96
White Crappie	0	0	0	0.06	0	0	0	47.75	1.48
Total	2.99	4.12	8.17	15.09	91.22	2.86	203.01	607.09	39.18

Table 3-9. Fish caught per hour (CPUE) within each habitat type in the Belleville Pool, Ohio River, during February - April 2002.

	Habitat types						
	Island		Back	Main		Deep	
Species	Head	Tail	water	channel	Trib	hole	Total
Bluegill	0	0	0	0	0.34	0	0.05
Channel catfish	4.08	1.87	3.79	2.11	25.84	0	5.84
Common carp	0	0	0	0	1.38	0	0.19
Emerald shiner	0	0	0	0	2.76	0	0.39
Flathead catfish	0	0	0	0.11	0	0	0.05
Freshwater drum	2.04	0.93	0.89	1.11	55.12	0	8.64
Gizzard shad	0	0	0	0.11	19.64	0	2.80
Highfin carpsucker	0	0	0	0	0.69	0	0.10
Hybrid striped bass	0	0	0	0	1.38	0	0.19
Mooneye	0	1.40	0.22	0.11	0.69	0	0.34
Orangespotted Sunfish	0	0	0	0	0.34	0	0.05
Quillback	0	0	0	0	0.69	0	0.10
River carpsucker	0	0	0	0	5.17	0	0.72
Walleye	0	0	0	0	1	0	0.10
Total	6.12	4.20	4.91	3.55	114.73	0	19.55

Table 3-10. Fish caught per hour (CPUE) within each habitat type in the Belleville Pool, Ohio River, during December 2002 through March 2003.

	Habitat types								
	Island		Back	Main		Deep	Wing	Embay-	
Species	Head	Tail	water	channel	Trib	hole	dam	ment	Total
Black Buffalo	0	0	0	0	0	0	7.52	0.00	0.04
Black Crappie	0	0	0	0	0.32	0	0	1.36	0.11
Bluegill	0	0	0	0	0	0	0	111.87	6.10
Bowfin	0	0	0	0	0	0	0	0.68	0.04
Channel Catfish	0	0	3.29	4.77	4.11	0.87	0	0.00	3.09
Common Carp	0	0.45	0.38	0.22	0.63	0	7.52	2.05	0.45
Emerald Shiner	0	0	0	0	0	0	15.04	93.45	5.17
Freshwater Drum	0	0.45	2.78	16.32	34.81	2.60	52.63	4.09	11.01
Gizzard Shad	0	0	0.25316	1.33	0.95	0	7.52	293.32	16.67
Golden Redhorse	0	0	0	0	0.32	0	0	0.00	0.04
Green Sunfish	0	0	0	0	0	0	0	4.77	0.26
Highfin Carpsucker	0	0	0	0	0.63	0	0	0.00	0.07
Hybrid Striped Bass	0	0	0	0.67	3.16	0	0	0.00	0.60
Largemouth Bass	0	0	0	0.11	0	0	0	2.05	0.15
Mooneye	0	0.90	0.76	0.33	0	0	0	0.00	0.41
Mosquitofish	0	0	0	0	0	0	0	0.68	0.04
Ohio Lamprey	0	0	0.13	0	0	0	0	0.00	0.04
Orangespotted Sunfish	0	0	0	0	0	0	0	33.42	1.82
Pumpkinseed	0	0	0	0	0	0	0	3.41	0.19
Quillback	0	0	0	0	0.63	0	0	0.00	0.07
River Carpsucker	0	0	0.25	0.22	1.90	0	7.52	2.73	0.56
Rock Bass	0	0	0.13	0	0	0	0	0.00	0.04
Sauger	0	0.45	0	0	0.63	0	0	0.00	0.11
Shorthead Redhorse	0	0	0	0.11	0	0	7.52	0.00	0.07
Silver Chub	0	1.80	0.51	0.67	0	0	0	0.00	0.52
Smallmouth Buffalo	0	0.90	1.27	1.33	9.49	0	90.23	0.68	2.49
Spotted Bass	0	0	0	0	0	1.73	0	0.00	0.07
Spotted Sucker	0	0	0	0	0	0	0	1.36	0.07
Walleye	0	0	0	0	0.31646	0	0	0.00	0.04
Warmouth	0	0	0	0	0	0	0	3.41	0.19
White Bass	0.53	0	0.38	0.44	11.71	0	7.52	0.00	1.71
White Crappie	0	0	0	0.11	0	0	0	47.75	2.64
Total	0.53	4.95	10.13	26.64	69.62	5.20	203.008	607.09	54.89

Table 3-11. Selection statistics for occupancy rate models fit to freshwater drum data including the second order adjustment to Akaike's Information Criterion (AICc), rescaled differences (Delta AICc), Akaike model weights, model likelihoods, number of model parameters (K) and model deviance.

Model	AICc	Delta AICc	AICc Weight	Model Likelihood	K	Model Deviance
{p(depth) psi(hab*yr)}	213.68	0	0.506	1	8	196.03
{p(.) psi(hab*yr)}	215.20	1.52	0.236	0.47	7	199.93
{p(flow) psi(hab*yr)}	217.03	3.35	0.095	0.19	8	199.37
{p(temp) psi(hab*yr)}	217.56	3.88	0.073	0.14	8	199.90
{p(cond) psi(hab*yr)}	217.58	3.90	0.072	0.14	8	199.93
{p(hab*yr) psi(hab*yr)}	220.27	6.59	0.019	0.04	12	192.51

Table 3-12. Actual and model-averaged estimates of the proportion of sites within three habitat types occupied by freshwater drum (ψ).

	Actual value with p = 1		Model-averaged with p < 1	
Habitats	ψ	SE	ψ	SE
Year 1				
Backwater	0.03	0.06	0.11	0.13
Main channel	0.11	0.08	0.42	0.27
Tributary	0.33	0.11	0.78	0.24
Year 2				
Backwater	0.15	0.06	0.36	0.37
Main channel	0.26	0.07	0.82	0.06
Tributary	0.21	0.10	0.56	0.33

Table 3-13. Results of gill net sampling at 11 sites on Belleville Pool. Site coordinates are in Table 3-2.

							Species captured			
Site	Habitat Type	Date Set	Time Set	Date Pulled	Time Pulled	hours fished	Mooneye	Sauger	Shorthead Redhorse	Carp
Bull Cr.	Tributary	12/12/2002	16:30	12/13/2002	10:00	17.5		2	1	
Marietta Is.	Is. Head	12/12/2002	16:45	12/13/2002	10:30	17.75				
River Mile 167	Main Channel	12/12/2002	16:15	12/13/2002	10:15	18				
Marietta Is. DH #1	Deep Hole	12/13/2002	13:20	1/12/2002	*	*				
Muskingum Is.	Is. Tail	12/13/2002	14:00	12/14/2002	13:40	23.6**				
Neal Is.	Is. Head	1/10/2003	12:00	1/10/2003	15:45	3.75				
Neal Is.	Is. Tail	1/10/2003	10:30	1/10/2003	16:15	5.75				
Neal Is.	Backwater	1/10/2003	11:30	1/10/2003	16:00	4.5	1			
Lee Cr.	Tributary	3/1/2003	11:30	3/1/2003	18:00	6.5				2
Hocking R.	Tributary	3/1/2003	12:15	3/1/2003	18:00	5.75				
Newberry Is.	Is. Tail	3/1/2003	13:00	3/1/2003	17:30	4.5				

*floats submerged during high flows in Dec., recovered in Jan., no fish present.

**Net tangled in LWD during high flows and cut into pieces during removal.

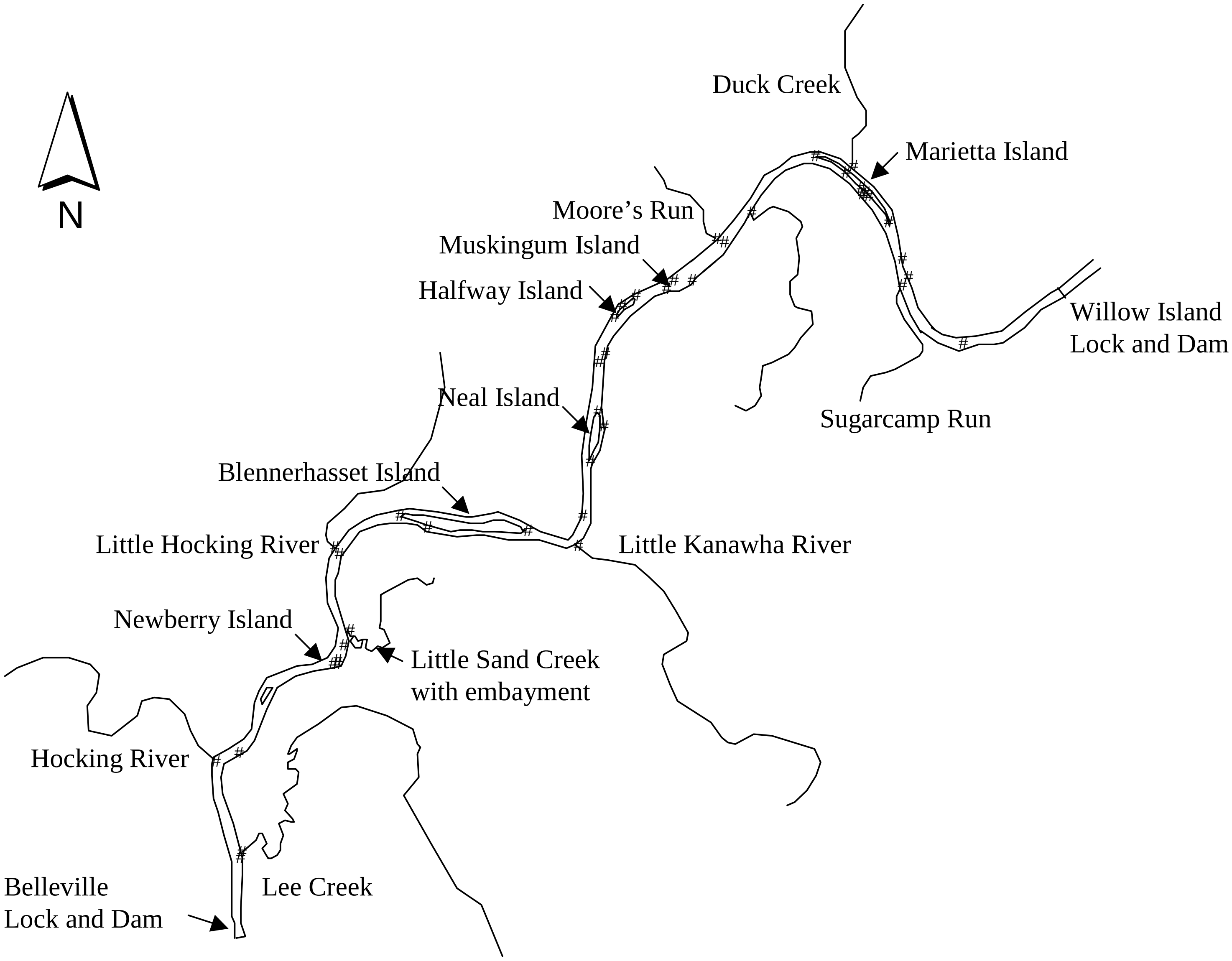
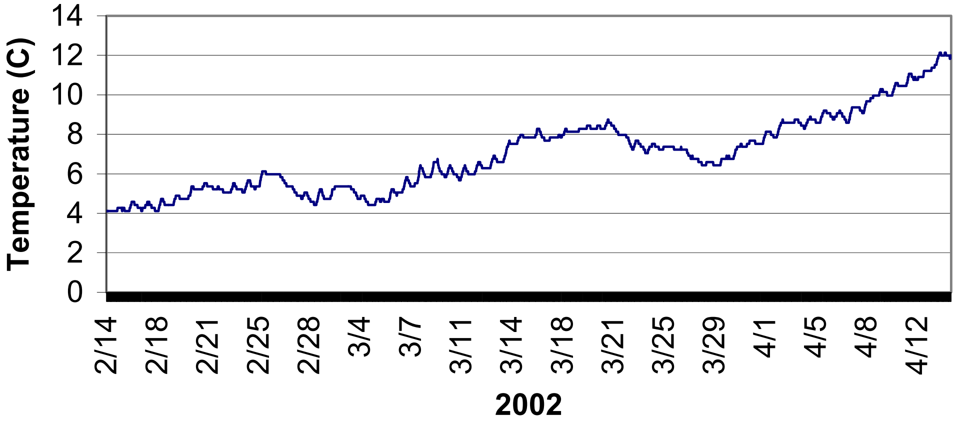


Figure 3-1. Locations of sample sites within Belleville Pool.

Figure 3-2. Temperature logger data from six sites in Belleville Pool, Ohio River, from 15 February 2002 to 15 April 2002.

Blennerhasset Island backwater



Newberry Island Backwater

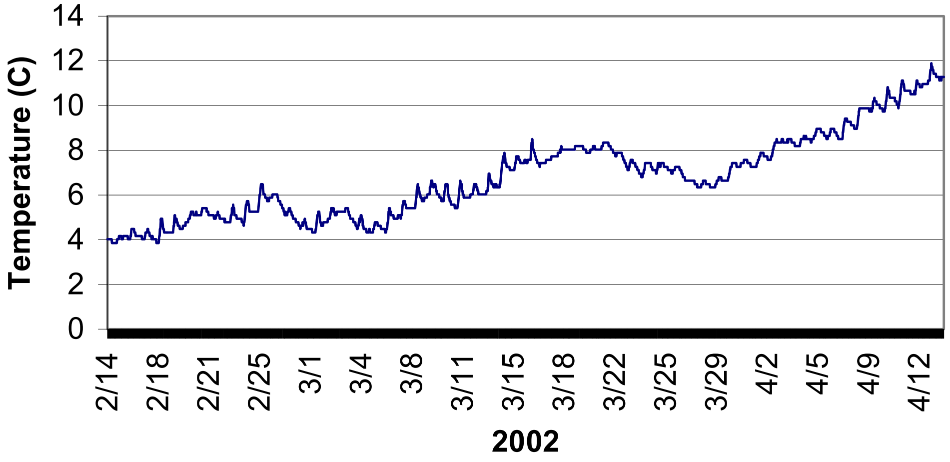
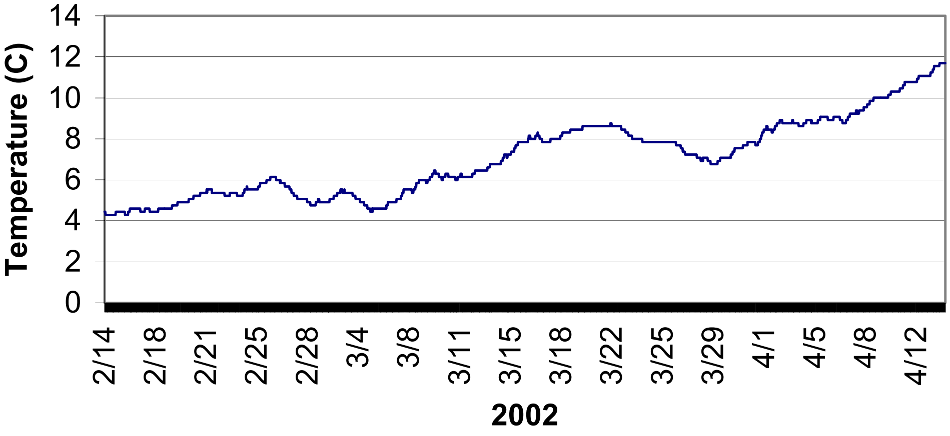


Figure 3-2. Continued

Neal Island backwater



Main channel river mile 196

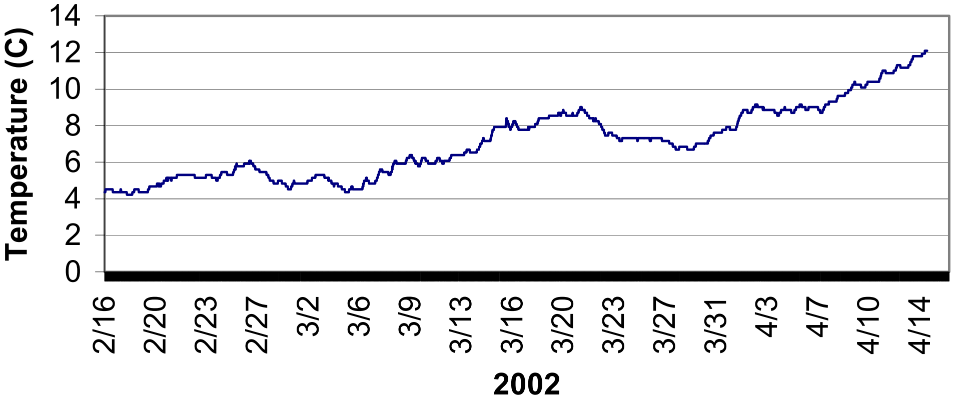
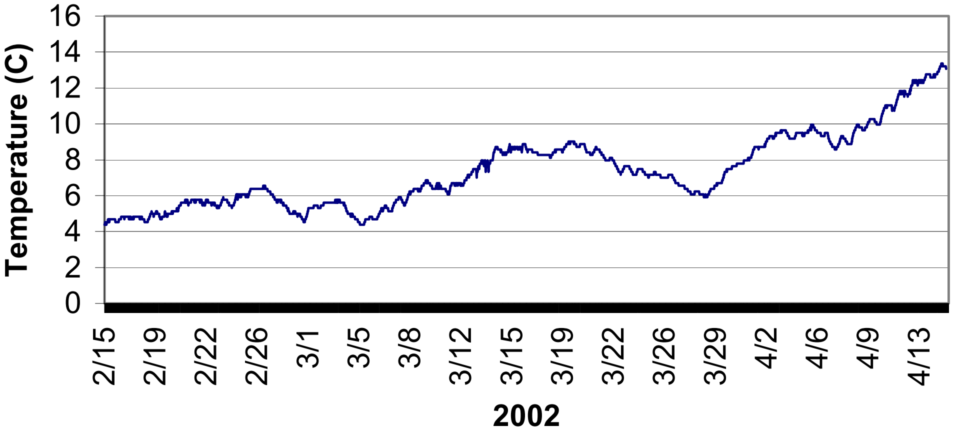


Figure 3-2. Continued

Main channel river mile 184



Marietta Island head

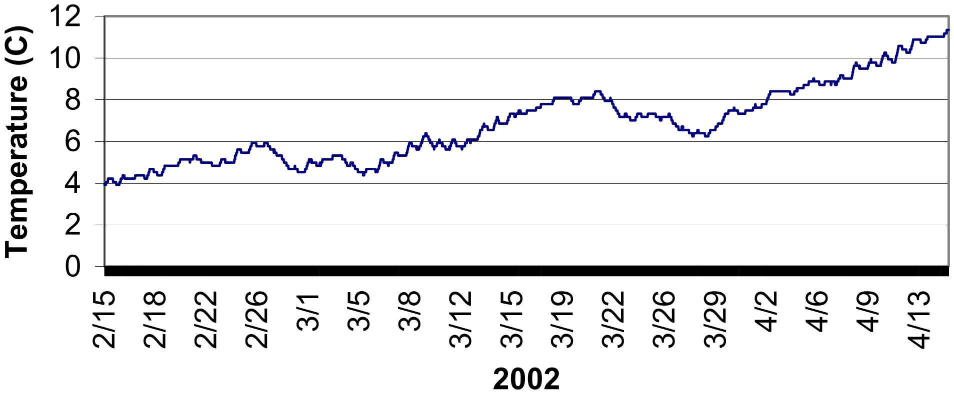
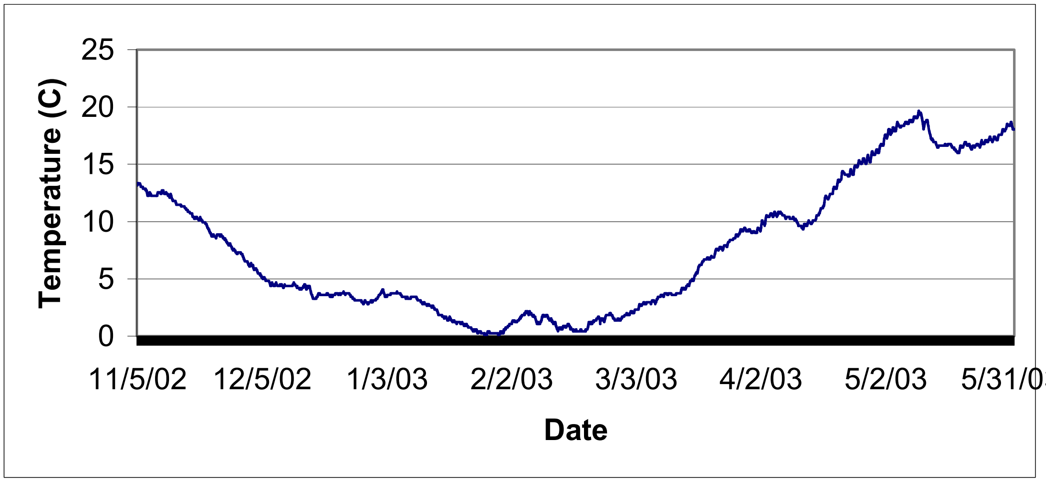


Figure 3-3. Temperature logger data from four sites in Belleville Pool, Ohio River, from winter 2002/2003.

Blennerhasset Island backwater



Newberry Island Backwater

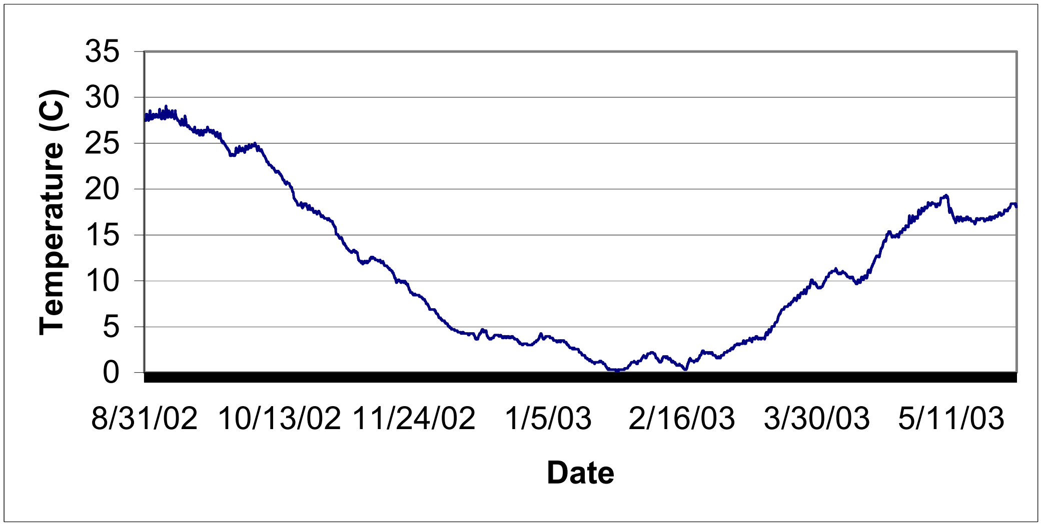
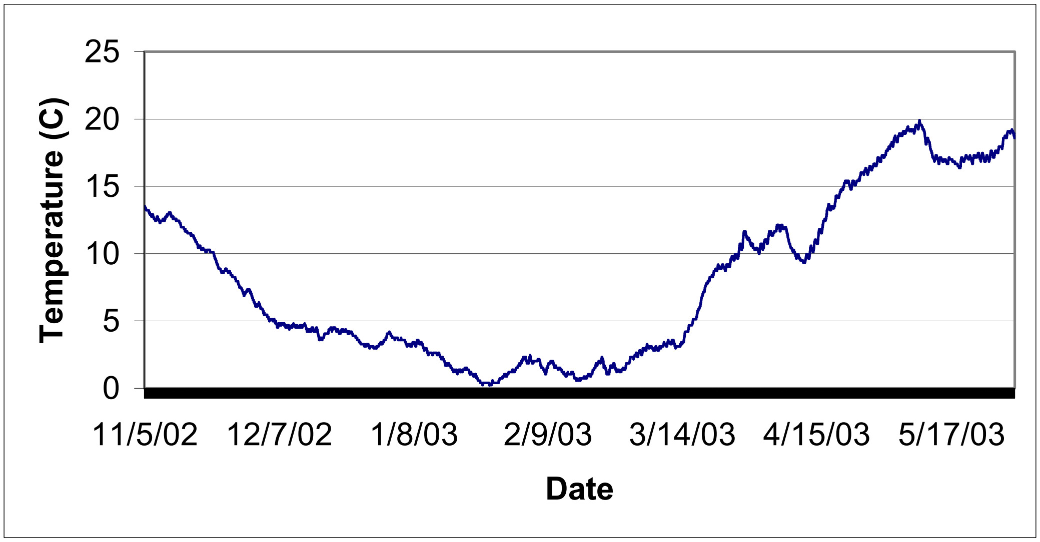
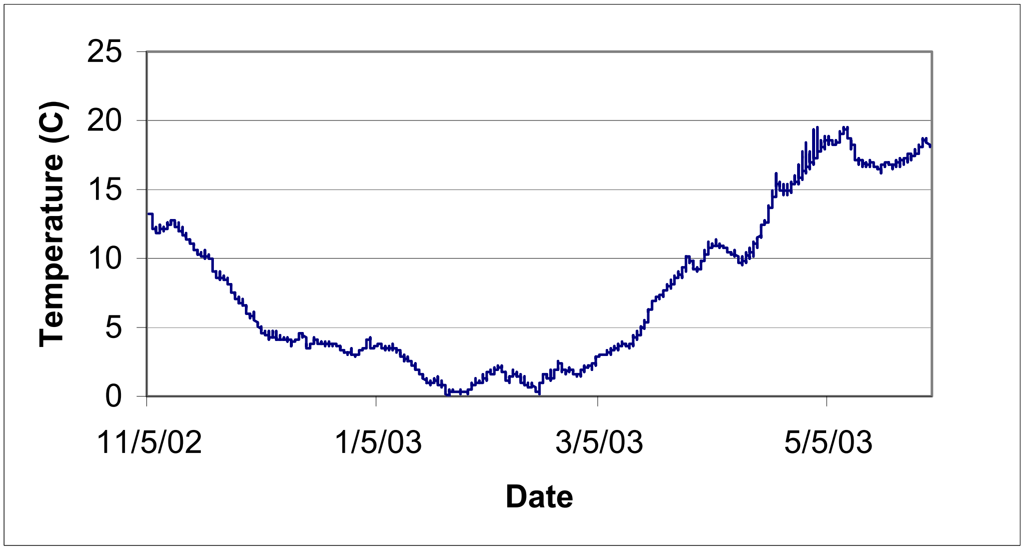


Figure 3-3. Continued.

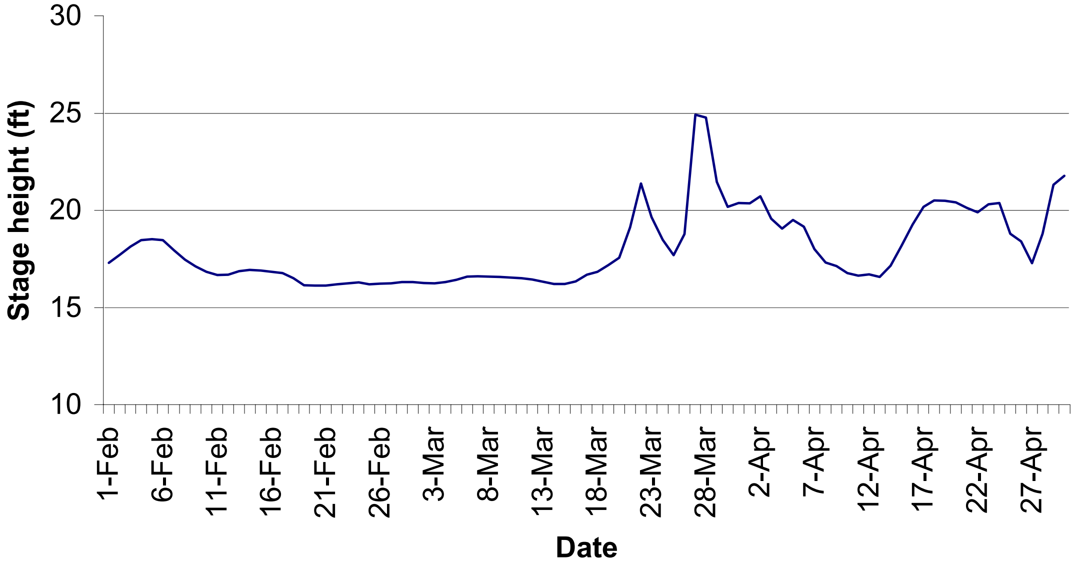
Main channel river mile 184



Marietta Island head



A



B

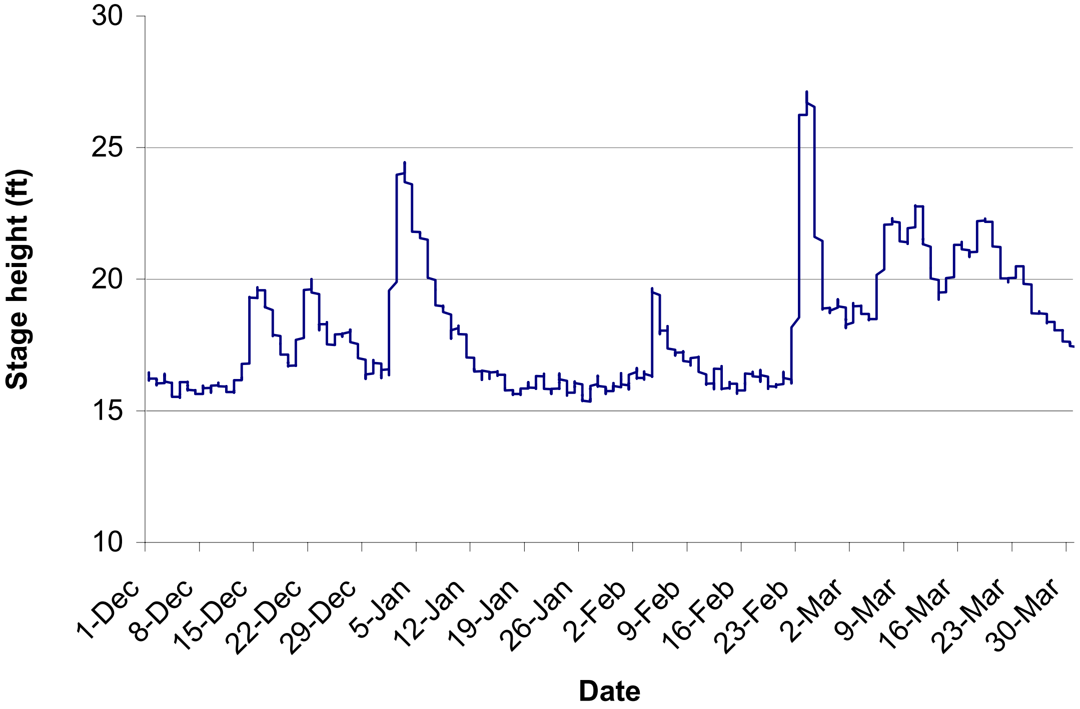


Figure 3-4. Stage data from Ohio River at Marietta during February through April 2002 (A) and December 2002 through March 2003 (B).

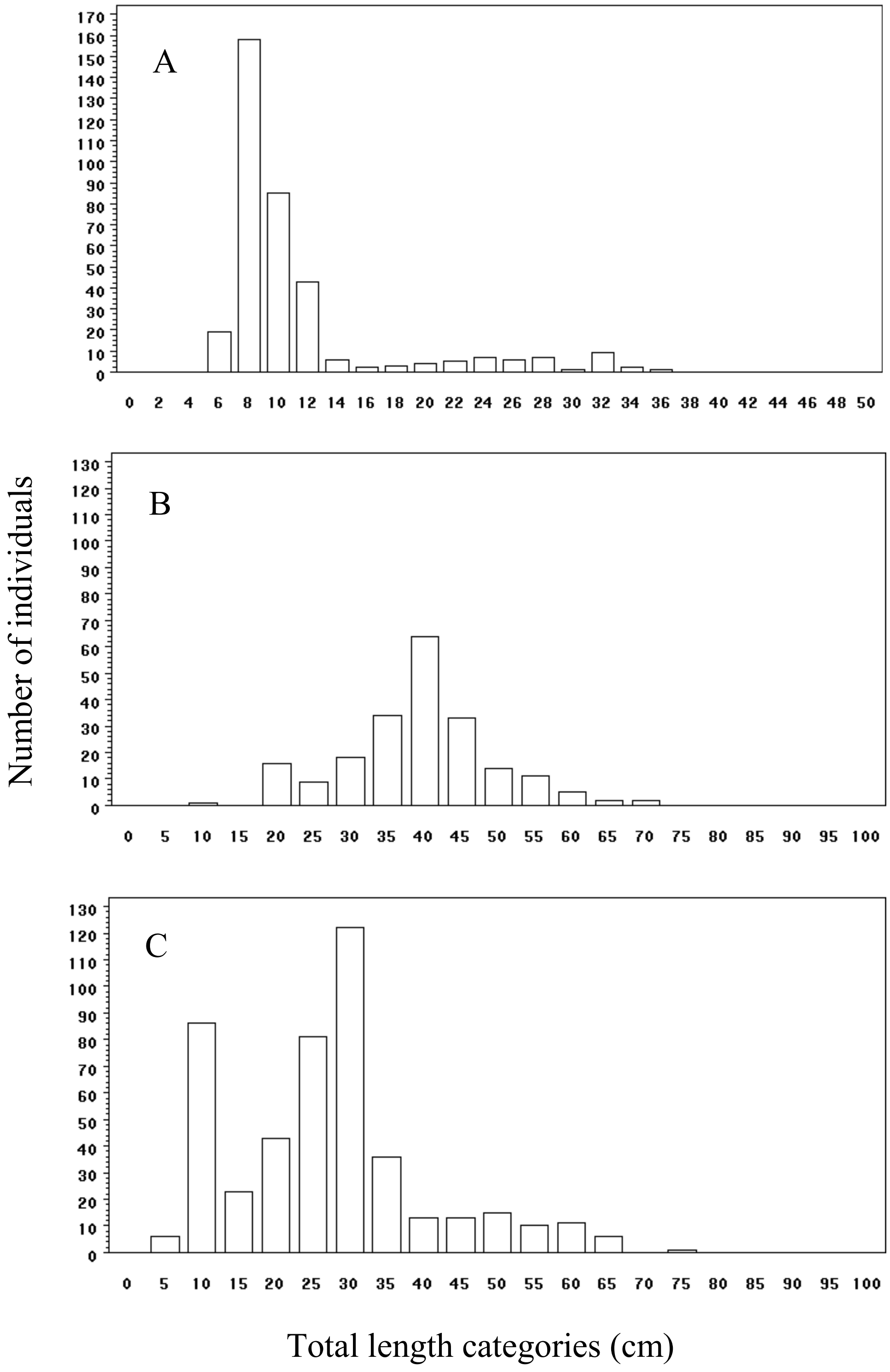


Figure 3-5. Length frequencies for gizzard shad (A; 2 cm length categories), channel catfish (B; 5 cm length categories), and freshwater drum (C; 5 cm length categories) collected from Belleville pool during February 2002 through March 2003.

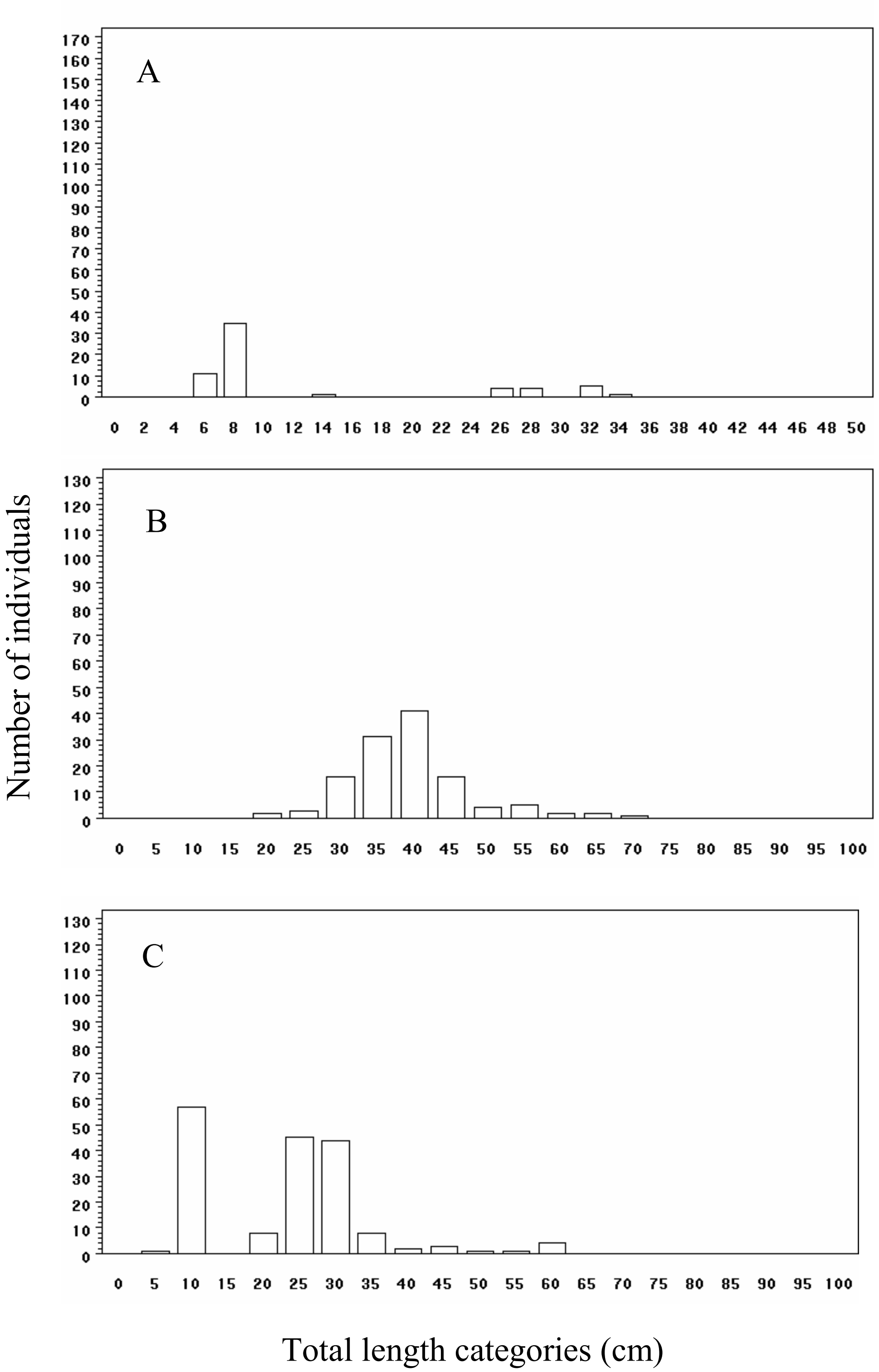


Figure 3-6. Length frequencies for gizzard shad (A; 2 cm length categories), channel catfish (B; 5 cm length categories), and freshwater drum (C; 5 cm length categories) collected from Belleville pool during February 2002 through April 2002.

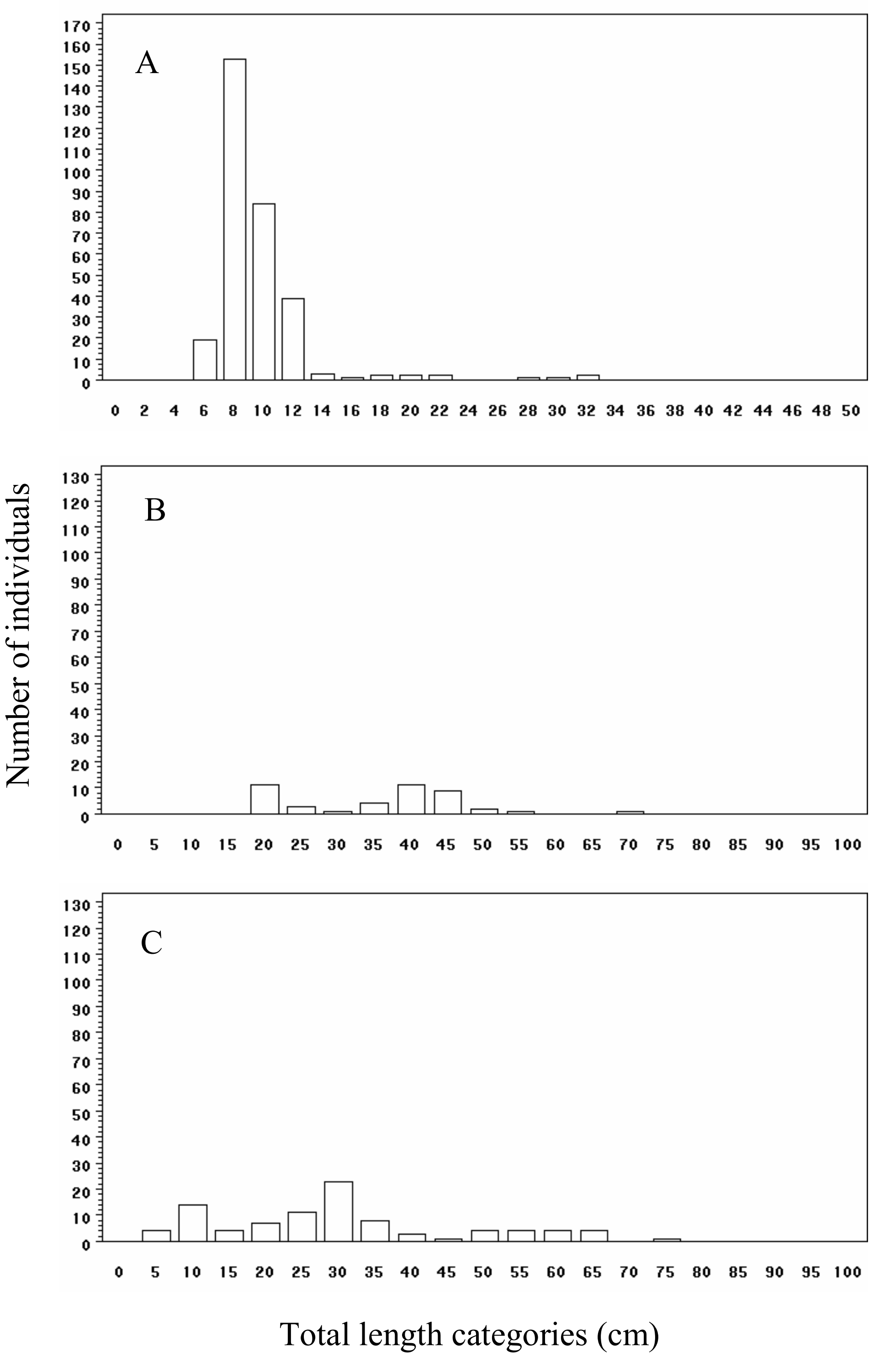


Figure 3-7. Length frequencies for gizzard shad (A; 2 cm length categories), channel catfish (B; 5 cm length categories), and freshwater drum (C; 5 cm length categories) collected from Belleville pool during December 2002 through March 2003.

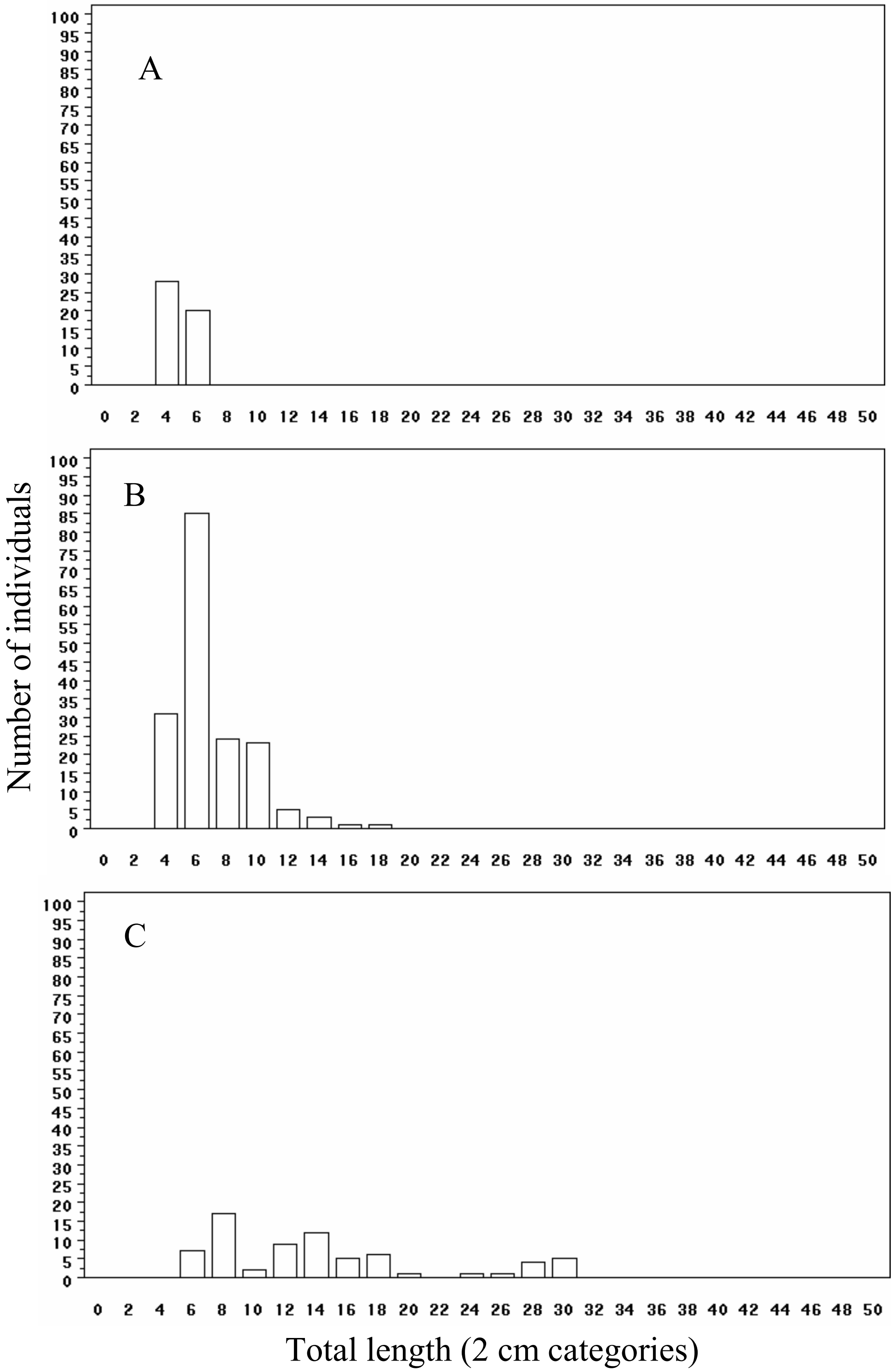


Figure 3-8. Length frequencies for orangespotted sunfish (A), bluegill (B), and white crappie (C) collected from Little Sand Creek embayment during December 2002 through March 2003.

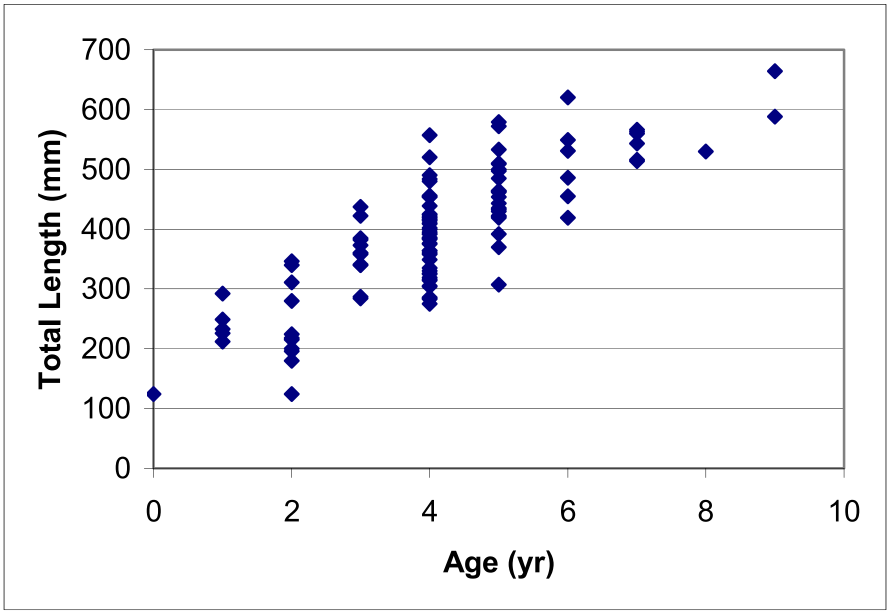


Figure 3-9. Age-length relationship from pectoral spine-based age estimates and total lengths of channel catfish from Ohio River, Belleville Pool.

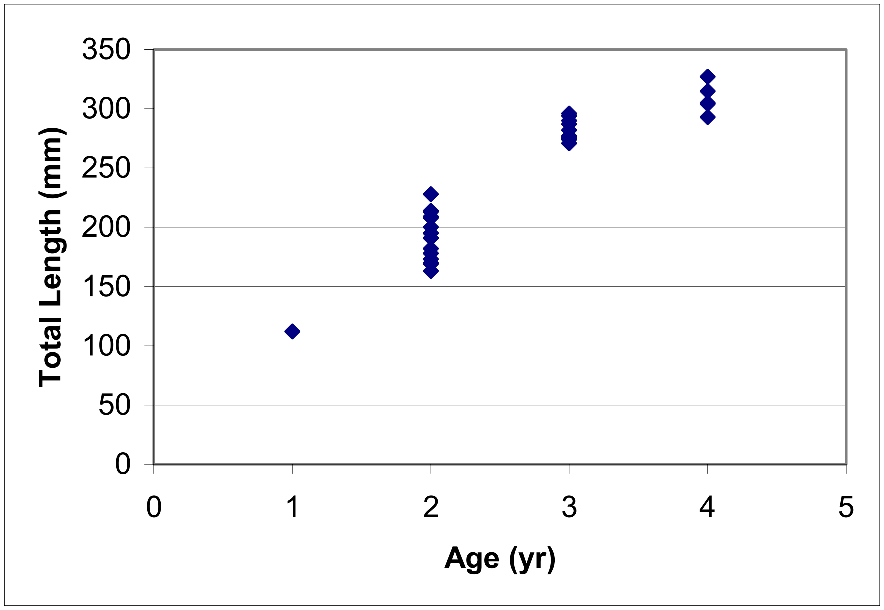


Figure 3-10. Age-length relationship from otolith-based age estimates and total lengths of white bass from Ohio River, Belleville Pool.

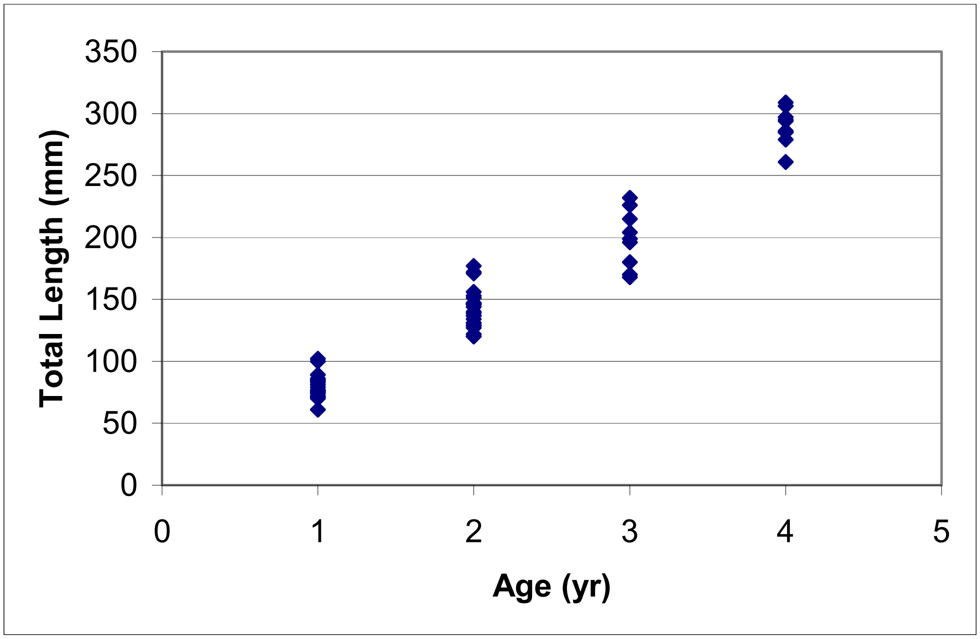


Figure 3-11. Age-length relationship from otolith-based age estimates and total lengths of white crappie from Ohio River, Belleville Pool.

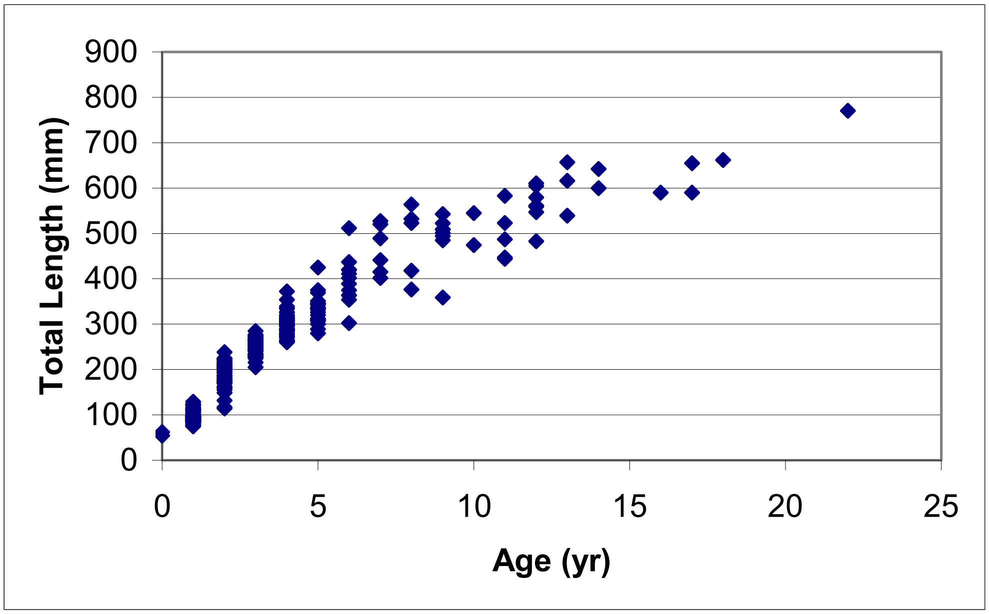


Figure 3-12. Age-length relationship from otolith-based age estimates and total lengths of freshwater drum from Ohio River, Belleville Pool.

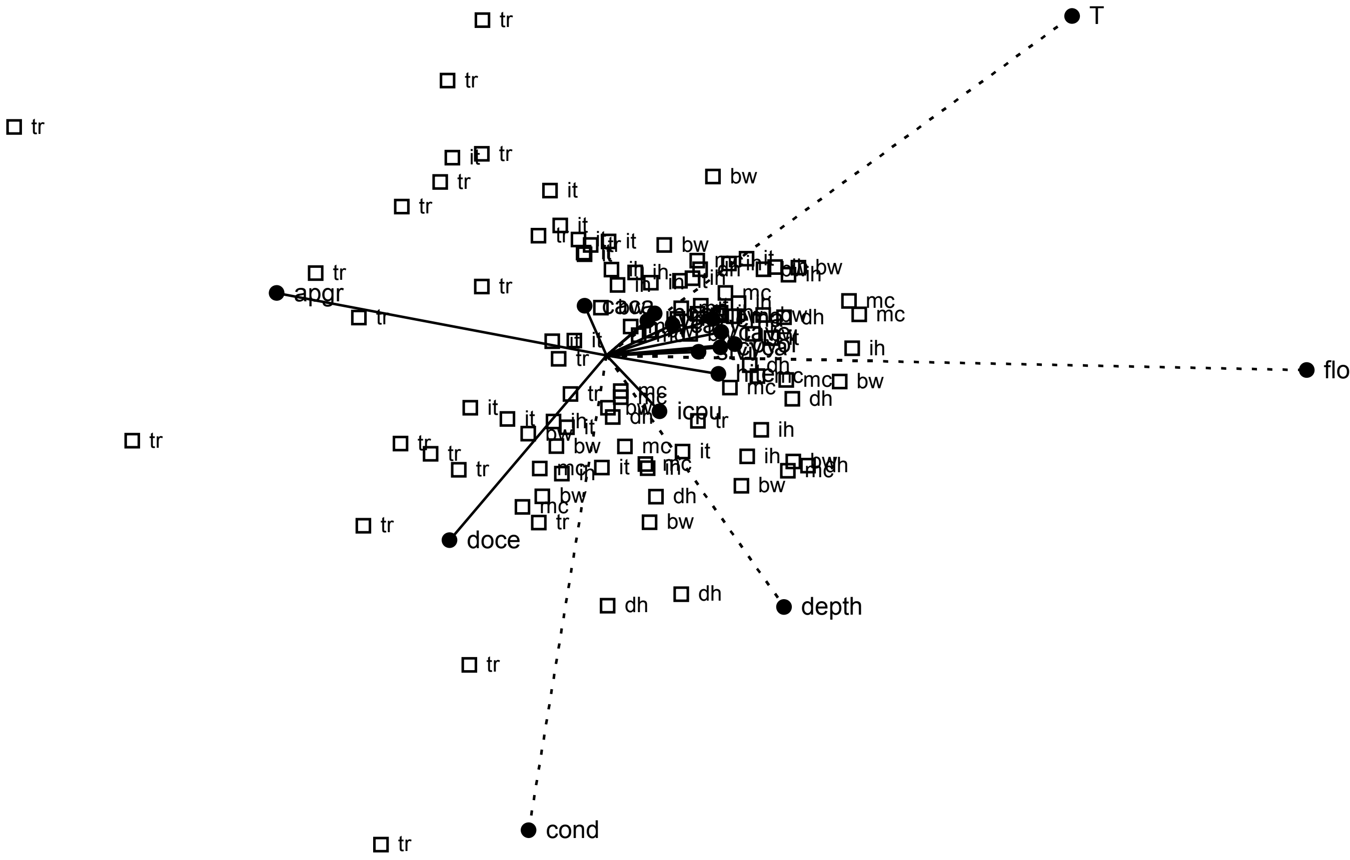


Figure 3-13. Triplot from canonical correspondence analysis (CCA) of species abundance, sites, and abiotic variables from 16 February – 7 April 2002. Sites are abbreviated as tr (tributary), bw (backwater), mc (main channel), ih (island head), it (island tail), and dh (deep hole). Abiotic variables are depth, specific conductivity (cond), temperature (T), and water velocity (flow). Species are denoted as the first two letters of the genus and specific epithet, e.g., freshwater drum (apgr), gizzard shad (doce) and channel catfish (icpu).

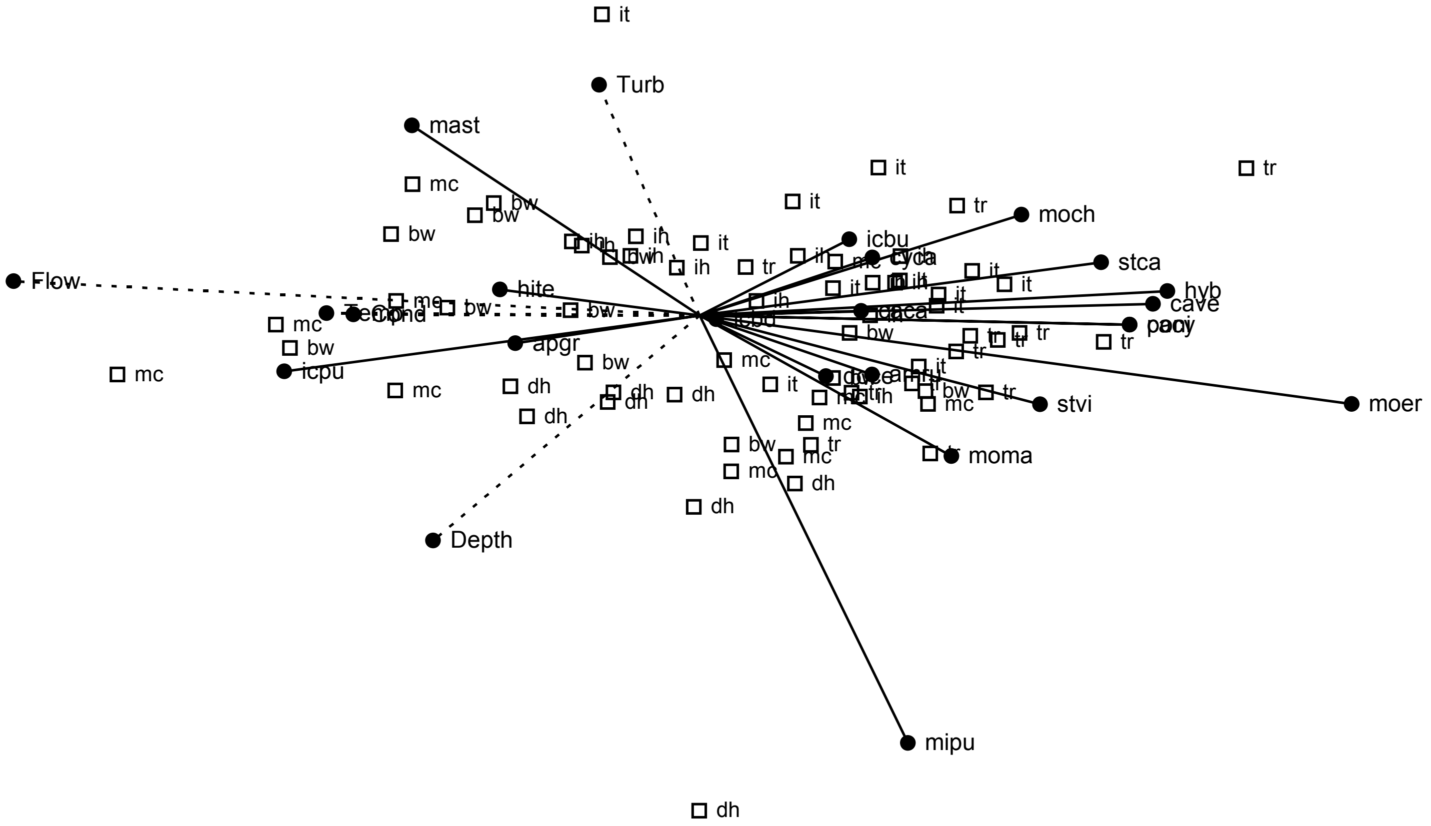


Figure 3-14. Triplot from canonical correspondence analysis (CCA) of species abundance, sites, and abiotic variables from December 2002 and January 2003. Sites are abbreviated as tr (tributary), bw (backwater), mc (main channel), ih (island head), it (island tail), and dh (deep hole). Abiotic variables are depth, specific conductivity (cond), temperature (Temp), turbidity (turb), and water velocity (flow). Species are denoted as the first two letters of the genus and specific epithet, e.g., freshwater drum (apgr), gizzard shad (doce) and channel catfish (icpu).

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APPENDIX I

WINTER HABITAT USE OF FISHES IN THE OHIO RIVER

Benjamin Ernst Lenz

Thesis submitted to the
Davis College of Agriculture, Forestry, and Consumer Science
at West Virginia University
in partial fulfillment of the requirements
for the degree of

Master of Science
in
Wildlife and Fisheries Resources

Stuart A. Welsh, Ph. D.
Kyle J. Hartman, Ph. D.
Alan J. Temple, Ph. D.

Department of Forestry

Morgantown, West Virginia

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Keywords: winter, juvenile, tributary, embayment, channel catfish (*Ictalurus punctatus*), freshwater drum (*Aplodinotus grunniens*), white bass (*Morone chrysops*)

ABSTRACT

Winter Habitat Use of Fishes in the Ohio River

Benjamin Ernst Lenz

Winter is a critical period during which fishes may suffer increased mortality. To identify the habitats that fishes use in large rivers during winter conditions, we electrofished six habitat types in the Belleville Pool, Ohio River. We collected the greatest diversity and numbers of fishes in low-velocity tributary confluences when water temperatures were > 4 °C. When water temperatures were < 4 °C, certain species were collected in greater abundance in faster-velocity main channel and back channel habitats while other species continued to associate with lower flows in tributary mouths. Differing habitat use between species obscures broad generalizations about when and how fishes use overwintering refuges.

In an additional habitat sampled, an embayment, 85% of all fishes collected were juveniles. Centrarchids, rarely collected in the mainstem portion of the river, were one of the dominant fishes collected in the embayment. Protecting large river embayments may prove important for managing recreational sunfish fisheries.

Channel catfish, *Ictalurus punctatus*, and freshwater drum, *Aplodinotus grunniens*, the most abundant fishes collected in the Belleville Pool, exhibited growth comparable to other populations in temperate large rivers in eastern North America. Conversely, white bass, *Morone chrysops*, growth was slower compared to other populations, possibly explaining why none of the white bass individuals collected were harvestable size. Population growth and the probability of survival of all fishes may

increase by protecting and enhancing tributary and embayment habitats in large rivers during winter.

Dedicated to my wife Carmen

ACKNOWLEDGMENTS

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Chapter 1. Introduction to Winter Habitat Use of Fishes in Large Rivers, Juvenile Mortality during Winter, and the Use of Age and Growth Information in Assessing the Condition of Sport Fisheries.

Overview

This manuscript attempts to define which habitats large river fishes use to survive during winter. We identify the specific abiotic conditions existing in habitats fishes use during winter in the upper Ohio River. Chapter 2 of this manuscript discusses the results from the winter habitat study of the mainstem portion of the Ohio River. Chapter 3 reveals the use of embayments by juvenile fishes during winter in the upper Ohio River. Lastly, Chapter 4 summarizes the results from the age and growth study of three popular game fishes collected during the winter habitat study.

Winter survival of fishes in large rivers

Winter is a critical period during which freshwater fishes suffer increased mortality (Hubbs and Trautman 1935; Cunjak 1988; Garvey et al. 1998). Young-of-year (YOY) fishes often experience the highest mortality during winter (Toneys and Coble 1979; Ludsin and DeVries 1997; Garvey et al. 1998). Yet, fishes of all ages suffer increased mortality during winter. To increase their probability of survival, fish use certain habitats during winter. Fishes in large rivers are no exception to this rule (Johnson et al. 1998).

In large temperate river systems, extremely low water temperatures during winter coupled with high flows increase mortality rates of fishes (Bodensteiner and Lewis 1992; Lyons 1997). Low levels of dissolved oxygen (D. O.) also increase mortality of fishes, and occur typically during ice-cover of backwater areas (Raibley et al. 1997). Many fishes forage infrequently during cold winter extremes, and select refuges that minimize energy depletion (Crawshaw 1984; Carlson 1992). Fishes often increase fat-reserves before winter; hence, reducing mortality associated with energy depletion (Fullerton et al. 2000). However, energy reserves may not suffice given long winters or energy expenditures due to disturbance, such as variation in river flows or boat traffic (Nielsen et al. 1986). Past research has shown which abiotic conditions large river fishes prefer to minimize mortality during winter.

Abiotic conditions that limit fish survival during winter

Temperature and flow

During winter, riverine fishes select habitats with relatively high temperatures and low flows. Riverine fishes overwinter in velocity shelters (Logsdon 1993; Bodensteiner and Lewis 1994; Johnson et al. 1998) and areas with warmer temperatures and lower flows than mainstem river sections, such as off-channel coves, marinas, embayments and industrial warm-water outflows (Sheehan et al. 1990; Knights et al. 1995; Gent et al. 1995; Raibley et al. 1997). Also, backwater areas with relatively warmer temperatures and lower flows provide winter habitats (Bodensteiner and Lewis 1992; Raibley et al. 1997; Sheehan and Rasmussen 1999). By occupying favorable habitats during winter, fishes avoid the stresses of variable flow velocity in the main channel portion of large rivers.

Sheehan et al. (1990) examined temperature and flow requirements for several fishes common in the Ohio River, such as gizzard shad, *Dorosoma cepedianum*, channel catfish, *Ictalurus punctatus*, and freshwater drum, *Aplodinotus grunniens*. Gizzard shad, channel catfish, and freshwater drum occupy relatively low velocity areas during winter (Heese and Newcomb 1982; Newcomb 1989; Sheehan et al 1990; Logsdon 1993;

Bodensteiner and Lewis 1994). Gizzard shad are vulnerable to winter die-offs during low water temperatures (Miller 1960). Some fishes experiencing extreme low temperatures suffer cold shock (Cichra et al. 1982). These fish lose their ability to maintain their position in a preferred habitat and can be swept downstream to open channel habitats, reducing their chances of survival (Sheehan et al.1990; Bodensteiner and Lewis 1994). Sheehan et al. (1990) reported temperature preferences of > 4 °C for many species in large rivers, such as green sunfish, *Lepomis cyanellus*, bluegill, *Lepomis macrochirus*, and freshwater drum. Some species, such as channel catfish, black crappie, *Pomoxis nigromaculatus*, and walleye, *Stizostedion vitreum*, can maintain swimming abilities at temperatures < 4 °C (Sheehan et al. 1990). Temperature and flow preferences during winter and swimming abilities during low temperatures are unknown for most riverine fishes.

Dissolved oxygen

Abiotic factors other than water temperature and flow velocity can influence the suitability of winter habitats. Backwater areas can become anoxic and unsuitable as overwintering areas (Bodensteiner and Lewis 1992; Knights et al. 1995; Johnson et al. 1998). Low D. O. levels can result in fish die-offs when backwater areas become isolated from the main channel during low water levels in winter (Raibley et al. 1997). In the West Virginia section of the Ohio River, dissolved oxygen is reduced by water pollution near cities, but normally remains above critical levels (Pearson and Krumholz 1984). In the upper Ohio River, the availability and quality of backwater habitat typical of larger rivers such as the Missouri and Mississippi is limited and largely unavailable for fishes. The steep topography of the riparian zone restricts lateral movement of waters outside of the main channel. Embayments are the habitat type in the upper Ohio River most similar to lower elevation large river backwaters.

Habitats available to fishes in the upper Ohio River during winter

The abiotic conditions of a particular habitat type may make them unsuitable for use by fishes during winter. As stated above, extreme and varying conditions during winter can increase mortality in fishes. To survive, fishes must choose habitats that offer refuge from the extreme conditions of winter. Habitats available to fishes during winter vary in their physical and chemical characteristics. A combination of physiochemical conditions, such as low-flow velocities and warmer temperatures, may offer the best refuge to overwintering fishes, yet these conditions can vary temporally, forcing fishes to use more than one specific habitat during winter.

Nine habitat types classified as main channel, deep hole, back channel, island head, island tail, tributary, wing dam, embayment, and tailwater are available for sampling in the upper Ohio River. Vallazza et al. (1994) and Cray (1999) discussed similar habitats, and our classification scheme is further described below. Main channel habitats are the open water portion of the river used as commercial navigation routes, and typically have shallow near-shore areas and deeper mid-channel sections. Deep hole habitats are relatively deep areas created by dredging or natural scour within main channel or back channel areas. Back channels, island head, and island tail habitats are associated with islands. Back channel habitats are also open waters, but are not typically used for barge navigation and occur between an island and the mainland. Habitats near the upstream and downstream ends of each island are island head and island tail habitats, respectively. Tributary habitats are located, specifically, where the joining waters form a confluence with the mainstem of the Ohio River. Wing dams (and other artificial flow barriers) create near-shore habitats with low water velocities. Tailwater habitats are the open often-turbulent water immediately below a dam. Embayment habitats are shallow bay-like areas connected to the main channel by a tributary or artificial channel.

Juvenile survival during winter

Survival probability of fishes during winter often increases with body size (Hubbs and Trautman 1935; Cunjak 1988). Juvenile and YOY (young-of-year) individuals suffer increased mortality during winter compared to larger individuals (Toneys and Coble 1979; Ludsin and Devries 1997; Garvey et al 1998). Due to the higher loss of young individuals, winter is a critical period for recruitment into a population (Oliver et al. 1979; Toneys and Coble 1979; Miranda and Hubbard 1994). Limiting exposure to severe winter conditions allows fishes to persist through winter. Juvenile fishes should occupy habitats that are favorable for increasing the probability of survival during winter.

Embayments

Embayment habitats offer critical overwintering refuge for fishes of all ages in large river systems. Embayments are shallow bay-like areas connected to the main channel by a tributary or artificial channel. Backwaters are similar in morphology and function as embayments, but embayments receive input (water, sediment, and aquatic organisms) from both associated tributaries and the riverine system. Backwaters only receive input from their associated river (Cray 1999). Similar to backwaters, embayments offer relatively high temperatures and low flows during winter. These velocity shelters are favorable for overwintering riverine fishes (Logsdon 1993; Bodensteiner and Lewis 1994; Johnson et al. 1998). The warmer temperatures and lower flows of embayments are often more benign than mainstem river conditions, offering fishes a refuge to escape the harsh conditions of winter (Sheehan et al. 1990, Knights et al. 1995, Gent et al. 1995; Raibley et al. 1997). These favorable conditions in embayments are optimal for overwintering fishes, especially juveniles, since they are most likely to suffer increased mortality during winter.

Importance of age and growth information about sport fisheries

Fish length-at-age estimates are important information used to assess the status of a fishery. The age of a fish can be determined in many ways. Bony parts of the fish such as otoliths, pectoral spines, and vertebrae can all be sectioned (cut) and, by simply counting the growth rings of the section, the reader can estimate the age of an individual. Regardless of the method used to determine ages of fishes, the information gathered yields important insight into age-related growth rates and the relative numbers of juvenile and mature fish in a population (DeVries and Frie 1996). The average size and size variation at different ages over several years can be used to determine growth patterns of a fish population over time or compare it with other populations. Changes in these measurements can be normal or may reflect unsuitable environmental conditions.

Fishery managers also use length and weight data as another method of assessing population condition. The sizes of individuals in a population also reflect growth rates. Knowing the abundance of certain sizes of fishes is important for evaluating the ability of a recreational fishery to support exploitation (Anderson and Neumann 1996). Harvest of recreational fisheries is often regulated by size limits. If few legal-sized individuals are available for harvest, it may be due to unfavorable conditions, which come in many forms (overharvest, pollution, competition for limited resources, overabundance, and more). If unhealthy conditions persist, fishery managers implement plans to improve the status of a fishery to make it viable for harvest. Without age and growth information, fishery managers would have difficulty in determining the status of sport fish populations.

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Chapter 2. Winter Habitat Use by Fishes in a Large River

Abstract

Winter is a critical period during which fishes suffer increased mortality. In order to identify the abiotic conditions large river fish communities use during winter, we electrofished six habitat types in the Belleville Pool, Ohio River. We collected the greatest diversity and abundance of fishes in low-velocity tributary confluences. When water temperatures were < 4 °C, certain species were collected in greater abundance in faster-velocity main channel and back channel habitats. The lack of temperatures > 4 °C may have left fishes susceptible to current velocity, carrying them out of tributaries into channel habitats. Not all species responded to decreasing water temperatures in the same manner. CCA (canonical correspondence analysis) results showed some species continued to associate with low-velocity tributaries at low temperatures. Species-specific responses to winter conditions may obscure broad generalizations about when and how riverine fishes use overwintering refuges. We recommend that protection and enhancement of tributary habitats can increase the probability of survival of fishes in large rivers during winter.

Introduction

Physiochemical tolerances of fishes influence range distributions and habitat use. In temperate climates, fishes shift habitats in response to seasonal variations in physiochemical factors. During winter conditions, fishes select refuge habitats where physiochemical factors are unlikely to exceed tolerance limits. In large temperate river systems, extremely low water temperatures during winter coupled with high flows increase mortality rates of fishes (Bodensteiner and Lewis 1992; Lyons 1997). Low levels of dissolved oxygen also increase mortality of fishes, and occur typically during ice-cover of backwater areas (Bodensteiner and Lewis 1992; Knights et al. 1995; Johnson et al. 1998).

Many fishes forage infrequently during cold winter extremes, and select refuges that minimize energy depletion (Crawshaw 1984; Carlson 1992). Fishes often increase fat-reserves before winter; hence, reducing mortality associated with energy depletion (Fullerton et al. 2000). However, energy reserves may not suffice given long winters or energy expenditures due to disturbance, such as variation in river flows or boat traffic (Nielsen et al. 1986).

During winter, riverine fishes select habitats with relatively high temperatures and low flows that offer velocity shelters (Logsdon 1993; Bodensteiner and Lewis 1994; Johnson et al. 1998). These conditions have been found in areas other than mainstem river sections, such as off-channel coves, marinas, embayments and industrial warm-water outflows (Sheehan et al. 1994; Gent et al. 1995: Knights et al. 1995; Raibley et al. 1997). Also, backwater areas with relatively warmer temperatures and lower flows provide winter refuge habitats (Bodensteiner and Lewis 1992; Raibley et al. 1997; Sheehan and Rasmussen 1999).

Sheehan et al. (1990) examined temperature and flow requirements in the laboratory for several fishes common in the Ohio River, such as gizzard shad, *Dorosoma cepedianum*, channel catfish, *Ictalurus punctatus*, and freshwater drum, *Aplodinotus grunniens*. These three fishes occupy relatively low velocity areas during winter (Heese and Newcomb 1982; Newcomb 1989; Sheehan et al. 1990; Logsdon 1993; Bodensteiner and Lewis 1994). Gizzard shad are vulnerable to winter die-offs during low water temperatures (Miller 1960). Sheehan et al. (1990) also reported temperature preferences of > 4 °C for many species in large rivers, such as green sunfish, *Lepomis cyanellus*, bluegill, *Lepomis macrochirus*, and freshwater drum. Some species, such as channel catfish, black crappie, *Pomoxis nigromaculatus*, and walleye, *Stizostedion vitreum*, can maintain swimming abilities at temperatures < 4 °C (Sheehan et al. 1990). However, temperature, flow preferences, and swimming abilities during low temperatures are unknown for most riverine fishes.

To quantify winter habitats of fishes in large rivers, we sampled the Belleville Pool of the Ohio River during the winter months of 2002 and 2003. Previous research is primarily limited to *in vitro* analysis of simulated winter abiotic conditions preferred by large river fishes. Our goal was to analyze *in situ* winter habitat use by fishes in large rivers. Thus, our main objective was to determine abiotic habitat characteristics associated with fish habitat use. We attempted to do this by examining species/habitat associations among main channel, tributary mouth, back channel, head of island, tail of island, and deep hole habitats during winter. Through an understanding of overwintering areas, we hope to provide resource managers with knowledge needed to reduce winter mortality of fishes by protecting and enhancing important habitats.

Methods

Study site

The Belleville Pool of the Ohio River, created by Belleville Lock and Dam (rkm 328.1), extends upstream to Willow Island Lock and Dam (rkm 260.2). The 67.9 km pool averages 404.5 m wide, 7.3 m deep, and comprises 2850 ha of surface area

(ORSANCO 1994). The deepest section of the pool (15 m) lies directly upstream of Belleville Lock and Dam. A navigation channel (3.7 m deep) is maintained for commercial barge traffic by the United States Army Corps of Engineers (USACE) (ORSANCO 1994). Two other large rivers, the Muskingum River in Ohio, and the Little Kanawha River in West Virginia are navigable tributaries of the Ohio River within the Belleville Pool. The riparian zone is a mixture of hardwood forests, urban and industrial frameworks, and agricultural settings. Most large floodplains near Belleville Pool are heavily urbanized. The two largest population centers along Belleville Pool are Parkersburg, WV (confluence of the Little Kanawha and Ohio rivers) and Marietta, OH (junction of Muskingum and Ohio rivers).

Habitat classification

For the purpose of defining habitat use by overwintering fishes, we classified six habitat types in the Belleville Pool: main channel, deep hole, back channel, island head, island tail, and tributary confluence (see Vallazza et al. 1994, Cray 1999). Main channel habitats are used as commercial navigation routes, and typically have shallow near-shore areas and deeper mid-channel sections. Deep hole habitats (> 8 m in depth) result from dredging or natural scour within main channel or back channel areas. Back channel, island head, and island tail habitats are associated with islands. Back channel habitats are not typically used for commercial navigation and occur between an island and the mainland. The waters immediately adjacent to the upstream and downstream ends of each island are island head and island tail habitats, respectively. Tributary habitats are located, specifically, where the joining waters form a confluence with the mainstem of the Ohio River.

Habitat selection

To evaluate winter habitat selection by fishes within the Ohio River, we sampled six sites in six habitat categories on six different occasions. Main channel and tributary sites were selected in a constrained random fashion according to their relative abundance in the upper and lower half of the Belleville Pool. We chose six of the seven island habitats located in the Belleville Pool. Island size (measured in length) differed among Blennerhasset (6.4 km), Halfway (1.6 km), Newberry (0.4 km), Marietta (4.8 km), Muskingum (3.2 km), and Neal (2.4 km) Islands, but sample areas within back channel, head, and tail habitats were similar among islands. Depths of main channel and back channel sites ranged from 3 to 8 m, and included near-shore and mid-channel transects. Tributary habitats were 2 to 9 m deep, and included near-shore areas and deeper scour holes. Depths of deep hole habitats ranged from 8 to 14 m, and those of island head and tail habitats ranged from 2 to 6 m.

Data collection

We sampled fish at the habitat sites during six periods (February 16 – 22, 2002, March 9 - 25, 2002, April 4 - 7, 2002, December 12 - 17, 2002, January 10 -19, 2003, and March 1 -17, 2003). At each site, we sampled fishes with a variable-depth AC electrofishing boat for water depths of 2-15 meters (Grunwald 1983, Newcomb 1989). Three weighted electrodes (2 m sections of 1.25 inch diameter corrugated conduit) were lowered to near the river bottom over a boom connected to the bow. The desired output of the Honda 5 kilowatt 3-phase AC generator, monitored by clip-on gauges, was above 7 Irms, and typically 9-10 Irms while collecting fish. One, two, or three transects were electrofished, (depending on the amount of available habitat at a site), in the downstream direction of the river current lasting up to 10-minutes (peddle time) for each transect. During peddle time, the boat (with bow upstream) drifted with the river current. This maintained electrodes near the river bottom, but caused longer transects during higher flows. In habitats with a wide range of depths such as back and main channel habitats, the three transects represented shallow and intermediate depths near each shore and deep areas in mid-channel. Peddle time and number of transects varied with habitat availability at each site. During and after peddle time, fishes were netted from a chase boat or the electrofishing boat. Collected fishes were identified to species, counted, measured (nearest mm total length, TL), and weighed. Large fishes (over 1 kg) were weighed to the nearest 25 g with a Pesola spring scale (5 kg maximum). Smaller fishes (less than 1 kg) were weighed to the nearest 1g with a Homs spring dial scale (1 kg maximum).

Abiotic conditions were measured at each site to further characterize habitat types. After electrofishing at a site, we measured specific conductivity, dissolved oxygen (DO), pH, and temperature at 1-m depth intervals (YSI 6820 meter or Hydrolab Surveyor 4), and estimated surface flow velocity (Marsh-McBirney Flowmate). We estimated turbidity near surface (secchi disk), and at 1 m depth intervals (YSI 6820 meter) during the second winter sampling (December 2002 to March 2003). We used Tidbit temperature loggers to record water temperature at three back channel and three main channel sites at depths between 1 and 2 m during both winter samples.

Statistical analyses

To characterize the six habitat categories, the abiotic variables were averaged by site and sample period. First, the profile values for each abiotic variable, from surface to near bottom were averaged as a single value for each site (except flow and secchi, which were single values). Second, the six site average values for each abiotic variable were averaged as a single value for each habitat type for each of the six periods (e.g., all average temperature values from tributary sites during December 12-17, 2002 were averaged as a single value). Third, the abiotic values from the three sample periods were averaged as a single value for each habitat category for both of the winter samples (February – April, 2002 and December, 2002 – March, 2003). Finally, standard deviations of the averaged abiotic variables were also calculated.

To determine which habitats particular species of fish used at critical low temperatures, we first calculated the proportion of the total catch for each species collected at average temperature values > 4 °C, 3 < 4 °C, and < 3 °C in each habitat category. These temperature values stem from the laboratory findings of Sheehan et al. (1990) suggesting < 4 °C is the critical water temperature when many riverine fishes lose their swimming ability and are unable to maintain their position in the water column. Second, we calculated the percentage of the total catch at each temperature range for the five most numerous fishes at each temperature range separately. All other less numerous fishes were calculated as a single group. Lastly, we counted the number of species collected in each habitat category.

We used canonical correspondence analysis (CCA) to explore relationships between species and abiotic variables. Canonical correspondence analysis, a constrained ordination approach, allowed concurrent analysis of species abundance, site, and environmental (abiotic) data (ter Braak 1995). A square root transformation of abundance data minimized affects of a few high abundance values (McGarigal et al. 2000). We conducted CCAs with data from each winter sample separately using an Excel macro (Eric Smith, Virginia Polytechnic Institute and State University). A significant high water event during March 2003 (see Figure 2b) interrupted our data collection and forced us to finish over a much greater length of time than the previous two sample periods. For this reason, the CCA for the second winter sample only represents data collected from December 12, 2002 through January 19, 2003.

Results

Tributary habitats represented important overwintering habitats for large river fishes. Tributary habitats consistently had the lowest average flow velocity (mode of 0.1 m/s) during all sample periods (Table 1). Low flow velocities likely contributed to the relatively high numbers of fishes caught at tributaries. Fifty-eight percent of the total individuals collected during both winter samples were from tributaries. More individuals were collected in tributaries during the warmer first winter sample (87 % of the total individuals from this sample) than the colder second winter sample (Table 1). Thirty-nine percent of the total individuals from the second winter sample were collected in tributaries.

Species presence and abundance in both back and main channel habitats increased during colder water temperatures. Forty-three percent and 14% of all individuals were collected in main channel and back channel habitats, respectively, during the colder winter sample. When sites had an average temperature > 4 °C, more individuals were collected in tributaries (66 %) than main and back channel sites (30 %) (Figure 1a). At temperatures between 3 and 4 °C, more individuals were still collected at tributaries, but at a reduced proportion compared to main and back channel sites at temperatures > 4 °C (Figure 1b). A shift to a greater proportion of individuals occupying main and back channel sites occurred when water temperatures at all habitat types were < 3 °C (Figure 1c). Sixty-six percent of the individuals were collected at main channel sites, while 31 % were collected at tributary sites at water temperatures < 3 °C.

Freshwater drum was the most abundant species captured, representing 48 % of the total catch from both winter samples. During the warmer first winter, 90% of the freshwater drum individuals were collected from tributaries. Freshwater drum dominated the pattern of shifting from tributary to main channel habitats when water temperatures at all habitat types were < 3 °C (Figure 1). During the colder sample, 37% of the freshwater drum individuals were collected from tributaries, while 50% were collected in main channel sites. Other less numerous species followed a similar pattern.

Channel catfish, the second most abundant species, represented 21% of the total catch from both winter samples. Sixty-three percent of the channel catfish individuals were collected from tributary habitats during the warmer sample. Channel catfish followed a similar yet more pronounced pattern as freshwater drum by shifting to main and back channel habitats when water temperatures at all habitat types were < 4 °C (Figure 1). Fifty-three percent of the channel catfish individuals were collected in tributaries and 43 % in main and back channel habitats at temperatures > 4 °C. At temperatures between 3 and 4 °C, 84 % of the channel catfish individuals were collected in main and back channel habitats. Likewise, 83 % of all channel catfish individuals were collected in main and back channel sites when temperatures were < 3 °C.

Tributary habitats also had the highest species diversity of all habitat types. A total of 19 species were collected in tributaries, while totals of 14 and 11 species were collected in main channel and back channel habitats, respectively (Figure 3). Even during January 10 –19, 2003, the coldest sampling period (average water temperatures ranged between 2.1 and 3.0 °C; Table 1), tributaries still contained the highest species diversity (N=13). However, most of the species collected in January 2003 were from one site, Bull Creek.

High abundance and species diversity occurred in Bull Creek (a tributary habitat) during both winter samples. During the second winter sample, 75 % of the fish captured in tributaries and 30 % of the total catch from all habitat types were from Bull Creek. Bull Creek had the single greatest total catch of fishes at one site (134 individuals on January 11, 2003) when the water temperature was 3.2 °C (Figure 5 shows a captured sonar image of this event). Interestingly, immediately downstream from Bull Creek, the largest single catch of fishes at a main channel site occurred on the same day.

The CCA results indicate which abiotic conditions correspond with individual species habitat use. The large difference between mean abiotic conditions of the two winter samples, (February 7, 2002 – April 7, 2002 had warmer water temperatures than December 12, 2002 – March 17, 2003; Figure 2 and Table 1), offered a chance to explore individual species differences in habitat use during winter. Because one fish species (freshwater drum) dominated our collections, these exploratory results allowed us to see if other species followed similar patterns of winter habitat use as freshwater drum.

Freshwater drum (# 23 in Figure 4a) corresponded with decreasing flow values and tributary sites during the warmer winter sample. Channel catfish (# 13 in Figure 4a) were weakly linked to increasing water temperatures and the sites that contained them (4 main channel sites and 1 tributary site, Duck Creek on March 24, 2002, when 50 of the 100 fishes collected were channel catfish) during the warmer sample. Only channel catfish weakly correlated with water temperatures during the warmer period, probably due to increased average water temperatures across all habitat types during this time period (Table 1). During the first winter sample, gizzard shad (# 2 in Figure 4a) closely associated with increased conductivity values of some tributary sites. The other species collected during the first sample period corresponded with relatively lower flows and slightly increasing depths. Most of these fishes (9 of the 13 species), however, were collected in negligible abundance from two tributary sites, Bull and Duck Creeks.

Contrary to the warmer sampling period, freshwater drum (# 23 in Figure 4b) corresponded equally (but to a slightly lesser intensity) with channel catfish (# 13 in Figure 4b) to increasing flow velocity, water temperature, and conductivity during the colder sampling period. Mooneye, *Hiodon tergisus*, (#3 in Figure 4b) also closely coincided with increasing values of these same abiotic variables. Main and back channel sites were associated with increasing flow velocity, temperature and conductivity axes. Fourteen of the 20 species were correlated with decreasing values of these three major axes and were associated with tributary sites.

Discussion

Low-velocity tributary habitats contained the highest abundances and diversity of fishes during February 2002 - March 2003 sample sessions. Although other unmeasured variables may explain fish use of tributary habitats during winter, we believe that low velocity is an important abiotic regulator of winter habitat use. Supporting this conclusion, largemouth bass, *Micropterus salmoides,* in the Hudson River (Carlson 1992), and river carpsucker, *Carpiodes carpio,* and sauger, *Stizostedion canadense*, in the Missouri River (Braaten and Guy 1999) also used tributary confluences during winter. We do not believe that electrofishing sampling efficiency was higher in tributary habitats because ambient conductivities (Reynolds 1996) were similar in all habitats during both years (ranged from 182 – 303 uS/cm) and were close to the standard conductivity of a fish (115 uS/cm) (Miranda and Dolan 2003).

River current velocities may overcome fishes' swimming ability to hold their position in preferred habitats such as tributaries as water temperatures decline below 4 °C. During our coldest sample periods (water temperatures < 4 °C), the catch of several species increased in back channel or main channel habitats, including channel catfish, and freshwater drum (Figure 1). We did not have high catches of fish in back and main channel habitats, except when average water temperatures in low-velocity tributary habitats were < 3 °C. On January 11, 2003, all tributary habitats were < 3 °C, except for Bull Creek (3.2 °C) when the single highest total catch of fishes occurred (Figure 5). It is possible that previous to this sampling date, the high flow conditions and declining water temperatures (Figure 2b) forced fishes to occupy relatively lower-velocity tributary sites like Bull Creek. On January 11, 2003, the declining temperatures may have limited fishes' swimming ability. The minimum amount of flow that existed in Bull Creek on that day may have swept fishes downstream into an eddy current along the main channel shoreline immediately below the mouth of Bull Creek, where they were collected. In the upper Mississippi River, Bodensteiner and Lewis (1994) documented increased flow velocity coupled with near-freezing water temperature caused freshwater drum to lose equilibrium and become incapacitated, resulting in large numbers of individuals floating downstream with the current.

The lack of sufficiently warmer temperatures may force fishes to occupy main and back channel habitats. Average water temperatures in channel habitats were higher than tributaries during January 2003, yet still below the critical 4 °C (Table 1). Sheehan et al. (1990) reported riverine fishes in laboratory conditions preferred water temperatures > 4 °C. If water temperatures > 4 °C are unavailable, current velocities may overwhelm fishes' swimming ability, sending them downstream where they collect in channel borders. However, the ability to withstand critically low water temperatures may vary between species.

Species-specific responses to winter conditions result in differential habitat use. Physiochemical tolerances vary among fish species (Sheehan et al. 1990), which was evident between our two most abundant species. For example, channel catfish occupied warmer and deeper habitats, while freshwater drum occupied shallower habitats with lower flow velocities during February 16 through April 7, 2002 (Figure 4a). During this time period, freshwater drum appeared less tolerant of higher flow velocities, but used shallower habitats than channel catfish. However, during the coldest months of 2003, freshwater drum occupied warmer and deeper habitats with higher flow velocities, similar to channel catfish (Figure 4b), suggesting a mutual tolerance of physiochemical factors during severe winter conditions. Conversely, other species continued to associate with lower temperatures at low-velocity tributaries (Figure 4b).

Our study was conditional on six habitats, but other overwintering habitats occur in Belleville Pool. We also sampled and found high diversity and abundance of fishes in an embayment, downstream of a wing dam, and within an industrial warm-water outflow, but these habitats (uncommon within Belleville Pool) were not part of our study design. Off-channel coves, marinas, embayments and industrial warm-water outflows have been shown to be valuable overwintering refuges for fishes (Sheehan et al. 1994; Gent et al. 1995; Knights et al. 1995; Raibley et al. 1997). Additional studies of alternative habitats, such as embayments, warm-water outflows, artificial structures, and tailwaters, are needed to further address fish-habitat relationships in large rivers.

In conclusion, our data support tributary confluences as important overwintering sites for fishes in the Belleville Pool, Ohio River. Some fishes, however, shift to main and back channel habitats when temperatures are < 3 °C. If altered or unprotected, the loss of overwintering habitats at tributary mouths could contribute to increased mortality of fishes during winter. Additionally, tributary mouths are susceptible to disturbance from boat and barge traffic, and fishes using these habitats during winter could be displaced. Nielsen (1986) and Sheehan and Rasmussen (1999) suggested detrimental effects of commercial boat traffic on fishes in large rivers. Passage of boats during winter causes turbulence, possibly forcing fish from their overwintering position. Those fishes forced into less suitable conditions may suffer increased mortality. Protecting tributary confluences from further degradation by commercial boat traffic, pollution, sedimentation, and channelization, among others, may increase the probability of survival of fishes in large rivers.

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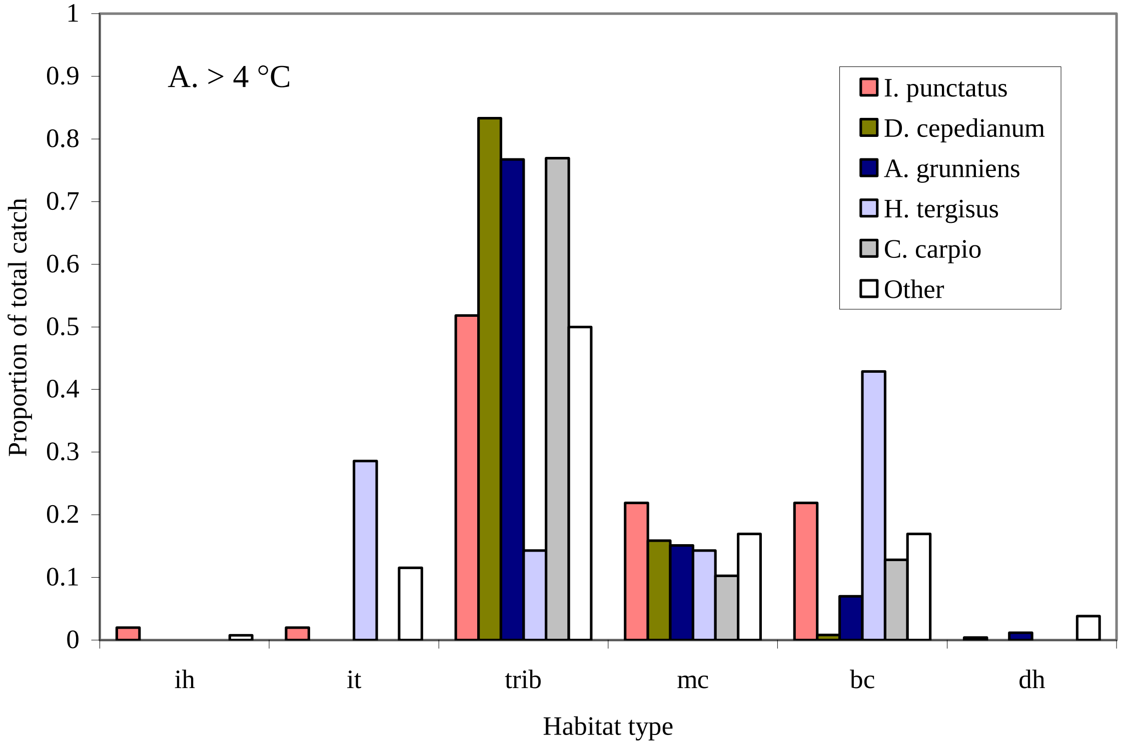
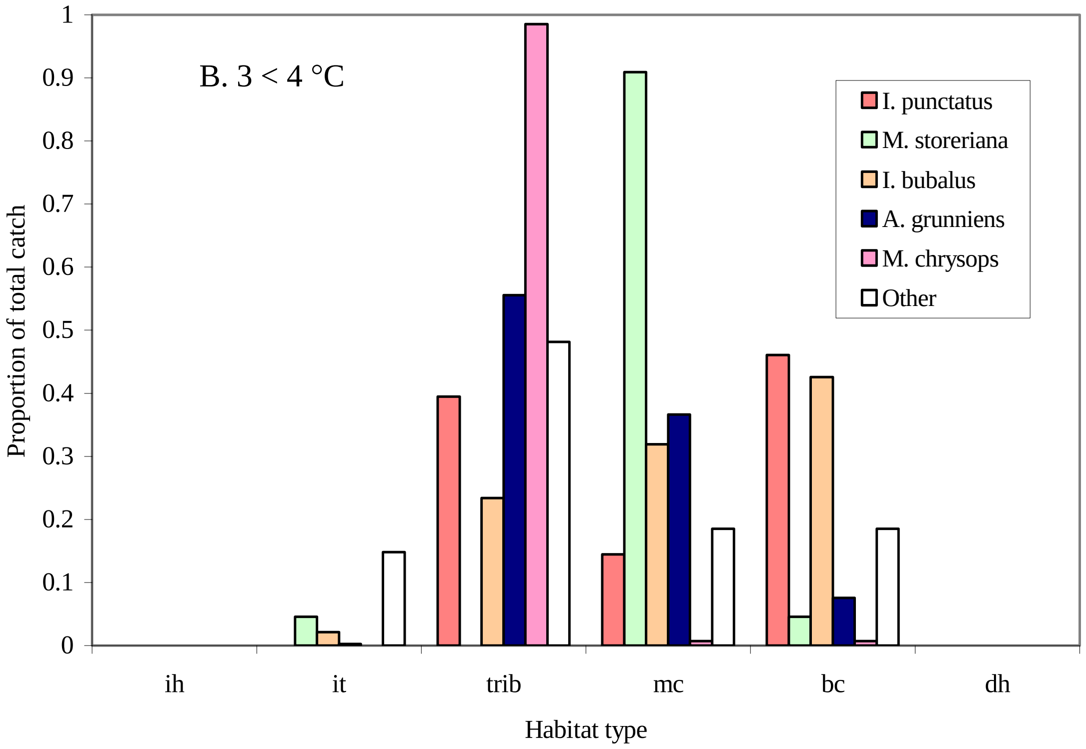
Figure 1. The proportion of the total catch of each species among habitat categories. Data are separated by water temperatures > 4 ˚C (A), 3 < 4 ˚C (B), and < 3 ˚C (C) within the Belleville Pool, Ohio River, during February 17 through April 7, 2002 and December 12, 2002 through March 17, 2003. Sites are abbreviated as bc (back channel), dh (deep hole), ih (island head), it (island tail), mc (main channel), and tr (tributary). Fish species are abbreviated as *D. cepedianum* (gizzard shad), *H. tergisus* (mooneye), *M. storeriana* (silver chub), *C. carpio* (river carpsucker), *I. bubalus* (smallmouth buffalo), *I. punctatus* (channel catfish), *M. chrysops* (white bass), *M. saxatilis x chrysops* (hybrid striped bass), and *A. grunniens* (freshwater drum).




B. 3 < 4 °C
Proportion of total catch
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
ih
it
trib
mc
bc
dh
Habitat type
I. punctatus
M. storeriana
I. bubalus
A. grunniens
M. chrysops
Other

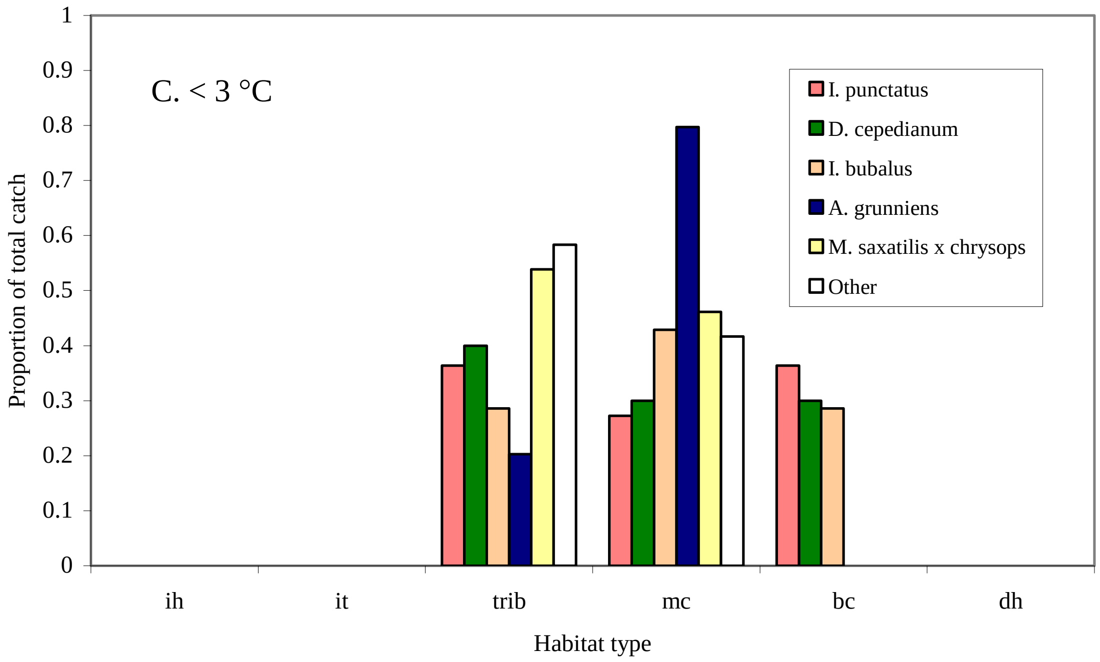
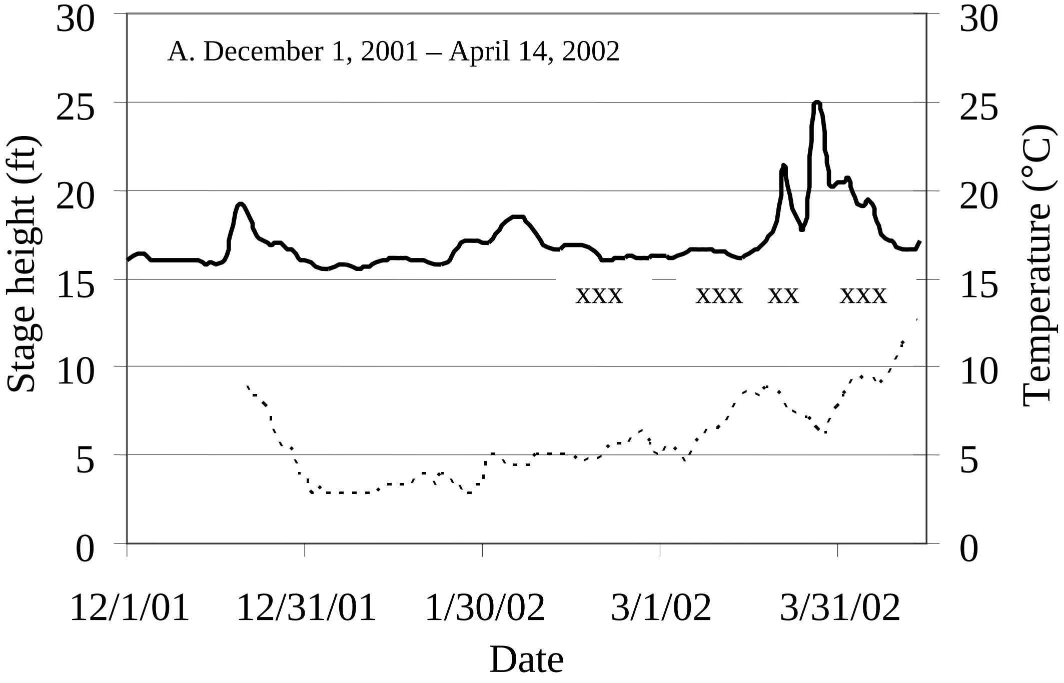

C. < 3 °C
Proportion of total catch
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
ih
it
trib
mc
bc
dh
Habitat type
I. punctatus
D. cepedianum
I. bubalus
A. grunniens
M. saxatilis x chrysops
Other

Figure 2. Water temperature (broken line), stage height (solid line), and sampling session dates (x) in Belleville Pool, Ohio River, during December 1, 2001 through April 14, 2002 (A) and December 1, 2002 through April 14, 2003 (B).



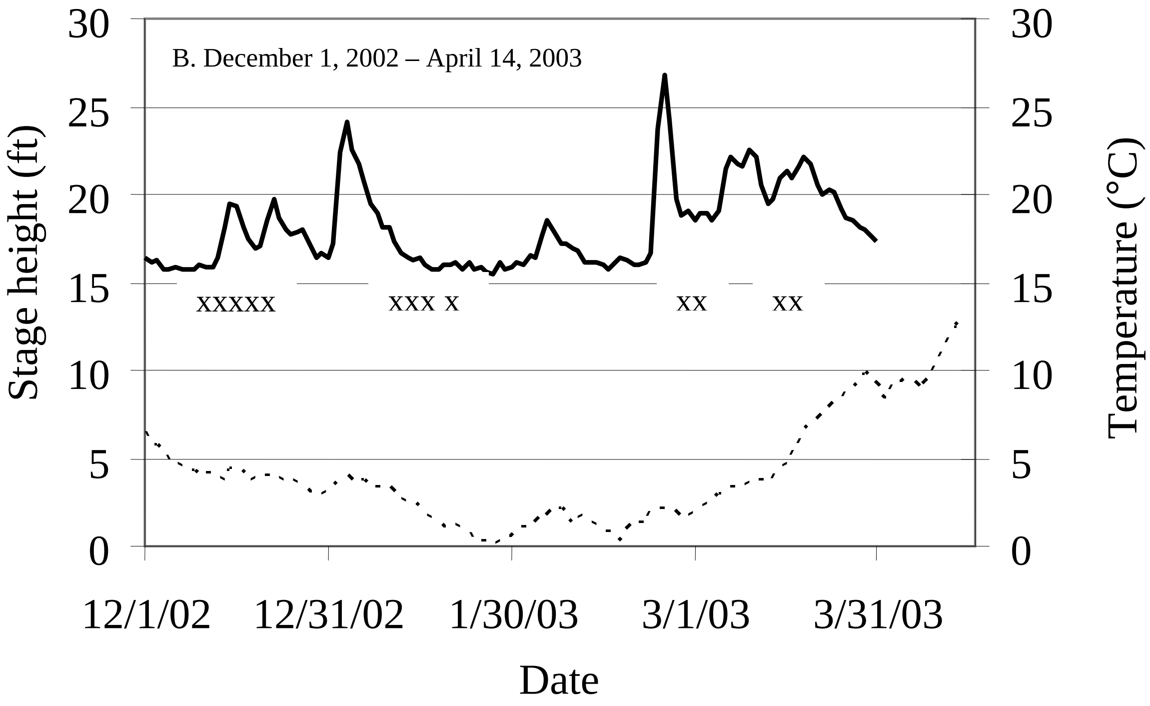

B. December 1, 2002 – April 14, 2003
Stage height (ft)
Temperature (°C)
30
25
20
15
10
5
0
xxxxx
xxx x
xx
xx
12/1/02
12/31/02
1/30/03
3/1/03
3/31/03
Date

Figure 3. The number of species in each habitat category collected in the Belleville Pool during December 1, 2001 through April 14, 2002 and December 1, 2002 through April 14, 2003. Sites are abbreviated as ih (island head), it (island tail), trib (tributary), mc (main channel), bc (back channel), and dh (deep hole).

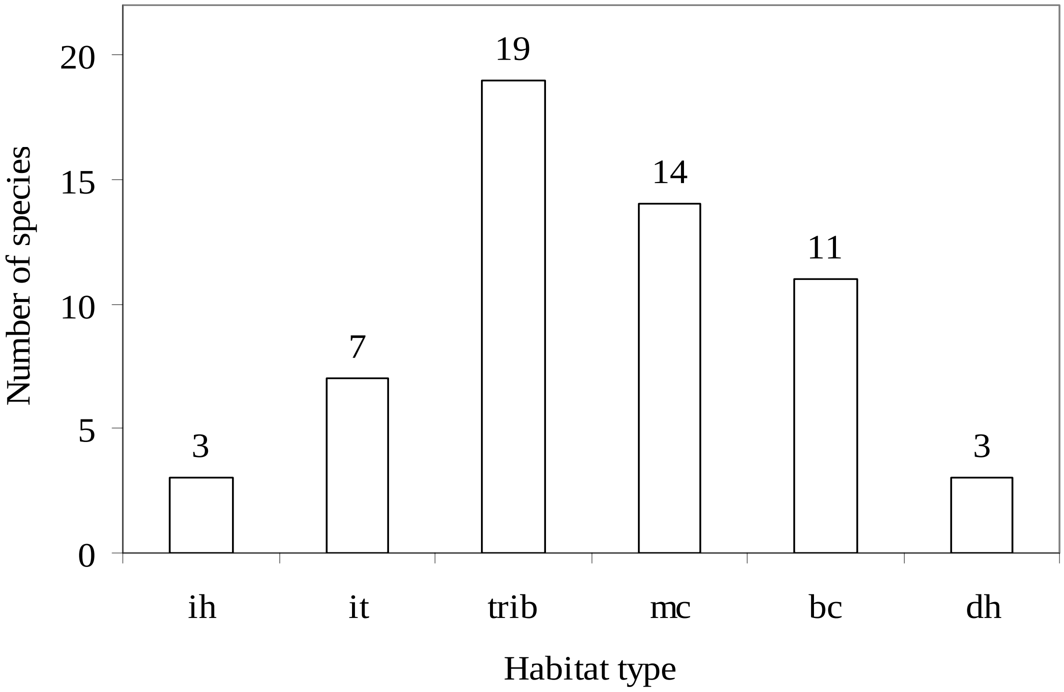
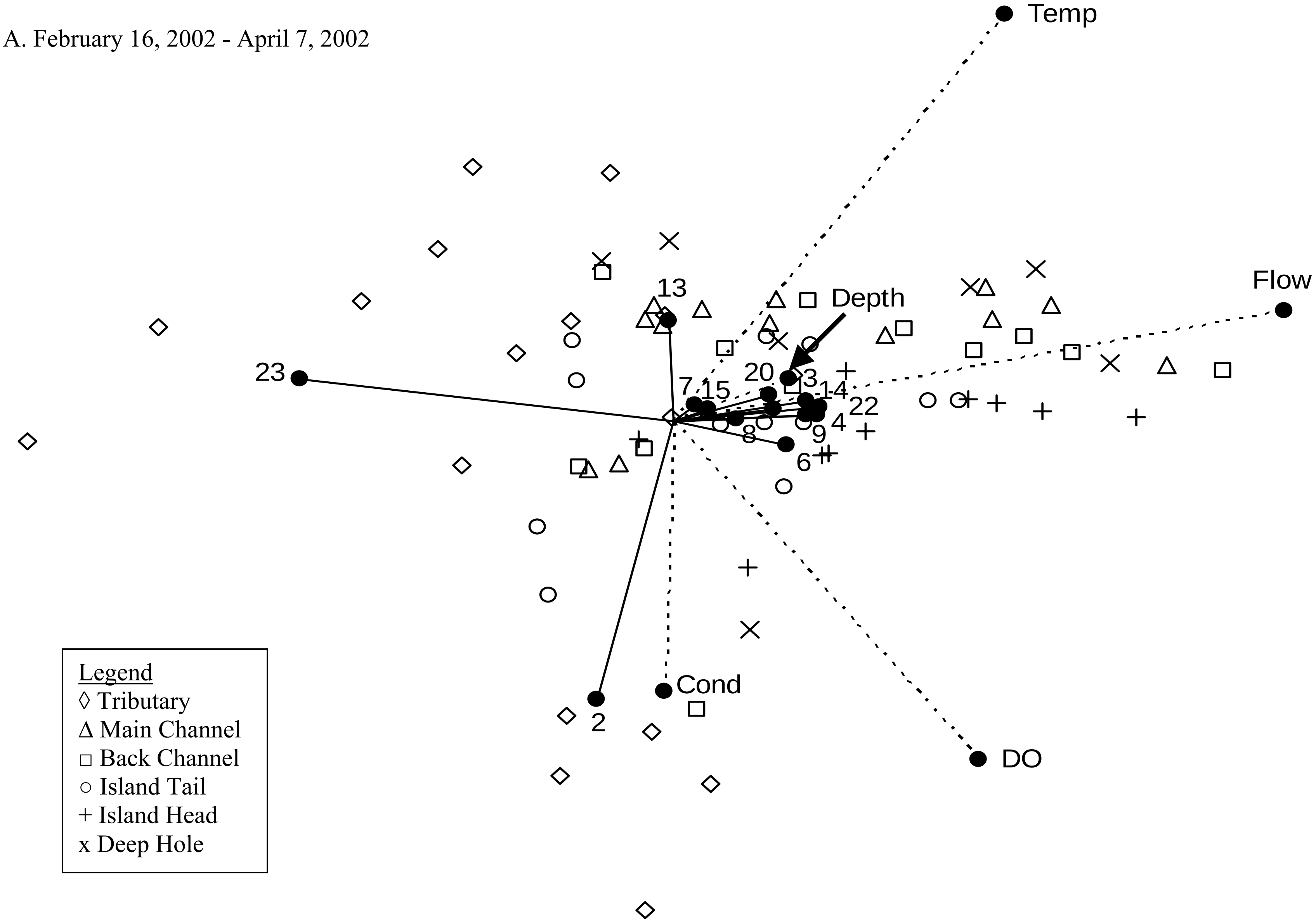


Figure 4. Triplot from canonical correspondence analysis (CCA) of species abundance, sites, and abiotic variables from February 16, 2002 through April 7, 2002 (A) and December 12, 2002 through January 19, 2003 (B) in the Belleville Pool, Ohio River. Sites are symbolized as ◊ (tributary), + (island head), ○ (island tail), □ (back channel), Δ (main channel), and x (deep hole). Abiotic variables are depth, specific conductivity (Cond), temperature (Temp), turbidity (Turb), and water velocity (Flow). Species are numbered as 1) *I. bdellium*, 2) *D. cepedianum*, 3) *H. tergisus*, 4) *Cyprinus carpio*, 5) *M. storeriana*, 6) *N. atherinoides*, 7) *Carpiodes carpio*, 8) *C. cyprinus*, 9) *C. velifer*, 10) *M. erythrurum*, 11) *M. macrolepidotum*, 12) *I. bubalus*, 13) *I. punctatus*, 14) *P. olivaris*, 15) *M. chrysops*, 16) *M. chrysops x saxatilis*, 17) *A. rupestris*, 18) *P. nigromaculatus*, 19) *M. punctatus*, 20) *L. macrochirus*, 21) *S. canadense*, 22) *S. vitreum*, and 23) *A. grunniens*.

A. February 16, 2002 - April 7, 2002



B. December 12, 2002 – January 19, 2003

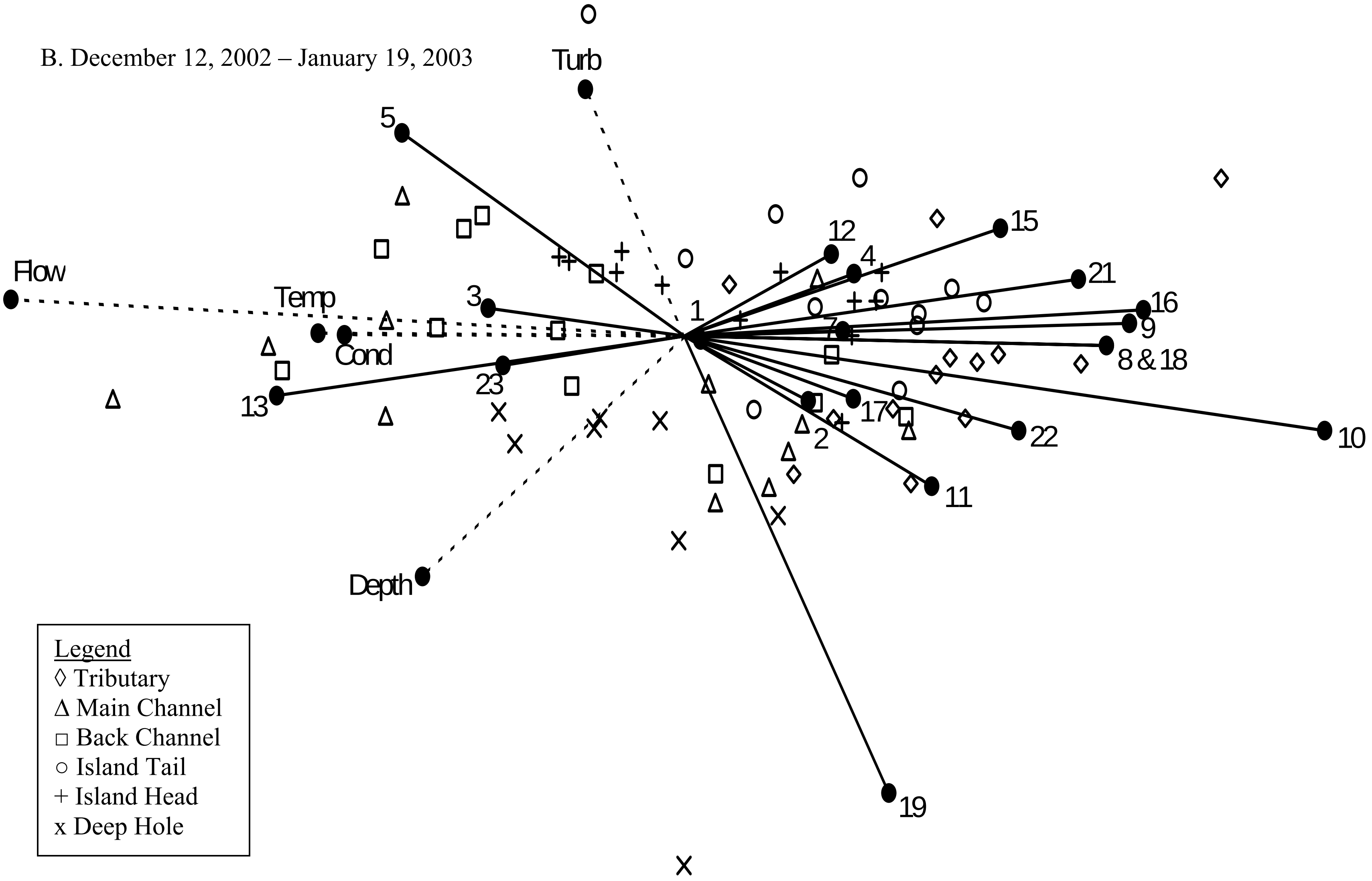


Figure 5. The captured sonar image from Bull Creek on January 11, 2003, when the single highest total catch of fishes occurred. Black streak like blotches are individual fish.

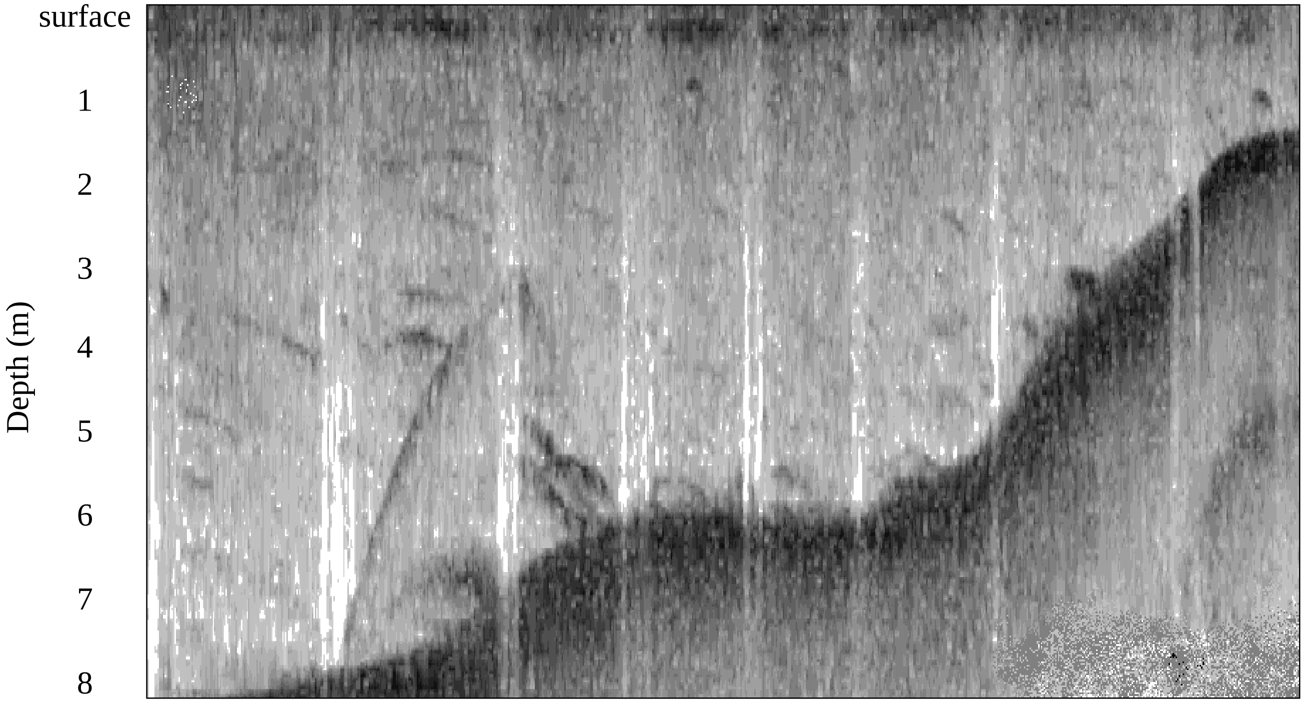


Table 1. Average abiotic conditions of all sites in six habitat types during six different sampling periods between February 16 through April 7, 2002 and December 12, 2002 through March 17, 2003 in the Belleville Pool, Ohio River. Standard deviations are in parentheses. Habitat types and abiotic variables with no values were not sampled during February 16 - 22, 2002 and the deep hole category with no standard deviation values only had one sample site during this period.

	Habitat types					
Date	Island Head	Island Tail	Back channel	Main channel	Tributary	Deep hole
February 16 – 22, 2002						
Temp. (°C)					4.8 (0.35)	5.4 (-)
D. O. (mg/L)					13.3 (0.25)	13.6 (-)
Flow (m/s)					0.1 (0.02)	
Spec. Cond. (uS/cm)					390.1 (87.1)	373.0 (-)
March 9 - 25, 2002						
Temp. (°C)	7.7 (0.54)	7.1 (0.60)	6.9 (1.22)	7.3 (0.07)	6.8 (0.74)	7.3 (0.03)
D. O. (mg/L)	8.3 (0.49)	8.3 (0.53)	8.4 (0.58)	8.5 (0.46)	8.1 (0.49)	8.5 (0.52)
Flow (m/s)	0.5 (0.30)	0.3 (0.20)	0.4 (0.29)	0.4 (0.17)	0.1 (0.13)	0.4 (0.06)
Spec. Cond. (uS/cm)	353.3 (46.7)	354.6 (45.0)	355.6 (40.5)	338.7 (47.1)	316.2 (48.1)	337.9 (53.6)
April 4 - 7, 2002						
Temp. (°C)	9.0 (0.28)	9.0 (0.30)	9.0 (0.37)	8.9 (0.20)	9.4 (0.73)	8.9 (0.09)
D. O. (mg/L)	10.7 (0.67)	10.5 (0.26)	10.5 (0.26)	10.8 (0.85)	9.5 (1.64)	11.0 (1.12)
Flow (m/s)	0.6 (0.24)	0.4 (0.22)	0.7 (0.23)	0.7 (0.24)	0.2 (0.22)	1.0 (0.15)
Spec. Cond. (uS/cm)	265.9 (47.4)	267.0 (46.5)	267.4 (50.7)	261.9 (38.2)	282.2 (103.7)	250.9 (7.00)
February 16 – April 7, 2002						
Temp. (°C)	8.4 (0.80)	8.1 (1.07)	6.9 (1.39)	8.3 (0.84)	7.5 (2.25)	7.7 (1.31)
D. O. (mg/L)	9.6 (1.38)	9.5 (1.19)	9.4 (1.13)	9.9 (1.37)	10.0 (2.24)	10.3 (2.06)
Flow (m/s)	0.6 (0.27)	0.4 (0.21)	0.5 (0.30)	0.6 (0.28)	0.1 (0.17)	0.7 (0.35)
Spec. Cond. (uS/cm)	306.2 (64.0)	307.4 (63.2)	311.5 (63.8)	292.6 (56.1)	319.3 (92.0)	305.6 (61.2)

Table 1. continued.

Date	Habitat types					
	Island Head	Island Tail	Back channel	Main channel	Tributary	Deep hole
December 12 - 17, 2002						
Temp. (°C)	4.0 (0.55)	4.2 (0.56)	4.1 (0.52)	4.0 (0.47)	4.1 (0.74)	4.2 (0.42)
D. O. (mg/L)	7.3 (0.14)	8.5 (1.09)	7.9 (0.67)	7.2 (0.11)	7.1 (0.58)	8.4 (0.00)
Flow (m/s)	0.6 (0.29)	0.2 (0.10)	0.7 (0.21)	0.5 (0.26)	0.1 (0.13)	0.5 (0.15)
Spec. Cond. (uS/cm)	424.5 (80.6)	434.2 (76.3)	423.5 (91.7)	460.3 (60.5)	336.5 (95.3)	405.3 (61.0)
January 10 -19, 2003						
Temp. (°C)	2.3 (1.10)	2.7 (1.07)	2.5 (1.29)	2.5 (0.97)	2.1 (1.05)	3.0 (0.73)
D. O. (mg/L)	13.4 (0.17)	13.3 (0.60)	13.4 (0.23)	13.4 (0.67)	13.7 (0.33)	13.5 (0.49)
Flow (m/s)	0.4 (0.20)	0.1 (0.08)	0.4 (0.25)	0.4 (0.28)	0.1 (0.08)	0.6 (0.23)
Spec. Cond. (uS/cm)	443.0 (41.0)	434.2 (41.5)	446.8 (51.0)	428.4 (32.6)	417.9 (54.0)	404.6 (13.2)
March 1 -17, 2003						
Temp. (°C)	4.1 (1.47)	4.1 (1.44)	4.1 (1.39)	3.8 (1.31)	4.1 (1.96)	2.7 (1.03)
D. O. (mg/L)	13.2 (0.35)	13.0 (0.35)	13.0 (0.37)	12.4 (1.04)	11.8 (0.56)	12.9 (0.29)
Flow (m/s)	0.8 (0.24)	0.4 (0.15)	0.7 (0.14)	0.6 (0.43)	0.1 (0.13)	0.6 (0.21)
Spec. Cond. (uS/cm)	448.6 (69.7)	445.1 (69.4)	439.9 (73.0)	435.4 (66.6)	353.9 (97.7)	383.4 (56.4)
December 12, 2002 - March 17, 2003						
Temp. (°C)	3.1 (1.34)	3.4 (1.23)	3.3 (1.34)	3.3 (1.14)	3.1 (1.59)	3.6 (0.98)
D. O. (mg/L)	10.4 (2.19)	10.9 (2.03)	10.7 (2.00)	10.3 (2.24)	10.4 (2.69)	11.7 (2.19)
Flow (m/s)	0.5 (0.30)	0.2 (0.16)	0.5 (0.25)	0.5 (0.33)	0.1 (0.11)	0.6 (0.19)
Spec. Cond. (uS/cm)	433.8 (62.8)	434.2 (60.5)	435.7 (70.0)	444.4 (53.8)	377.2 (86.6)	415.0 (46.8)

Chapter 3. Juvenile Use of a Large River Embayment during Winter

Abstract

The severity of winter conditions regulates juvenile fish mortality rates. Identifying habitats used by juveniles is essential for understanding where fishes survive during winter. Shallow, low-gradient, off-channel embayments, like Little Sandy Creek adjacent to the Ohio River, are ideal refuges for overwintering juvenile species. Eighty-five percent of all fishes collected in Little Sandy Creek embayment during this study were juveniles. Many of the fishes collected were juvenile sunfish (Centrarchidae). Bluegill, *Lepomis macrochirus*, and white crappie, *Pomoxis annularis*, were the dominant sunfishes collected. Protecting and modifying embayment habitats may reduce juvenile mortality during winter and improve recreational angling opportunities for sunfish in large river systems.

Introduction

Winter, a critical period for juvenile riverine fishes in temperate climates, reduces probabilities of survival (Bodensteiner and Lewis 1992; Lyons 1997) and recruitment (Oliver et al. 1979; Toneys and Coble 1979; Miranda and Hubbard 1994). Fishes enter a torpor-like state during low winter temperatures (Crawshaw 1984) where metabolic rates and consequently, respiration and activity rates are low (Bodensteiner and Lewis 1992; Carlson 1992; Cunjak 1996). Fishes increase fat-reserves before winter; hence, reducing mortality associated with energy depletion (Post and Evans 1989; Cargnelli and Gross 1996). During torpor, however, juvenile fishes are susceptible to predation (Garvey et al. 1998) and adverse physiochemical conditions, such as low dissolved oxygen concentrations and strong current velocities (Cunjak 1996). Consequently, optimal winter habitats should provide protection from predators as well as amiable abiotic conditions that minimize energy depletion (Crawshaw 1984).

Riverine fishes overwinter in areas of low flow and relatively warm temperatures (Logsdon 1993; Bodensteiner and Lewis 1994; Johnson et al. 1998), such as off-channel coves, backwaters, marinas, embayments and industrial warm-water outflows (Sheehan et al. 1990; Gent et al. 1995; Knights et al. 1995; Raibley et al. 1997; Sheehan and Rasmussen 1999). Although riverine fishes select thermal refuges and areas of relatively low flow during winter, high winter mortality rates of juvenile fishes have been documented (Bodensteiner and Lewis 1992; Lyons 1997). Rates of juvenile survival influence numbers of individuals recruited into future fisheries (Toneys and Coble 1979; Miranda and Hubbard 1994). Given the link between winter temperature and fish mortality, and the importance of juvenile survival to fishery recruitment, fishery managers need to locate and protect winter refuge habitats of juvenile fishes.

In the Ohio River, channelization and impoundment from lock and dams have homogenized habitats, and reduced low-velocity mainstem habitats. However, embayments, shallow off-channel areas, offer low-velocity habitat for fishes during winter. Embayments contain riverine fishes during winter (Sheehan et al. 1990; Gent et al. 1995; Knights et al. 1995; Raibley et al. 1997), but their importance in the Belleville Pool of the Ohio River was undocumented before this study.

Objectives

Our primary objective was to examine species composition and size classes (juveniles vs. adults) of fishes in Little Sandy Creek embayment, Belleville Pool, Ohio River, West Virginia, during winter 2002-2003. A secondary objective was to quantify age-length relationships of white crappie, *Pomoxis annularis*, a popular sport fish for recreational anglers. This study was part of a larger evaluation of winter habitats used by fishes in main channels, island back channels, island heads and tails, and tributary mouths within Belleville Pool (see Chapter 2).

Study site

Little Sandy Creek drains 26 sq. km and includes a 12.4 ha embayment (39° 13' 57" N, 81° 41'10" W) near its confluence with the Ohio River. The embayment reaches a maximum 2 m channel depth, but is mostly shallow (< 0.5 m) during normal flows. The riparian zone is a mixture of agricultural fields, mixed deciduous forest, and housing developments.

Methods

Data collection

During the winter of 2002-2003, we electrofished (Smith-Root pulsed DC electrofishing boat) Little Sandy Creek embayment on 15 December 2002, and 1 and 17 March 2003. On each sample date, we electrofished two near-shore transects and one mid-channel transect. Transects were sampled for 10 minutes (peddle time). Ice cover prevented sampling during January and February. Fishes were captured, identified to species, measured (nearest mm total length, TL), and weighed. Weights for large fishes (over 1kg) were taken to the nearest 25g with a Pesola spring scale (5 kg maximum). Smaller fishes (less than 1 kg) were weighed to the nearest 1g with a Homs spring dial scale (1kg maximum). After measuring the weights and lengths of 100 individuals of a species collected during a single sample date, the remaining individuals were counted, (except for emerald shiner, *Notropis atherinoides*, due to its extremely small size). When collected, five white crappie individuals from each 50 mm size class were kept during each sample date for age analysis.

To describe the abiotic conditions of Little Sandy Creek embayment, we measured specific conductivity, dissolved oxygen (D. O.), pH, and temperature with an YSI 6820 during each sample date. Additionally, we estimated turbidity (secchi disk, and NTUs with YSI 6820), and flow velocity (Marsh-McBirney Flowmate 2000).

Length-at-maturity and age analysis

To evaluate the importance of Little Sandy Creek embayment to juvenile fishes, we defined juveniles (except white crappie) based on published length-at-maturity data from Trautman (1981), Mittelbach (1984), Etnier and Starnes (1993), Jenkins and Burkhead (1993), and Johnson and Jennings (1998). We defined white crappie individuals as juveniles or adults based on our age estimates.

We examined age structure of white crappie with otoliths. Otoliths were removed from a subset of the white crappie, sectioned with an Isomet 1000 precision saw with a 12.7 cm x 0.4 mm blade, and viewed with a dissecting scope. Two observers estimated age independently, and a third observer resolved discrepancies. In order to simplify the aging process because these fish were collected in winter, we assumed January 1 as the birth date (DeVries and Frie 1996) and assigned ages as if all individuals were collected on or after January 1.

Statistical analysis

We used length-frequency distributions for the five most abundant species and compiled the information from the sources listed above for the least abundant species to establish juvenile length ranges for all species collected in Little Sandy Creek embayment. We calculated the proportion of juveniles of each species by sampling dates. To further classify the age-length distribution of white crappie, the length range, mean length, and variance were calculated for each white crappie age class.

Results

Abiotic conditions

Water temperatures rose from 2.95 to 11.24 °C between 1 and 17 March 2003. During the 15 December 2002 sample, the water temperature was 4.08 °C. Dissolved oxygen ranged from 11.16 to 11.75 mg/L. Specific conductivity (uS/cm) values were 257.3, 257, and 350, and pH values were 6.9, 7.3, and 7.7 during the first, second, and third sample dates, respectively. A null flow velocity measurement (0 m/s) was recorded during all three sample dates. Turbidity (NTU) was lowest during the March 1 sample (55) and highest during the March 17 sample (84). Secchi disk readings corresponded with the turbidity measurements, the highest value recorded during March 1 (39 cm) and the lowest during March 17 (25 cm).

Fish species and abundance

Juveniles represented the majority of the individuals collected in the Little Sandy Creek embayment during winter. Eighty-five percent of all fishes collected were juveniles (Table 2). The five most abundant species, gizzard shad, *Dorosoma cepedianum,* bluegill, *Lepomis macrochirus*, emerald shiner, white crappie, and orangespotted sunfish, *Lepomis humilus*, represented 96% of the total catch (Table 2). Of these five most abundant species, juveniles represented 83% of the total individuals. The length frequency distributions for these five species also show that shorter individuals (juveniles) were more numerous than longer individuals (Figure 6). Nearly all (97% and

94%, respectively) of the gizzard shad and orangespotted sunfish individuals were juveniles (Table 2). Of the 305 centrarchid individuals collected, 81% were juvenile. Interestingly, the proportion of the total individuals represented by juveniles decreased during the March 1 and 17, 2003 sample dates (Table 2).

Seventeen species were collected during the three sampling periods (Table 2). Fish numbers differed among sample periods (717 individuals on 15 December, 52 on 1 March, and 121 on 17 March) (Table 2). The most abundant fish, gizzard shad, was only collected in large abundance during a single sample date, December 15. One each of bowfin, *Amia calva*, mosquitofish, *Gambusia affinis*, and smallmouth buffalo, *Ictiobus bubalus*, were collected during all sample periods, none of which were juveniles. Only one fish, white crappie, was consistently collected in relatively equal numbers and abundance (Table 2).

Five different size classes of white crappie were collected representing age classes one through five (Table 3 and Figure 6d). Eighteen age-one (juvenile) white crappie represented 29% of the aged individuals. Age-two white crappies were most abundant, representing 40% of the aged individuals. Age-three, four, and five white crappies consisted of 14.5%, 8%, and 8%, respectively, of the aged individuals.

Discussion

The Little Sandy Creek embayment, a shallow off-channel, low velocity habitat, provides an important winter refuge for juvenile fishes. The upper Ohio River, with steep topography and a restricted channel, lacks the slow-moving isolated sloughs found in other large river systems in temperate North America. Embayments in the upper Ohio River, however, are similar in abiotic characteristics to other large river backwater habitats that are important overwintering habitats for fishes of all ages (Sheehan et al. 1990; Gent et al. 1995; Knights et al. 1995; Raibley et al. 1997; Sheehan and Rasmussen 1999). Previous to this study, the value of these shallow, low-velocity, off-channel habitats, specifically for overwintering juvenile fishes, was undocumented.

The shallow, low-gradient physical characteristics of embayments make them ideal refuges for overwintering fishes. However, reductions in flow velocities in backwaters and embayments coupled with ice-cover can lead to low D. O. concentrations (Bodensteiner and Lewis 1992; Knights et al. 1995; Johnson et al. 1998). This reduction in D. O. content may either cause mortality in fishes or force them to seek alternative overwintering refuges in other habitat types. We do not know whether or not D. O. levels decreased below sufficient levels for fishes during the ice cover event in January and February 2003, but the measured D. O. concentrations were above critical minimal values before and after ice cover in Little Sandy Creek. Regardless of flow conditions, when temperatures fall below 4 °C, fishes may prefer warmer habitats, if available. In laboratory settings, Sheehan et al. (1990) reported temperature preferences of > 4 °C for many species in large rivers, such as green sunfish, *Lepomis cyanellus*, bluegill, and freshwater drum, *Aplodinotus grunniens*. Our data collected on species residing in the mainstem portions of the Ohio River show that some fishes will select higher-velocity warmer habitats over lower velocity colder habitats during winter (see Chapter 2). Increased mortality of fishes may occur because they cannot survive the low temperatures or dissolved oxygen concentrations in an embayment, forcing them to inhabit suboptimal habitats in the mainstem portions of large rivers. Fishery managers can modify embayments to better suit the abiotic requirements of overwintering fishes to avoid increased mortalities due to these factors.

Given that centrarchids are popular game fishes, recreational fishery managers may want to consider the importance of embayments as overwintering sites for juvenile centrarchids of all ages, (but especially juveniles since they are the most susceptible to winter mortality), and protect these habitats. In our study, eight of the 17 species were comprised primarily juveniles of bluegill, green sunfish, orangespotted sunfish, pumpkinseed, *Lepomis gibbosus*, warmouth, *Lepomis gulosus*, white crappie, black crappie, and largemouth bass, *Micropterus salmoides*. Juvenile and adult white crappie used Little Sandy Creek embayment during winter, stressing the importance of this habitat for this species. Adult centrarchids use embayments during winter because of the low flow velocities (Oliver et al. 1979; Knights et al. 1995; Johnson et al. 1998; Jackson and Noble 2000). Juvenile centrarchids may use embayment habitats during winter to avoid predation. Santucci and Wahl (2003) reported 75 % to 85 % mortality rates during the first winter of young-of-the-year bluegills due to predation by largemouth bass. We captured few large predatory fishes during our samples, and juveniles were primarily associated with near-shore structure (overhanging vegetation, woody debris, and undercut banks). The use of structure by juveniles to avoid predation is well documented (Mittelbach 1988; Gotceitas 1990; Miranda and Hubbard 1994). The addition of woody debris into embayments would increase the amount of cover offering escape from predation, possibly increasing survival of juveniles.

A reduction of the proportion of juveniles in Little Sandy Creek embayment during the course of this study may have been due to mortality loss from the severely cold temperatures during the winter of 2002-2003. High winter mortality rates of juvenile freshwater drum in the Mississippi River have been documented when water temperatures approached 0 °C (Bodensteiner and Lewis 1994). We believe water temperatures within Little Sandy Creek embayment approached 0 °C during ice-cover in January and February. Low levels of dissolved oxygen during ice-cover of backwater areas have increased mortality of fishes (Bodensteiner and Lewis 1992; Knights et al. 1995; Johnson et al. 1998). These critically low temperatures (coupled with possible reductions in D. O. concentrations) may have led to increased mortality, which explains the reduction in the numbers of total individuals present in early March, after the embayment thawed.

Increasing flow rates to minimal levels (> 0) in embayments could limit mortality losses due to insufficient dissolved oxygen levels. Knights et al. (1995) showed that overwintering bluegill and black crappie, *Pomoxis nigromaculatus*, required flow velocities > 0 cm/s, but ≤ 1 cm/s to ensure dissolved oxygen concentrations > 2 mg/ L in backwater lakes of the Mississippi River. Increasing flows > 1 cm/s rendered these habitats unsuitable to these centrarchid species (Knights et al. 1995; Johnson et al. 1998). In the Ohio River, reduction in the elevation of the impounded pool of water during freezing temperatures would allow minimal flows in and out of embayments, reducing the probability of hypoxia. Care would need to be taken to avoid releasing water so quickly that flow velocities in the embayments carry fishes (especially juveniles) out of these areas into the main channel of the river. Extended research into the specific flow velocity requirements of fishes during winter would provide more insight into how embayments can be manipulated in order to improve juvenile survival during winter.

In summary, the severity of winter conditions regulates juvenile fish mortality rates (Bodensteiner and Lewis 1994; Post et al. 1998; Wright et al. 1999; Fullerton et al. 2000; Jackson and Noble 2000). Shallow low-velocity embayments offer a refuge for juvenile fishes so as to improve their probability of survival during winter. Protection, creation, and modification of embayment habitats may reduce juvenile mortality and spur increased sunfish production in large river systems by providing critical overwintering habitat. Whether modified or not, those embayment habitats that offer low current velocities (≤1 cm/s), warmer temperatures (≥4 °C), and sufficient dissolved oxygen levels (≥2 mg/L), can be beneficial to overwintering juvenile fishes.

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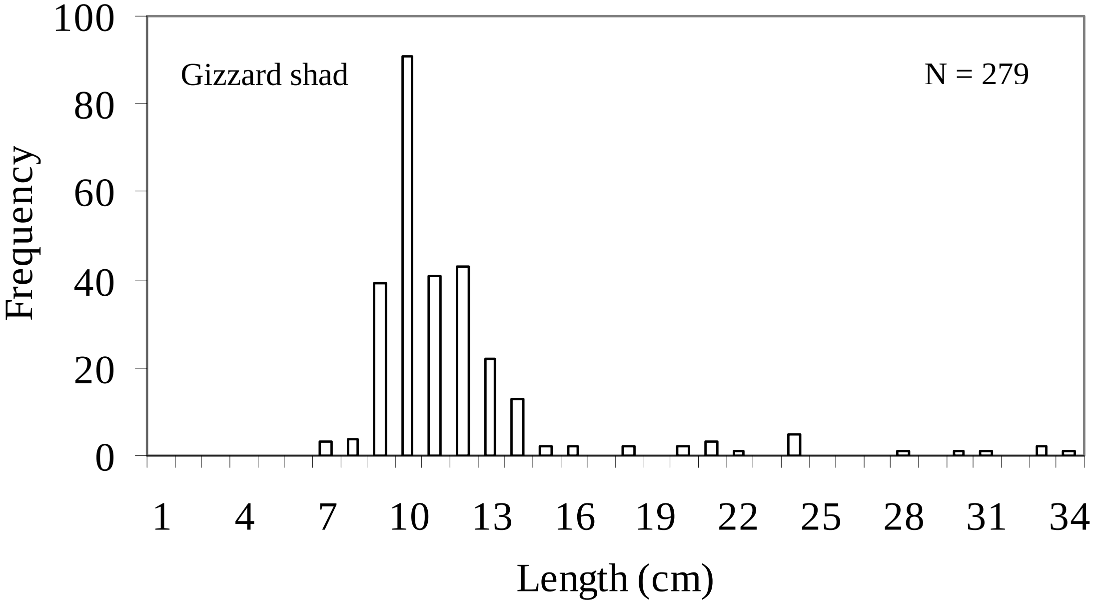
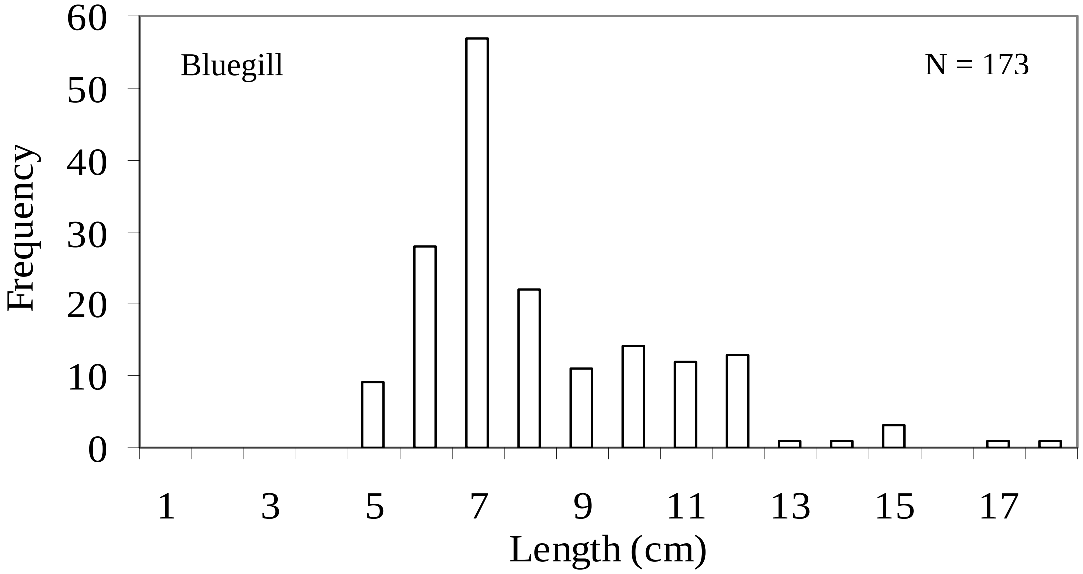
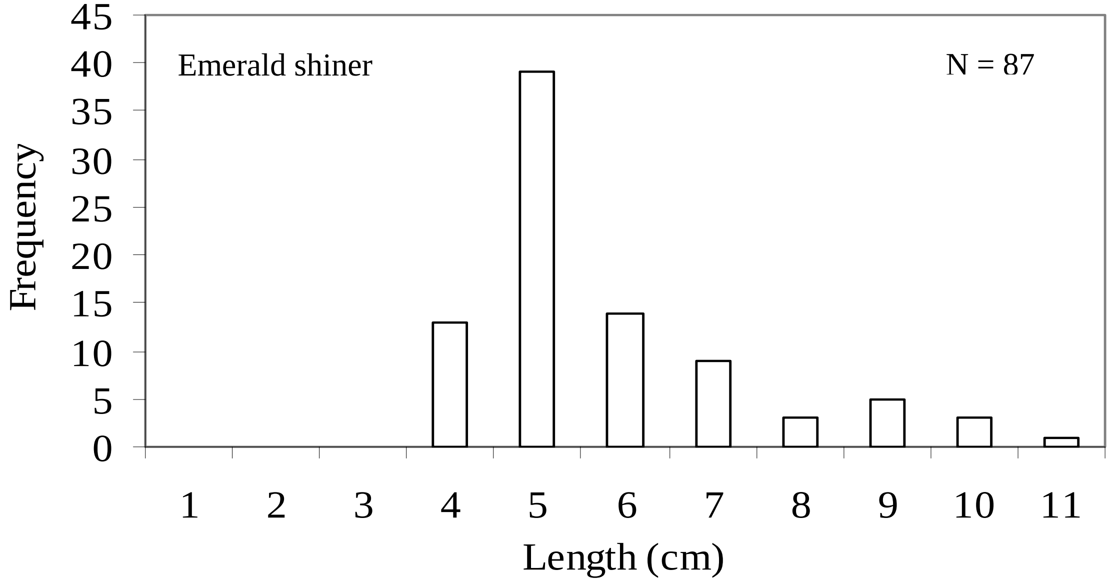
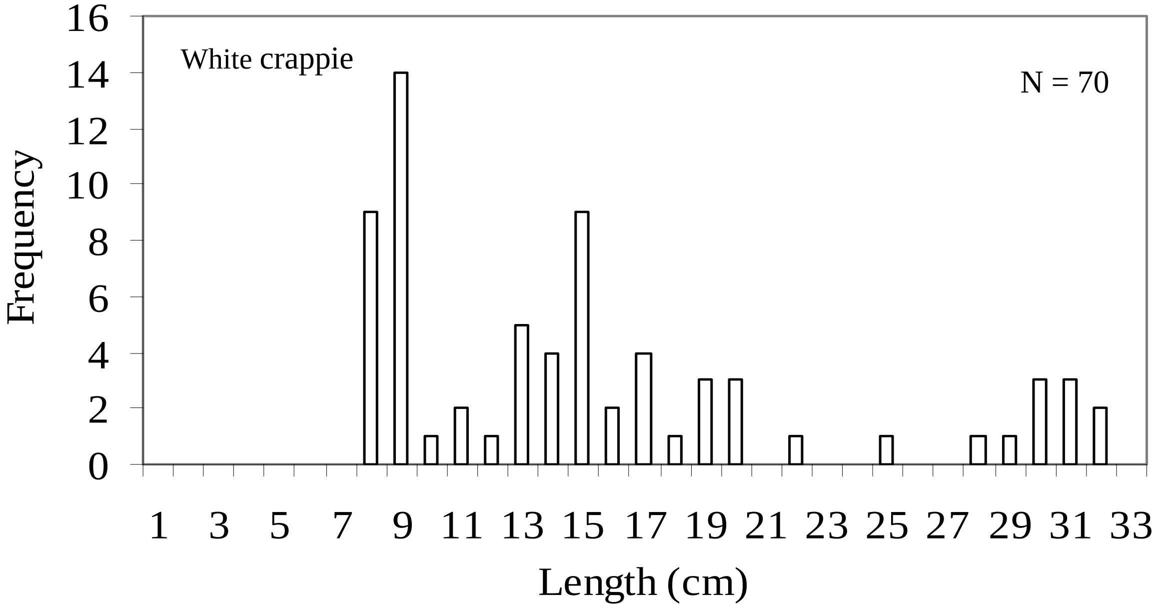
Figure 6. Length-frequencies of gizzard shad, bluegill, emerald shiner, white crappie, and orangespotted sunfish collected by pulsed DC electrofishing in the Little Sandy Creek embayment, West Virginia, during December 15, 2002 through March 17, 2003.






Emerald shiner
N = 87
Frequency
0
5
10
15
20
25
30
35
40
45
1
2
3
4
5
6
7
8
9
10
11
Length (cm)


White crappie
N = 70
Frequency
0
2
4
6
8
10
12
14
16
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Length (cm)

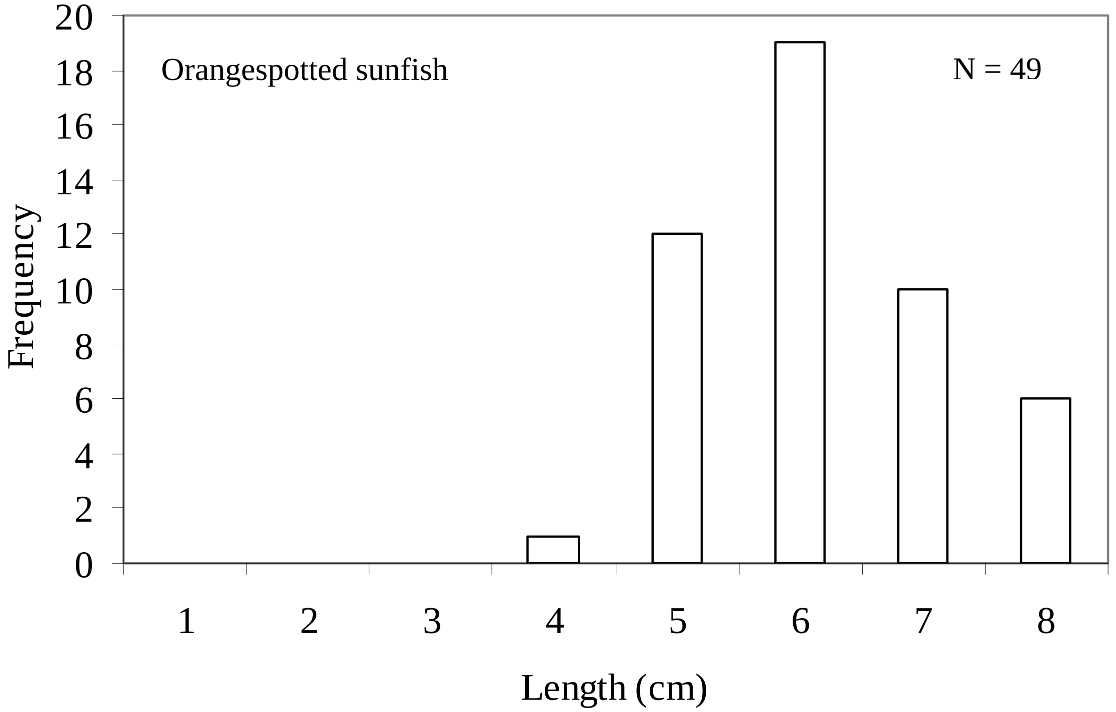

Orangespotted sunfish
N = 49
Frequency
20
18
16
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
Length (cm)

Table 2. Total number of individuals and juvenile proportion of the total for each fish species collected by pulsed DC electrofishing in the Little Sandy Creek embayment, West Virginia, during December 15, 2002 through March 17, 2003. Values in parentheses are the proportion of the total individuals represented by juveniles for that sampling date.

	Number collected				
Taxon	15-Dec-02	1-Mar-03	17-Mar-03	Total	Juvenile proportion
Black crappie *Pomoxis nigromaculatus*	1	0	1	2	1
Bluegill *Lepomis macrochirus*	113	10	41	164	0.85
Bowfin *Amia calva*	0	0	1	1	0
Common carp *Cyprinus carpio*	0	0	3	3	0
Emerald shiner *Notropis atherinoides*	120	1	16	137	0.68
Freshwater Drum *Aplodinotus grunniens*	4	0	2	6	0.5
Gizzard shad *Dorosoma cepedianum*	404	5	21	430	0.97
Green sunfish *Lepomis cyanellus*	3	1	3	7	0.29
Largemouth bass *Micropterus salmoides*	0	2	1	3	0.33
Mosquitofish *Gambusia affinis*	1	0	0	1	0
Orangespotted sunfish *Lepomis humilis*	35	6	8	49	0.94
Pumpkinseed *Lepomis gibbosus*	0	3	2	5	0.2
River carpsucker *Carpiodes carpio*	0	0	4	4	1
Smallmouth buffalo *Ictiobus bubalus*	0	0	1	1	0
Spotted sucker *Minytrema melanops*	1	1	0	2	0
Warmouth *Lepomis gulosus*	2	2	1	5	0.2
White crappie *Pomoxis annularis*	33	21	16	70	0.79
Total	717 (0.92)	52 (0.65)	121 (0.44)	890	0.83

Table 3. The length range, mean length, and variance at age for white crappies collected by pulsed DC electrofishing in the Little Sandy Creek embayment, West Virginia, during December 15, 2002 through March 17, 2003.

Age	Length range (cm)	Mean length (cm)	Variance (cm)	Number collected
1	6.1 – 10.2	7.6	1.1	18
2	12 – 17.2	13.8	2.4	25
3	16.8 – 23.2	19.4	5.3	9
4	26.1 – 28.6	27.4	0.8	5
5	29.4 – 30.9	29.4	0.3	5

Chapter 4. Growth Assessment of three Sport Fishes of the Ohio River

Abstract

Channel catfish, *Ictalurus punctatus*, freshwater drum, *Aplodinotus grunniens*, and white bass, *Morone chrysops*, are popular sport fishes in the Ohio River. Standard age and growth statistics were computed to assess the population growth and condition of these fishes. Channel catfish reached larger mean-lengths at all ages compared to specimens collected over 30 years ago in the Ohio River. Numerous older and larger freshwater drum individuals were collected, suggesting plentiful trophy-sized individuals exist in the Ohio River. None of the white bass collected were harvestable size, suggesting larger individuals may use different habitats than smaller individuals or that environmental conditions are unsuitable for appreciable growth of this species in the Ohio River. Although the population status appears satisfactory for channel catfish and freshwater drum, more information is needed to better assess the condition of white bass in the Ohio River.

Introduction

Channel catfish, *Ictalurus punctatus*, freshwater drum, *Aplodinotus grunniens*, and white bass, *Morone chrysops*, are popular gamefishes of the Ohio River, West Virginia. Currently, harvest regulations for the Ohio River, West Virginia, do not restrict lengths or numbers of channel catfish and freshwater drum, but impose a daily creel limit of four white bass > 38 cm. Little published information exists on the population dynamics of these three fishes in West Virginia waters of the Ohio River. An understanding of age, length, and weight relationships of these important fishes is needed to manage and maintain viable recreational fisheries (Anderson and Neumann 1996).

Channel catfish live to a maximum age of 24 years and can attain weights of 34 kg (Etnier and Starnes 1993). In 1973, Schoumacher reported a maximum mean length of 43 cm at age eight for Ohio River specimens. Quist and Guy (1998) also reported a maximum age of eight for channel catfish specimens from the Kansas River, but the mean length at age eight was a greater 59 cm. Maximum ages and mean lengths reported for freshwater drum differ, however, a maximum age of 10 to 11 years and a mean length of 69 cm generalizes Goeman et al. (1984), Etnier and Starnes (1993), and Braaten and Guy (2002). The maximum age of white bass from Tennessee is 8 (Etnier and Starnes 1993), while Colvin (2002) recorded age-7 white bass specimens from the Missouri River.

Objectives

The objective of this study was to document growth relationships of channel catfish, freshwater drum, and white bass from Belleville Pool, Ohio River, West Virginia. Age-frequency distributions, the von Bertalanffy growth equation (Ricker 1975) and the allometric growth equation are used in this analysis in order to assess the population condition, structure, and growth of these three commonly occurring sport fishes in the Ohio River.

Study site

The Belleville Pool of the Ohio River, created by Belleville Lock and Dam (rkm 328.1), extends upstream to Willow Island Lock and Dam (rkm 260.2). The 67.9 km pool averages 404.5 m wide, 7.3 m deep, and comprises 2850 ha of surface area

(ORSANCO 1994). The deepest section of the pool (15 m) lies directly upstream of Belleville Lock and Dam. A navigation channel (3.7 m deep) is maintained for commercial barge traffic by the United States Army Corps of Engineers (USACE) (ORSANCO 1994). The riparian zone is a mixture of hardwood forests, urban and industrial frameworks, and agricultural settings. Most large floodplains near Belleville Pool are heavily urbanized, including cities of Parkersburg, WV (confluence of the Little Kanawha and Ohio rivers) and Marietta, OH (junction of Muskingum and Ohio rivers).

Methods

Data collection

We sampled the Belleville Pool during two periods (February 2002 – April 2002, and December 2002 to March 2002) with a variable-depth AC electrofishing boat for water depths of 2-15 meters (Grunwald 1983, Newcomb 1989). Fishes were identified to species, measured (nearest mm total length, TL), and weighed. Large fishes (over 1 kg) were weighed to the nearest 25 g with a Pesola spring scale (5 kg maximum). Smaller fishes (less than 1 kg) were weighed to the nearest 1g with a Homs spring dial scale (1 kg maximum). When collected, five individuals from each 50 mm size class of channel catfish, freshwater drum, and white bass were frozen for age analysis.

Age analysis

Sagittal otoliths were extracted from freshwater drum and white bass and sectioned with an Isomet 1000 precision saw with a 12.7 cm x 0.4 mm blade (DeVries and Frie 1996). Transverse otolith sections (approximately 1 mm thickness) were stained with iodine. When illuminated, most small otoliths (age classes 0-2, especially in freshwater drum) were aged without sectioning. Pectoral spines of channel catfish were removed and softened in 4% nitric acid solution (HNO_3) (K. Hartman pers. comm.). Each spine was sectioned at the distal end of the basal groove (Sneed 1951) with a single-edge razor blade. Annuli of otolith and pectoral spine sections were counted under magnification (2-4 X). Two observers estimated age independently, and a third observer resolved discrepancies. In order to simplify the aging process because these fish were collected in winter, we assumed January 1 as the birth date (DeVries and Frie 1996) and assigned ages as if all individuals were collected on or after January 1.

Mean length for each age class and the variance of these values were calculated for all species. The frequency of each age class for all species was also calculated. We used the von Bertalanffy (Ricker 1975) equation $L_t = L_\infty * (1 - e^{(-K * t_0)})$ to describe the relationship of age and length of these three species. This equation calculated L_t (length at a specific age) values for channel catfish, freshwater drum, and white bass by estimating the asymptotic length (L_∞ (cm)), growth coefficient (K), and t_0 (theoretical age in years when length = 0). Standard errors of these three parameters were also calculated. We also used the allometric growth equation $W = aL^b$, where W = weight (g), a = y-intercept, and b = slope, and L = length (mm), to describe the length-weight relationship of the three species. Standard errors of the slope and y-intercept were also calculated.

Results

Younger age classes represented the greatest proportion of individuals of white bass and freshwater drum (Figure 7). The greatest number of individuals was age-4 for channel catfish, age-1 for freshwater drum, and age-2 for white bass (Figure 7). Freshwater drum were represented by the oldest age class (22), while the oldest age classes of channel catfish and white bass were 9 and 4, respectively (Table 4). The longest freshwater drum individual was 77 cm, 62 cm for channel catfish, and approximately 30 cm for white bass (Table 4). Surprisingly, no white bass individuals collected were longer than the harvest minimum size limit of > 38 cm. High variances of mean-length-at-age values occurred due to low sample sizes for older age classes of freshwater drum and most age classes of channel catfish (Table 4).

The growth parameters calculated by the von Bertalanffy and allometric growth equations varied between the three species. The von Bertalanffy growth parameter estimates are as follows: for channel catfish, the $L_\infty = 113$ cm (SE = 1.34), K = 0.077 (SE = 0.056), and $t_0 = 1.71$ (SE = 0.46) (Figure 8a); for freshwater drum, the $L_\infty = 118$ cm (SE = 6.82), K = 0.051 (SE = 0.013), and $t_0 = 1.47$ (SE = 0.38) (Figure 8b); for white bass, the $L_\infty = 48$ cm (SE = 3.36), K = 0.248 (SE = 0.32), and $t_0 = 1.16$ (SE = 0.21) (Figure 8c). The allometric growth parameter estimates are as follows: for channel catfish, the slope = 3.35 (SE = 0.268), and y-intercept = 1.0×10^{-6} (SE = 2.35×10^{-7}) (Figure 9a); for freshwater drum, the slope = 3.39 (SE = 0.179), and y-intercept = 1.0×10^{-6} (SE = 1.12×10^{-7}) (Figure 9b); for white bass, the slope = 3.13 (SE = 0.492), and y-intercept = 1.7×10^{-6} (SE = 4.61×10^{-7}) (Figure 9c).

Discussion

White bass growth appears to be deficient for angling harvest in the upper Ohio River. It is possible that we failed to locate larger white bass individuals in the habitats we sampled, but none of the individuals collected were greater than the minimum size limit set for harvest, > 38 cm, by the West Virginia Department of Natural Resources (Table 4). Even though the von Bertalanffy maximum length (L_∞) value was 48 cm and the growth coefficient (K) was highest of all species, collected white bass individuals did not approach harvestable size. Our L_∞ value for white bass agrees with Colvin's Missouri River specimens (2002), while our K value is considerably lower, denoting that Ohio River white bass may attain relatively equal maximum sizes but at a slower rate. White bass specimens from the Roach Lake, Ohio had mean lengths (cm) of 14.0, 26.9, and 36.6 for ages 1, 2, and 3, respectively (Carlander 1997), substantially larger sizes than our Ohio River specimens (Table 4). Our mean-length-at-age estimates for the four white bass age classes measured were considerably less than those from Tennessee (Etnier and Starnes 1993), further suggesting that white bass growth in the Ohio River is limited.

Channel catfish growth is extremely variable across spatial and temporal boundaries (Etnier and Starnes 1993). Our low von Bertalanffy K value suggests channel catfish are not growing quickly in the upper Ohio River. However, our mean-length-at-age estimates for channel catfish were higher for all age classes than Schoumacher's (1973) Ohio River specimens (also taken from the Belleville Pool). Mississippi River specimens were reported as having mean lengths (cm) of 15.0, 21.1, and 25.4 for ages 2, 3, and 4, respectively (Carlander 1969), also significantly less than our Ohio River specimens. However, our maximum mean length agrees with the mean-length-at-age 8 (Table 4) from Tennessee (Etnier and Starnes 1993) and Kansas River specimens (Quist and Guy 1998). This suggests that channel catfish in the upper Ohio River may be growing at a higher rate and attaining larger sizes faster than in the past.

Freshwater drum reach considerable sizes in the Belleville Pool, Ohio River. The maximum age estimate for our freshwater drum specimens (Table 4) is greater than most published information. The oldest freshwater drum individual collected in the Belleville Pool was estimated to be 22 years of age, measured 77 cm in length, and weighed 7.4 kg.

In Lake Erie, Cunningham (1989) recorded a 33-yr old freshwater drum and numerous individuals older than 10 years. A relatively large number of freshwater drum individuals collected were of older age classes (> 10) (Figure 7b and Table 4), suggesting that conditions in the upper Ohio River are favorable for long life expectancy of freshwater drum.

In summary, the age and growth information presented here is useful in assessing the population growth and condition of these three popular sport fishes in the Ohio River. None of the white bass collected were harvestable size, possibly indicating larger white bass either use different habitats than smaller individuals or sub optimal environmental conditions exist in the Belleville Pool for this species. Channel catfish appear to be growing at faster rates than in the past, suggesting environmental conditions have improved for this species over time. The impressive sizes that freshwater drum reach in the Belleville Pool should delight any angler seeking trophy-sized individuals of this species. Hopefully, this information proves useful for fishery managers seeking to improve conditions or assess past management actions for these three sport fisheries in the Ohio River.

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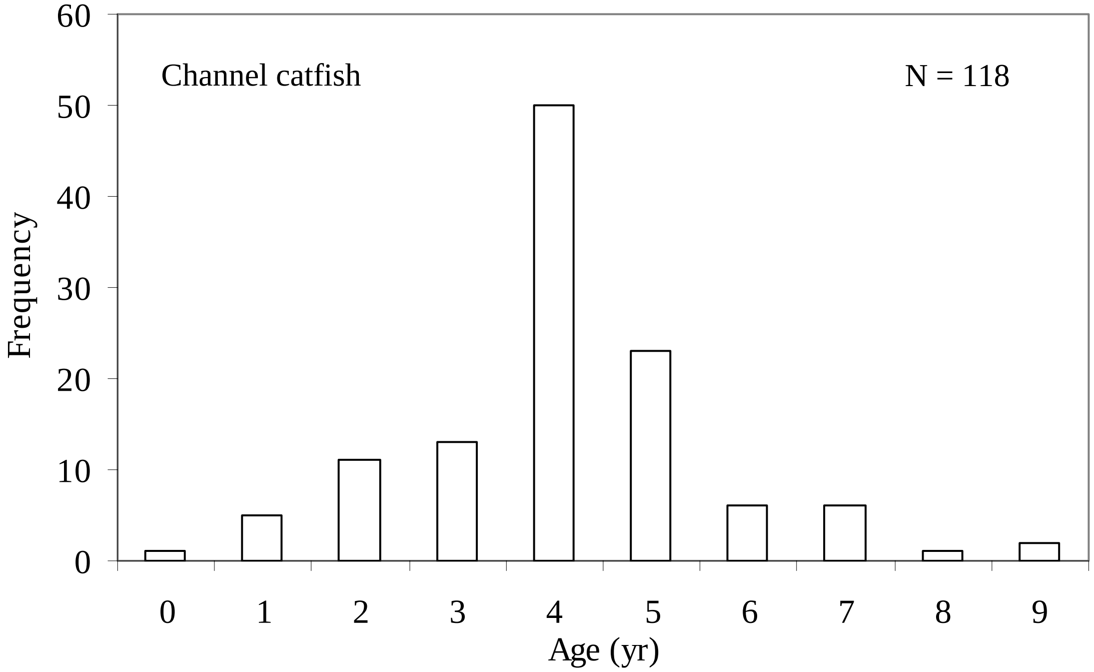
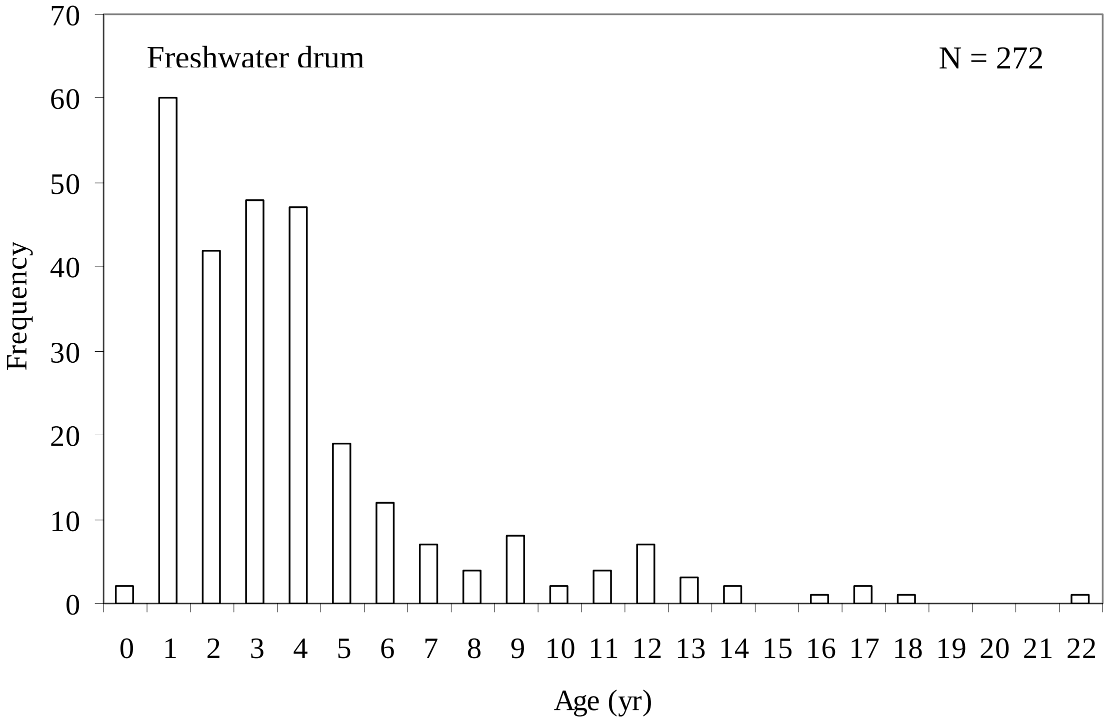
Figure 7. The age frequencies of channel catfish, freshwater drum, and white bass collected in the Belleville Pool, Ohio River during February 17 through April 7, 2002 and December 12, 2002 through March 17, 2003.




Freshwater drum
N = 272
Frequency
70
60
50
40
30
20
10
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Age (yr)

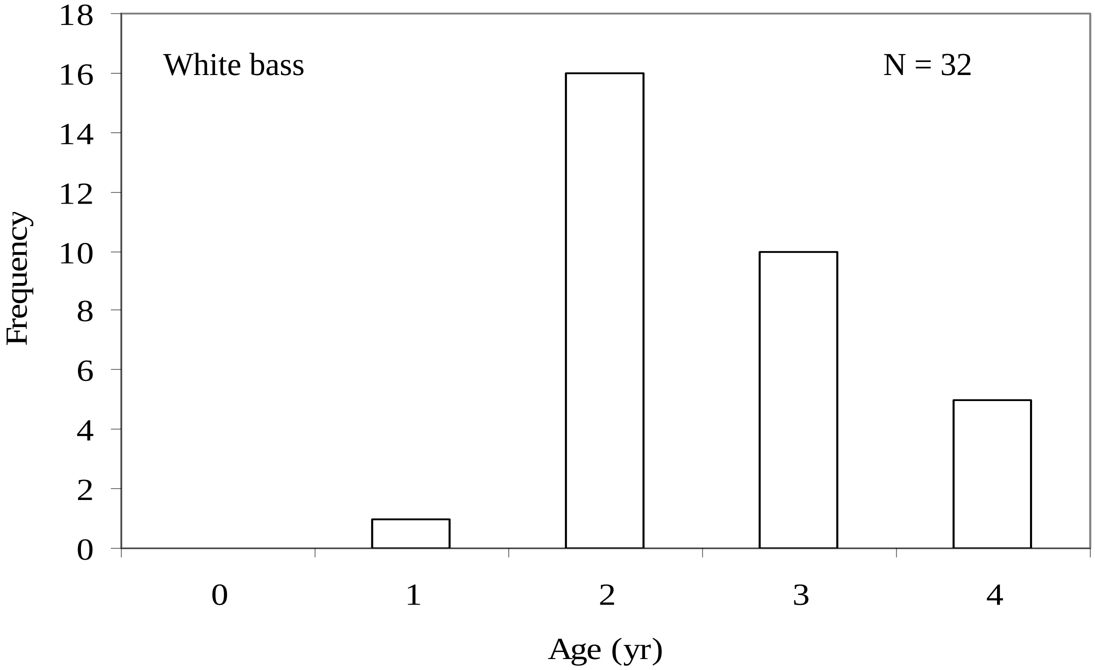
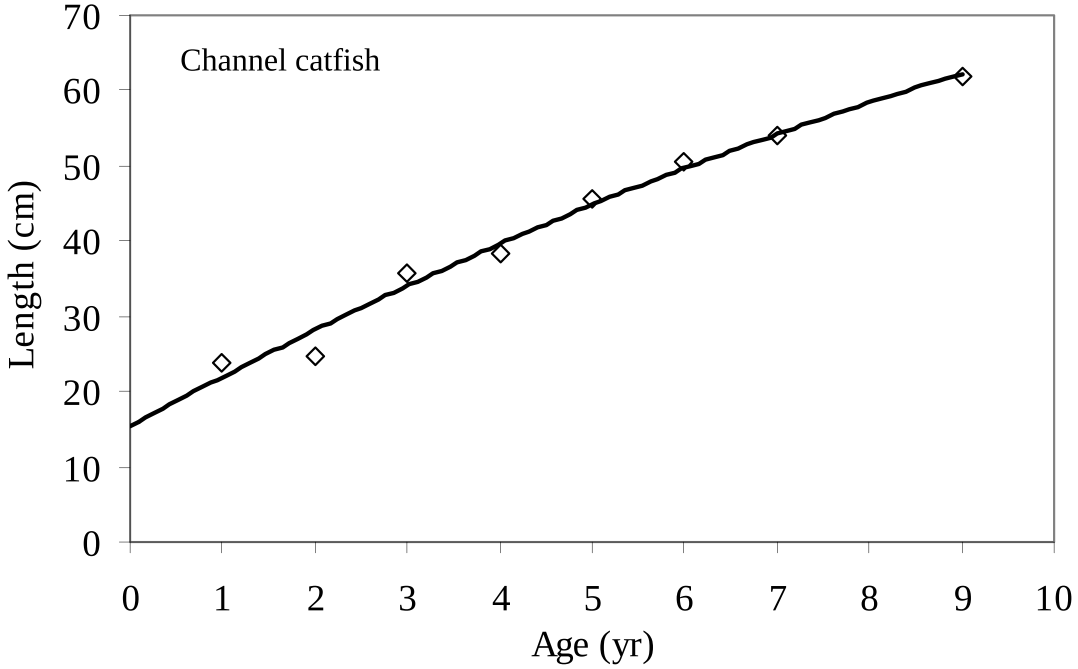
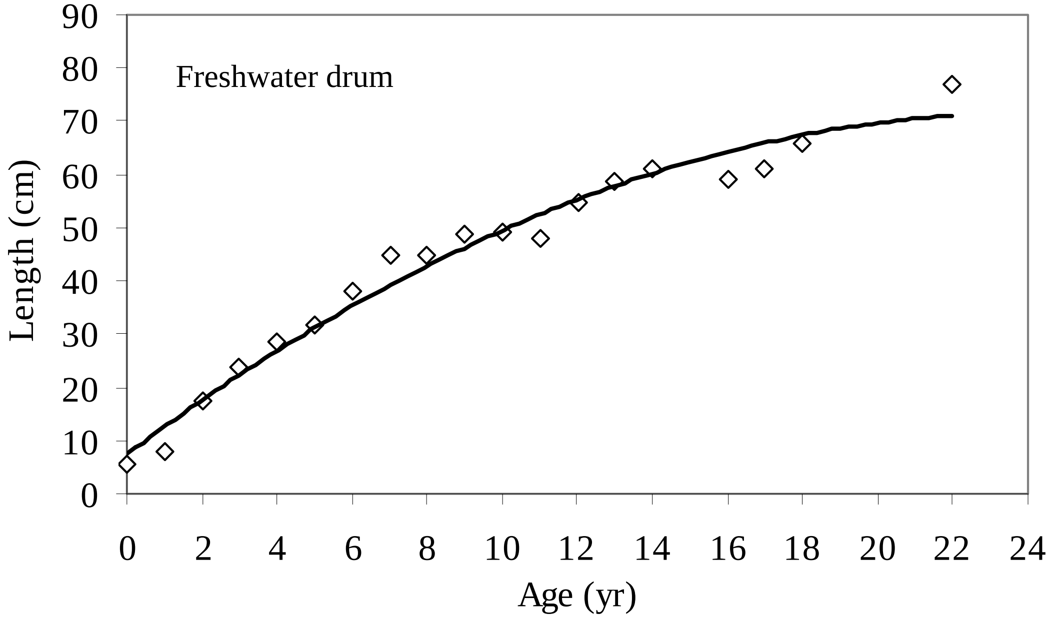

White bass
N = 32
Frequency
18
16
14
12
10
8
6
4
2
0
0
1
2
3
4
Age (yr)

Figure 8. The von Bertalanffy growth curves of channel catfish, freshwater drum, and white bass collected in the Belleville Pool, Ohio River.




Freshwater drum
Length (cm)
0
10
20
30
40
50
60
70
80
90
Age (yr)
0
2
4
6
8
10
12
14
16
18
20
22
24

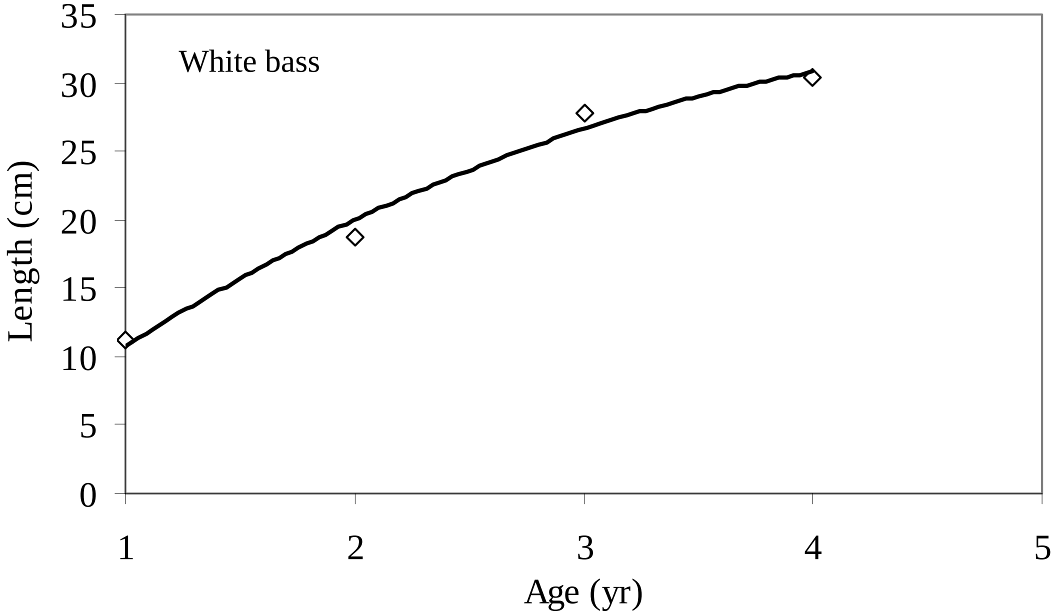
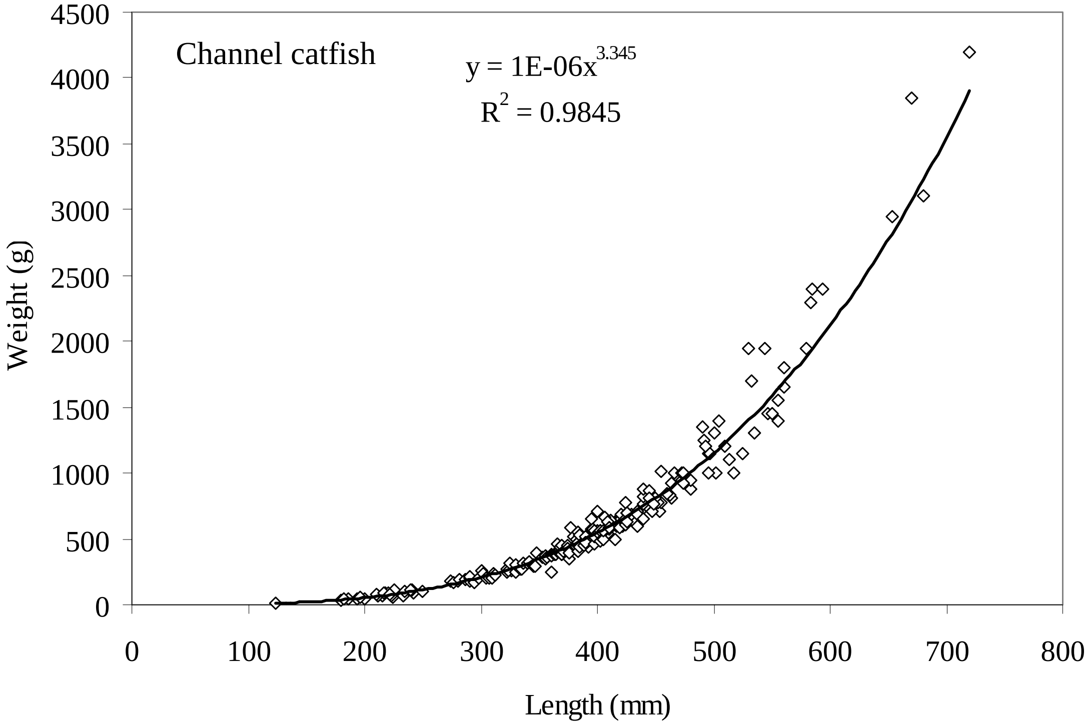
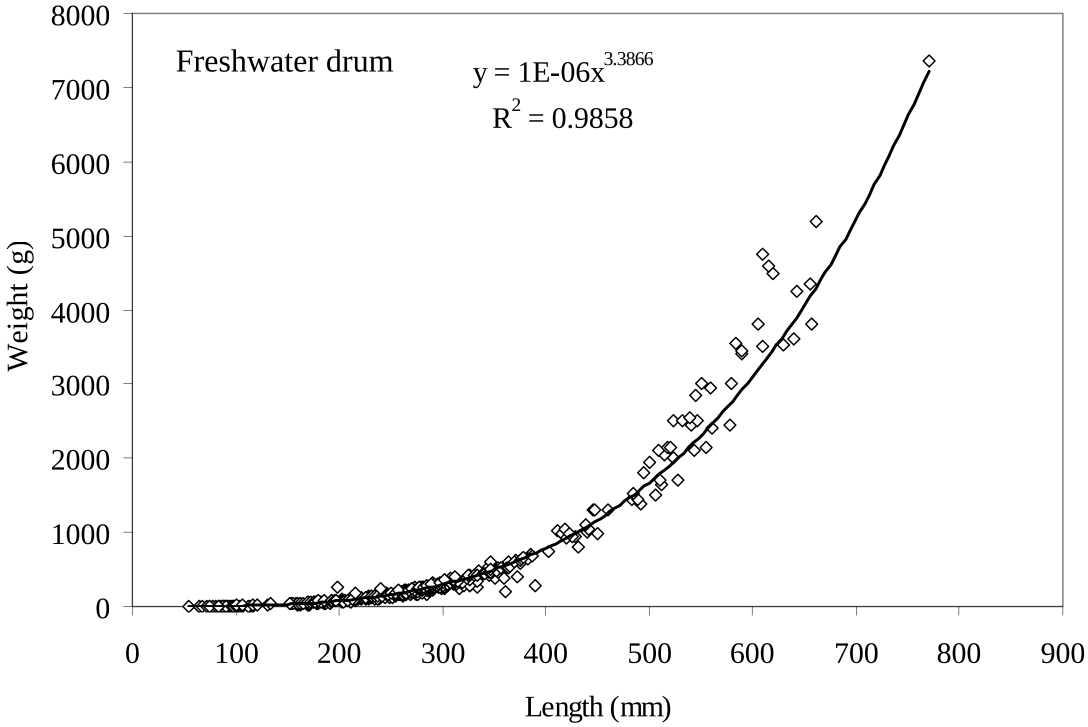

White bass
Length (cm)
0
5
10
15
20
25
30
35
Age (yr)
1
2
3
4
5

Figure 9. The allometric growth of channel catfish, freshwater drum, and white bass collected in the Belleville Pool, Ohio River.




Freshwater drum
$y = 1E\text{-}06x^{3.3866}$
$R^2 = 0.9858$
Weight (g)
8000
7000
6000
5000
4000
3000
2000
1000
0
0
100
200
300
400
500
600
700
800
900
Length (mm)

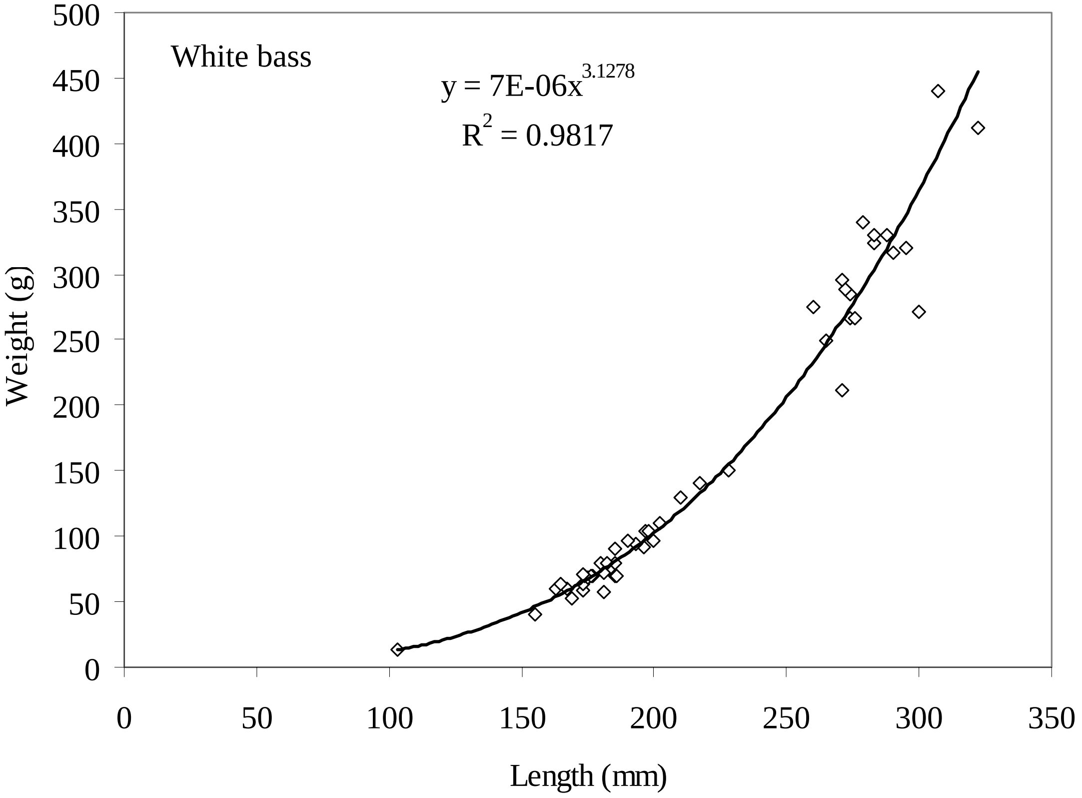

White bass
y = 7E-06x^3.1278
R^2 = 0.9817
Weight (g)
Length (mm)
0
50
100
150
200
250
300
350
400
450
500
0
50
100
150
200
250
300
350

Table 4. Mean length-at-age of channel catfish, freshwater drum, and white bass collected in the Belleville Pool, Ohio River during February 17 through April 7, 2002 and December 12, 2002 through March 17, 2003. Variances are in parentheses; no values indicate only one individual for that age group was collected.

	Mean length (cm)					
Age	Channel catfish		Freshwater drum		White bass	
0	23.8	(9.7)	5.5	(0.5)		
1	24.8	(39.7)	8.0	(1.6)	11.2	
2	35.6	(19.4)	17.3	(8.2)	18.8	(3.4)
3	38.4	(40.7)	23.8	(2.5)	27.8	(0.8)
4	45.6	(37.8)	28.6	(5.6)	30.4	(1.3)
5	50.5	(55.5)	31.6	(5.4)		
6	54.0	(53.2)	37.9	(8.1)		
7	56.8	(46.8)	45.0	(27.6)		
8	59.2		44.8	(63.6)		
9	62.0	(32.0)	48.7	(5.9)		
10			49.0	(32.0)		
11			48.0	(36.0)		
12			54.7	(21.2)		
13			58.7	(37.3)		
14			61.0	(8.0)		
16			59.0			
17			61.0	(18.0)		
18			66.0			
22			77.0			

SUMMARY

Winter is a critical period during which fishes suffer increased mortality. During winter conditions, fishes select refuge habitats where physiochemical factors are unlikely to exceed tolerance limits. In large temperate river systems, such as the Ohio River, extremely low water temperatures during winter coupled with high flows could be expected to increase mortality rates of fishes. Juvenile fishes are most susceptible to winter mortality due to their small size and lack of energy reserves. The greatest diversity and abundance of fishes were collected by electrofishing in the Belleville Pool, Ohio River, in low-velocity tributary confluences and an embayment at temperatures > 3 - 4 °C. When water temperatures were < 3 °C, more individuals of certain species were collected in faster-velocity main channel and back channel habitats. Other species collected at temperatures < 3 °C continued to associate with the lower flows in tributaries. The lack of water temperatures > 4 °C in tributaries may have left some fishes susceptible to current velocity, which carried them into channel habitats.

Species- and age-specific responses to winter conditions may obscure broad generalizations about when and how certain species use overwintering refuges. For example, in the Little Sandy Creek embayment, adjacent to the Belleville Pool, 85% of all fishes collected were juveniles. Centrarchids, popular sport fishes, while collected in low numbers in the mainstem portion of the river, were one of the dominant fishes collected in the embayment. Protecting and modifying embayment habitats may reduce juvenile mortality during winter and improve recreational angling opportunities for sunfish in large river systems

Populations of channel catfish, *Ictalurus punctatus*, and freshwater drum, *Aplodinotus grunniens*, the most abundant fishes collected in the Belleville Pool, exhibit satisfactory population growth and condition. Channel catfish reach larger mean-lengths at all ages compared to specimens collected over 30 years ago in the Belleville Pool. Numerous older and larger freshwater drum individuals were collected, suggesting plentiful trophy-sized individuals exist in the Ohio River. Conversely, none of the white bass, *Morone chrysops*, individuals collected were harvestable size. Fishery managers can use this information to assess the population growth and condition of these three species and make management decisions according to their goals for each species. Possibly, the population growth and the probability of survival of fishes of all ages may increase by protecting and enhancing tributary and embayment habitats in large rivers during winter.

APPENDIX A

Fish caught per hour (CPUE) within each habitat type in the Belleville Pool, Ohio River. No values indicate habitat not sampled.

February 2002 session

	Habitat types						
	Island		Back	Main		Deep	
Species	Head	Tail	channel	channel	Trib	hole	Total
Emerald Shiner			0		1.6	0	1.0
Freshwater Drum			0		6.5	0	4.2
Gizzard Shad			0		68.5	0	43.6
River Carpsucker			0		1.6	0	1.0
Total			0		78.3	0	49.8

March 2002 session

	Habitat types						
	Island		Back	Main		Deep	
Species	Head	Tail	channel	channel	Trib	hole	Total
Channel Catfish	4.4	0	3.2	1.1	65.4	0	11.1
Common Carp	0	0	0	0	3.9	0	0.6
Emerald Shiner	0	0	0	0	2.9	0	0.4
Freshwater Drum	0	0	0.8	2.8	129.8	0	20.8
Gizzard Shad	0	0	0	0	12.7	0	1.9
Hybrid Striped Bass	0	0	0	0	3.9	0	0.6
Mooneye	0	3.0	0	0	2.0	0	0.7
Quillback	0	0	0	0	2.0	0	0.3
River Carpsucker	0	0	0	0	3.9	0	0.6
Walleye	0	0	0	0	2.0	0	0.3
Total	4.4	3.0	4.0	3.9	228.3	0	37.3

Early April 2002 session

	Habitat types						
	Island		Back	Main		Deep	
Species	Head	Tail	channel	channel	Trib	hole	Total
Channel Catfish	0	1.7	5.6	2.9	0	0	2.9
Emerald Shiner	0	0	0	0	1.5	0	0.1
Flathead Catfish	0	0	0	0.3	0	0	0.1
Freshwater Drum	0	0	0.6	0.3	21.4	0	2.2
Gizzard Shad	0	0	0	0	3.1	0	0.3
Highfin Carpsucker	0	0	0	0	3.1	0	0.3
Mooneye	0	0	0.6	0	0	0	0.1
River Carpsucker	0	0	0	0	6.1	0	0.6
Total	0	1.7	6.7	3.5	35.2	0	6.7

Mid-April 2002 Session

	Habitat types						
	Island		Back	Main		Deep	
Species	Head	Tail	channel	channel	Trib	hole	Total
Bluegill	0	0	0	0	1.7	0	0.2
Channel Catfish	7.1	1.8	2.1	2.2	13.1	0	3.6
Emerald Shiner	0	0	0	0	4.9	0	0.5
Freshwater Drum	5.3	3.5	1.4	0.4	14.8	0	2.8
Gizzard Shad	0	0	0	0.4	0	0	0.2
Mooneye	0	0	0	0.4	0	0	0.2
Orangespotted Sunfish	0	0	0	0	1.6	0	0.2
River Carpsucker	0	0	0	0	9.8	0	1.0
Total	12.4	5.3	3.5	3.3	46.0	0	8.5

February - April 2002 sessions total

	Habitat types						
	Island		Back	Main		Deep	
Species	Head	Tail	channel	channel	Trib	hole	Total
Bluegill	0	0	0	0	0.3	0	0.1
Channel catfish	4.1	1.9	3.8	2.1	25.8	0	5.8
Common carp	0	0	0	0	1.4	0	0.2
Emerald shiner	0	0	0	0	2.8	0	0.4
Flathead catfish	0	0	0	0.1	0	0	0.1
Freshwater drum	2.0	0.9	0.9	1.1	55.1	0	8.6
Gizzard shad	0	0	0	0.1	19.6	0	2.8
Highfin carpsucker	0	0	0	0	0.7	0	0.1
Hybrid striped bass	0	0	0	0	1.4	0	0.2
Mooneye	0	1.4	0.2	0.1	0.7	0	0.3
Orangespotted Sunfish	0	0	0	0	0.3	0	0.1
Quillback	0	0	0	0	0.7	0	0.1
River carpsucker	0	0	0	0	5.2	0	0.7
Walleye	0	0	0	0	1.0	0	0.1
Total	6.1	4.2	4.9	3.6	114.7	0	19.6

December 2002 session

	Habitat types							
	Island		Back	Main		Deep	Embay-	
Species	Head	Tail	channel	channel	Trib	hole	ment	Total
Black Crappie	0	0	0	0	0	0	1.8	0.1
Bluegill	0	0	0	0	0	0	198.3	13.1
Channel Catfish	0	0	2.6	7.0	0	2.7	0	3.2
Common Carp	0	0	0.4	0	0	0	0	0.1
Emerald Shiner	0	0	0	0	0	0	210.5	13.9
Freshwater Drum	0	1.0	5.6	10.4	0	8.2	7.0	6.1
Gizzard Shad	0	0	0	0.4	0	0	708.8	46.9
Green Sunfish	0	0	0	0	0	0	5.3	0.4
Mooneye	0	1.9	1.5	0	0	0	0	0.7
Mosquitofish	0	0	0	0	0	0	1.8	0.1
Ohio Lamprey	0	0	0.4	0	0	0	0	0.1
Orangespotted Sunfish	0	0	0	0	0	0	61.4	4.1
River Carpsucker	0	0	0	0.4	0	0	0	0.1
Sauger	0	1.0	0	0	0	0	0	0.1
Silver Chub	0	6.7	0.4	1.7	0	0	0	1.2
Smallmouth Buffalo	0	1.0	0.7	0.4	0	0	0	0.5
Spotted Bass	0	0	0	0	0	5.5	0	0.2
Spotted Sucker	0	0	0	0	0	0	1.8	0.1
Warmouth	0	0	0	0	0	0	3.5	0.2
White Bass	0	0	0.4	0	0	0	0	0.1
White Crappie	0	0	0	0	0	0	57.9	3.7
Total	0	11.4	11.9	20.2	0	16.4	1257.9	95.0

January 2003 session							
	Habitat types						
	Island		Back	Main		Deep	
Species	Head	Tail	channel	channel	Trib	hole	Total
Black Buffalo	0	0	0	0	0	0	0.1
Black Crappie	0	0	0	0	0.9	0	0.1
Channel Catfish	0	0	1.1	1.3	6.4	0	1.6
Common Carp	0	1.4	0.7	0	1.8	0	0.7
Emerald Shiner	0	0	0	0	0	0	0.2
Freshwater Drum	0	0	1.8	3.0	50.9	0	8.7
Gizzard Shad	0	0	0.4	0	0.9	0	0.3
Golden Redhorse	0	0	0	0	0.9	0	0.1
Highfin Carpsucker	0	0	0	0	1.8	0	0.2
Hybrid Striped Bass	0	0	0	0	3.0	0	0.3
Mooneye	0	0	0	0.7	0	0	0.2
Quillback	0	0	0	0	0.9	0	0.1
River Carpsucker	0	0	0	0	3.6	0	0.6
Rock Bass	0	0	0.4	0	0	0	0.1
Sauger	0	0	0	0	0.9	0	0.1
Shorthead Redhorse	0	0	0	0.3	0	0	0.2
Silver Chub	0	0	0.4	0	0	0	0.1
Smallmouth Buffalo	0	0	1.4	1.0	24.5	0	5.2
White Bass	0	0	0	0.3	30.9	0	4.1
Total	0	1.4	6.0	6.7	127.3	0	23.1

March 2003 session								
	Habitat types							
	Island		Back	Main		Deep	Embay-	
Species	Head	Tail	channel	channel	Trib	hole	ment	Total
Black Crappie	0	0	0	0	0	0	1.1	0.1
Bluegill	0	0	0	0	0	0	56.9	5.5
Bowfin	0	0	0	0	0	0	1.1	0.1
Channel Catfish	0	0	6.7	4.5	4.5	0	0.0	3.9
Common Carp	0	0	0	0.6	0	0	3.4	0.5
Emerald Shiner	0	0	0	0	0	0	19.0	1.8
Freshwater Drum	0	0	0.8	34.1	40.3	0	2.2	17.6
Gizzard Shad	0	0	0.4	3.5	1.5	0	29.0	4.3
Green Sunfish	0	0	0	0	0	0	4.5	0.4
Hybrid Striped Bass	0	0	0	1.9	5.2	0	0	1.4
Largemouth Bass	0	0	0	0	0	0	3.4	0.3
Mooneye	0	0	0.8	0.3	0	0	0	0.3
Orangespotted Sunfish	0	0	0	0	0	0	15.6	1.5
Pumpkinseed	0	0	0	0	0	0	5.6	0.5
Quillback	0	0	0	0	0.8	0	0	0.1
River Carpsucker	0	0	0.8	0.3	1.5	0	4.5	1.0
Sauger	0	0	0	0	0.8	0	0	0.1
Silver Chub	0	0	0.4	0.3	0	0	0	0.2
Smallmouth Buffalo	0	1.5	1.7	2.3	2.2	0	1.1	1.7
Spotted Sucker	0	0	0	0	0	0	1.1	0.1
Walleye	0	0	0	0	0.8	0	0	0.1
Warmouth	0	0	0	0	0	0	3.4	0.3
White Bass	1.6	0	0.8	1.0	2.2	0	0	1.0
White Crappie	0	0	0	0.3	0	0	41.3	4.1
Total	1.6	1.5	12.6	49.2	59.6	0	193.1	46.9

December 2002-March 2003 sessions total

	Habitat types								
	Island								
Species	Head	Tail	Back channel	Main channel	Trib	Deep hole	Wing dam	Embayment	Total
Black Buffalo	0	0	0	0	0	0	7.5	0	0.04
Black Crappie	0	0	0	0	0.3	0	0	1.4	0.1
Bluegill	0	0	0	0	0	0	0	111.9	6.1
Bowfin	0	0	0	0	0	0	0	0.7	0.04
Channel Catfish	0	0	3.3	4.8	4.1	0.9	0	0	3.1
Common Carp	0	0.5	0.4	0.2	0.6	0	7.5	2.1	0.5
Emerald Shiner	0	0	0	0	0	0	15.0	93.5	5.2
Freshwater Drum	0	0.5	2.8	16.3	34.8	2.6	52.6	4.1	11.0
Gizzard Shad	0	0	0.3	1.3	1.0	0	7.5	293.3	16.7
Golden Redhorse	0	0	0	0	0.3	0	0	0	0.04
Green Sunfish	0	0	0	0	0	0	0	4.8	0.3
Highfin Carpsucker	0	0	0	0	0.6	0	0	0	0.1
Hybrid Striped Bass	0	0	0	0.7	3.2	0	0	0	0.6
Largemouth Bass	0	0	0	0.1	0	0	0	2.1	0.2
Mooneye	0	0.9	0.8	0.3	0	0	0	0	0.4
Mosquitofish	0	0	0	0	0	0	0	0.7	0.04
Ohio Lamprey	0	0	0.1	0	0	0	0	0	0.04
Orangespotted Sunfish	0	0	0	0	0	0	0	33.4	1.8
Pumpkinseed	0	0	0	0	0	0	0	3.4	0.2
Quillback	0	0	0	0	0.6	0	0	0	0.1
River Carpsucker	0	0	0.3	0.2	1.9	0	7.5	2.7	0.6
Rock Bass	0	0	0.1	0	0	0	0	0	0.04
Sauger	0	0.5	0	0	0.6	0	0	0	0.1
Shorthead Redhorse	0	0	0	0.1	0	0	7.5	0	0.1
Silver Chub	0	1.8	0.5	0.7	0	0	0	0	0.5
Smallmouth Buffalo	0	0.9	1.3	1.3	9.5	0	90.2	0.7	2.5
Spotted Bass	0	0	0	0	0	1.7	0	0	0.1
Spotted Sucker	0	0	0	0	0	0	0	1.4	0.1
Walleye	0	0	0	0	0.3	0	0	0	0.04
Warmouth	0	0	0	0	0	0	0	3.4	0.2
White Bass	0.5	0	0.4	0.4	11.7	0	7.5	0	1.7
White Crappie	0	0	0	0.1	0	0	0	47.8	2.6
Total	0.5	5.0	10.1	26.6	69.6	5.2	203.0	607.1	54.9

VITA

November 7, 1975……………………………….Born – Pullman, Washington

1999………………………………………………..B. S. College of Agricultural Science,
University of Wisconsin-Madison

2001-present……………………………………..Graduate Research Assistant,
West Virginia University

PRESENTATIONS

Lenz, B., S. Welsh, K. Hartman. Winter habitats of fishes in the Ohio River. Presented at the American Fisheries Society annual meeting, Quebec City, Canada, 12 August 2003.

Lenz, B., S. Welsh, K. Hartman. Winter habitats of fishes in the Belleville Pool, Ohio River. Presented at the West Virginia Cooperative Fish and Wildlife Unit annual meeting, Morgantown, WV, 24 April 2003.

Lenz, B., S. Welsh, K. Hartman. Winter habitats of channel catfish and freshwater drum in the Belleville Pool, Ohio River. Presented at the Wildlife Society annual meeting, Morgantown, WV, 6 March 2003.

Lenz, B., S. Welsh, K. Hartman. Winter habitats of channel catfish and freshwater drum in the Belleville Pool, Ohio River. Presented at the Tri-State (Kentucky, Virginia and West Virginia) annual meeting, Ashland, KY, 5 March 2003.

Lenz, B., S. Welsh, K. Hartman. Winter habitats of channel catfish and freshwater drum in the Belleville Pool, Ohio River. Presented at the Southern Division of the American Fisheries Society annual meeting, Wilmington, NC, 16 February 2003.

FIELDS OF STUDY

Major Field: Zoology

Specialization: Aquatic Ecology