DISTRIBUTION OF LARVAL FISHES IN THE WINFIELD POOL, KANAWHA RIVER, AND DIRECT IMPACTS OF COMMERCIAL NAVIGATION TRAFFIC ON LARVAL FISH SURVIVAL

by

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(ABSTRACT)

Distributions of larval fishes in the Winfield Pool, Kanawha River, West Virginia, were determined by sampling two sites with bongo and push nets. Cyprinids, clupeids, and *Aplodinotus grunniens* dominated collections. Main channel densities were a fraction of the densities along the shoreline, indicating the importance of the shoreline as a nursery. Diel trends in abundance were evident for several taxa, but were likely caused by diel changes in gear avoidance and distribution of larvae. Vertical trends in abundance were apparent for several taxa at the deeper and more lentic sampling site (lower pool). *Aplodinotus grunniens* were generally more abundant near the bottom, especially during daylight. Cyprinids were more abundant near the bottom in mid-June, but displayed no vertical trends on other sampling dates. Clupeids were more abundant at middepth or surface during daylight, while equally dispersed or near the bottom at night. Vertical trends were not evident at the shallower and more lotic site (upper pool) except for *Aplodinotus grunniens*, which displayed the same preference for the bottom, as at the lower site.

Bongo nets were used to collect larval fish from the sailing line before and immediately after barge passage in June and July 1983. The percent of live larvae in samples taken before and after barge passage did not differ (at the $P = 0.05$ level) for either sampling period. High handling mortality and variation among samples may have masked any impacts.

Bluegill (*Lepomis macrochirus*), common carp (*Cyprinus carpio*), walleye (*Stizostedion vitreum*), and channel catfish (*Ictalurus punctatus*) yolk-sac larvae were subjected to experimental high velocity water flows for 60 seconds. Mortality rates (one hour post-exposure) varied significantly among species. Bluegills (smallest larvae) exhibited the lowest survival, followed by common carp and walleyes (intermediate in size). All channel catfish (largest larvae) survived all levels of flow. All species exhibited positive rheotaxis and increased swimming effort in response to water flows, and showed signs of stress immediately following exposure. The addition of suspended sediments decreased bluegill survival but had no effect on channel catfish survival.

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INTRODUCTION

Commercial navigation traffic on the Mississippi River and its tributaries is expected to increase in the future (ANSP 1980; UMRBC 1982; USACE 1983), thereby stimulating concern about the impacts vessel passage may have on fish communities (Nielsen et al. 1986). Direct mortality resulting from barge passage probably is not a significant impact to adult fishes due to their ability to sense and avoid approaching vessels (ANSP 1980), but fish eggs and larvae are less mobile and, therefore, more likely to be affected. Eggs and larvae within the sailing line may be subject to a variety of lethal forces including hull shear (Morgan et al. 1976), entrainment through the propulsion mechanism (abrupt changes in hydrostatic pressure and shear forces), and exposure to the turbulent high velocities within the prop wash. Ichthyoplankton along the shoreline may be subject to lethal drawdowns created by approaching barges (Holland 1987) and vessel-generated waves breaking along the shore (Bhowmik et al. 1982).

Despite the concern that barge traffic may have significant impacts on ichthyoplankton in inland rivers, attempts to study these effects have been scarce (Holland 1987). Aside from investigations into ichthyoplankton distribution patterns only three studies addressing barge impacts on ichthyoplankton have been published. Morgan et al. (1976) subjected eggs and larvae of striped bass (*Morone saxatilis*) and white perch (*M. americana*) to a variety of shear fields in the laboratory, and applied the results (mortality levels) to speculate on the impacts of shear generated by the hull of a moving vessel. Holland (1986a) examined eggs and larvae from samples collected in the main channel of the Upper Mississippi River prior to and immediately after barge passage. Larvae were rarely damaged, but significant increases in damaged freshwater drum (*Aplodinotus grunniens*) eggs did occur. Downstream-loaded barges caused a higher percentage of damaged eggs (50%) than did unloaded-upstream tows (20%). This was attributed to the facts that 1) loaded barges have a greater wetted surface

area and, therefore, larger shear fields, and 2) freshwater drum eggs would be floating in the same direction as the moving barge and would, therefore, be in the shear field longer. Holland (1987) found that dewatering of eggs and larvae of walleye (*Stizostedion vitreum*) and northern pike (*Esox lucius*), at frequencies and durations common to shallows along 50% of the Upper Mississippi River (2-min durations every 3 h; equivalent to 8 barge passages/d) significantly affected survival of larvae, but not eggs.

Relevant studies concerning the impacts of wind-generated waves have documented that wave action can significantly affect survival of fish embryos in shallow areas (Johnson 1961, Kramer and Smith 1962, Rupp 1965, Miller and Kramer 1971, Clady 1976). However, projecting these findings to predict impacts of barge-generated waves is difficult due to differences in frequency, duration, and magnitude. Wind-generated waves can have larger magnitudes and longer durations than barge-generated waves, but significant wind-generated waves might occur only a few times during the year, while barge-generated waves occur several times each day (Bhowmik 1982). The lack of hard data regarding the impacts of vessel-related waves on ichthyoplankton has resulted in conflicting conclusions: ANSP (1980) speculated that barge-generated waves probably would not result in significant impacts, but Sparks (1975, cited in Wright 1982) inferred the opposite.

Previous studies have provided a foundation for a limited understanding of ichthyoplankton distribution trends in rivers, especially for species whose eggs and/or larvae are pelagic, and consequently vulnerable to commonly employed sampling methods (Holland 1986b). Knowledge of distribution patterns is of primary importance in determining which species may be more vulnerable to barge-associated impacts and when impacts occur. Clupeids, cyprinids, and freshwater drum are the three most abundant taxa in Upper Mississippi River ichthyoplankton collections (Holland 1986b). These same taxa, along with catostomids, also dominate Ohio River collections (Pearson and Krumholz 1984). Several researchers have observed higher densities of larvae in near-shore areas than in the main channel (Gale and

Mohr 1978; Lathrop 1982; Holland 1986b). R.W. Flanders (Geo-Marine, personal communication) advised that during daylight sampling on the Ohio River in 1981, larval fish densities were higher along the shoreline than in the main channel, and species compositions in the two habitats similar, except for freshwater drum. Although abundant in the main channel, freshwater drum were rarely captured near shore. However, Holland (1986b) reported that older freshwater drum larvae become prominent in near-shore areas in the Upper Mississippi River.

Substantial data gaps exist to adequately assess direct impacts of barge passage on ichthyoplankton in the Kanawha River, West Virginia, a navigable tributary of the Ohio River. Commercial navigation traffic on the Kanawha River increased 140% during the period 1950-1980, and is expected to increase 65% over 1980 levels by the year 2000 (USACE 1983). A mean of 11.1 tows/day passed through Winfield Locks and Dam (the lowermost dam on the Kanawha River) in 1980 (USACE 1983). Ichthyoplankton composition and distribution data for this river are scarce, and information of this type is needed to determine if and how the Kanawha River ichthyoplankton community differs from other navigable rivers. In addition, information documenting direct mortality of fish larvae caused by tow boat passage would be unique, as such mortality has not been verified. Ideally, it would be desirable to establish the relationship between the mortality of ichthyoplankton and exposure to turbulent high velocity water flows so that one could predict impacts to ichthyoplankton in habitats where velocities are known.

In 1983 and 1984, three separate investigations were conducted to provide information useful in evaluating the direct impacts of barge passage on ichthyoplankton in the Kanawha River. Realizing that the existing data gaps are too substantial to be eliminated by one graduate student, efforts were confined to the following three objectives aimed at addressing direct impacts to larval fish in the main channel: (1) determine spatial and temporal distribution of larval fishes in the main channel of the Kanawha River; (2) investigate (on a

spatial and temporal basis) barge-related direct mortality of larval fish in the main channel; and (3) determine the relative mortality rates of several species of larval fish when subjected to standardized levels of experimental turbulent high velocity water flows.

STUDY AREA

The Kanawha River is a sixth-order stream formed by the confluence of the New and Gauley Rivers in south-central West Virginia, and flows northwesterly to the Ohio River at Point Pleasant, West Virginia (Figure 1). Most of its 188 km are made navigable by locks and dams which create four navigational pools: Gallipolis (river km 0-50), Winfield (river km 50-109), Marmet (river km 109-133), and London (river km 133-146). Average annual discharge at Charleston, West Virginia, on the Winfield Pool (USGS Gage 03198000, river km 87.4, drainage area 29,985 sq km) is 424.8 m^3/s. Maximum daily discharge for water year 1983 was 2916.6 m^3/s on April 25 (Embree et al. 1984).

The Winfield Pool is a heterotrophic system dependent upon allochthonous energy sources (VPISU 1985). Aquatic macrophytes are rare. Deciduous vegetation lines the shoreline except within industrial sections of the Charleston area. The Winfield Pool is lotic and lacking backwaters at the upstream end, grading to a more lentic nature with frequent small embayments (inundated tributaries) in the downstream end.

Two sampling sites were selected in Winfield Pool, representing upper and lower pool conditions. Each site was chosen for its straight channel of at least 1.0 km and lack of underwater obstructions for ease of sampling. Both sites had symmetrical bottom profiles, steep banks, and relatively uniform river depths.

The river at the upper Winfield Pool sampling site (UW), river km 104 (Figure 2), is approximately 200 m wide with a midchannel depth of approximately 4.0 m (during periods of low flow). Water depth increases by as much as 2 m during high flows. Noticeable current flows at all times, and the substrate is predominantly cobble and pebble. At the lower Winfield Pool site (LW), river km 58.6 (Figure 3), water velocities are much reduced, and the substrate

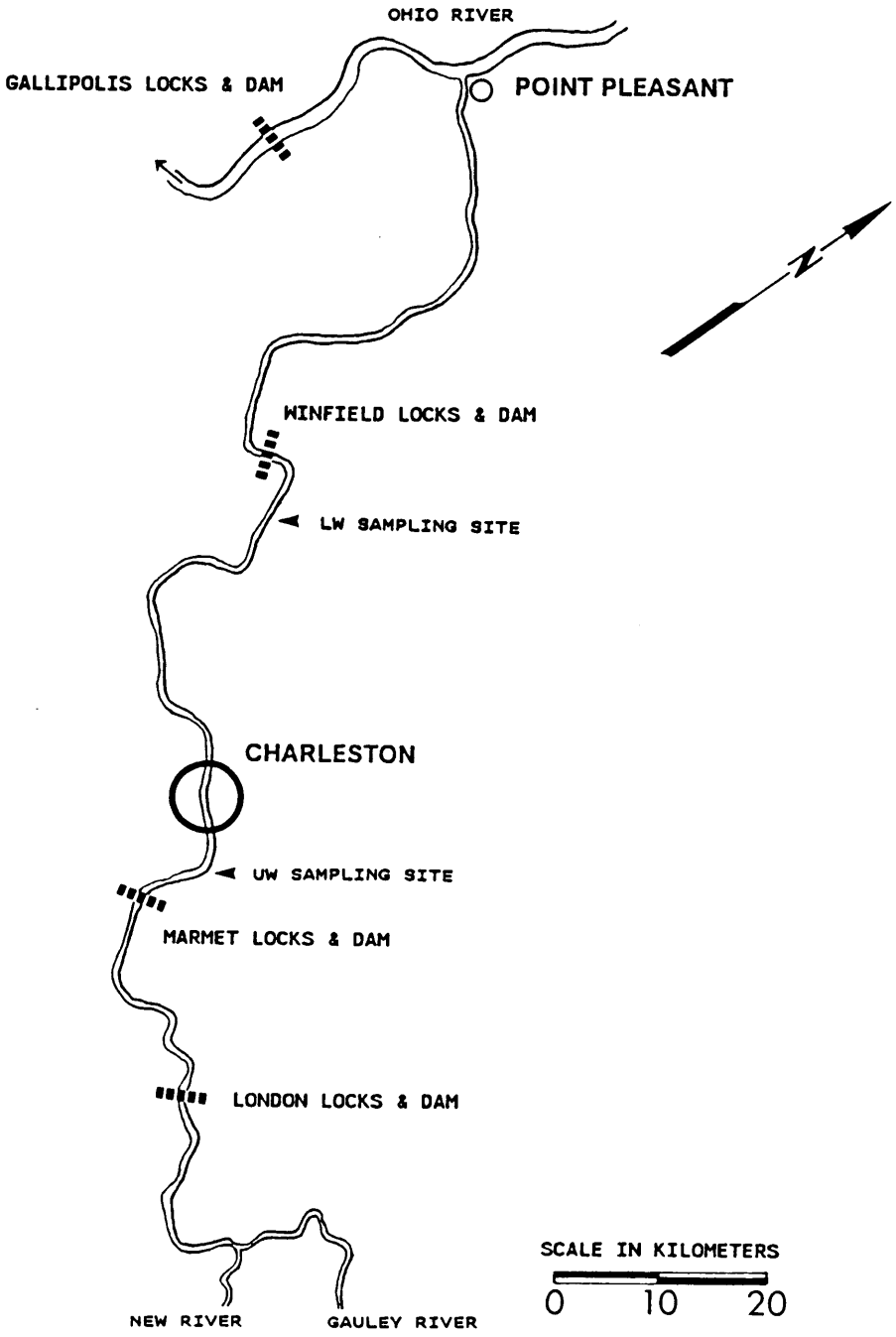

Figure 1. Map of the Kanawha River, West Virginia.

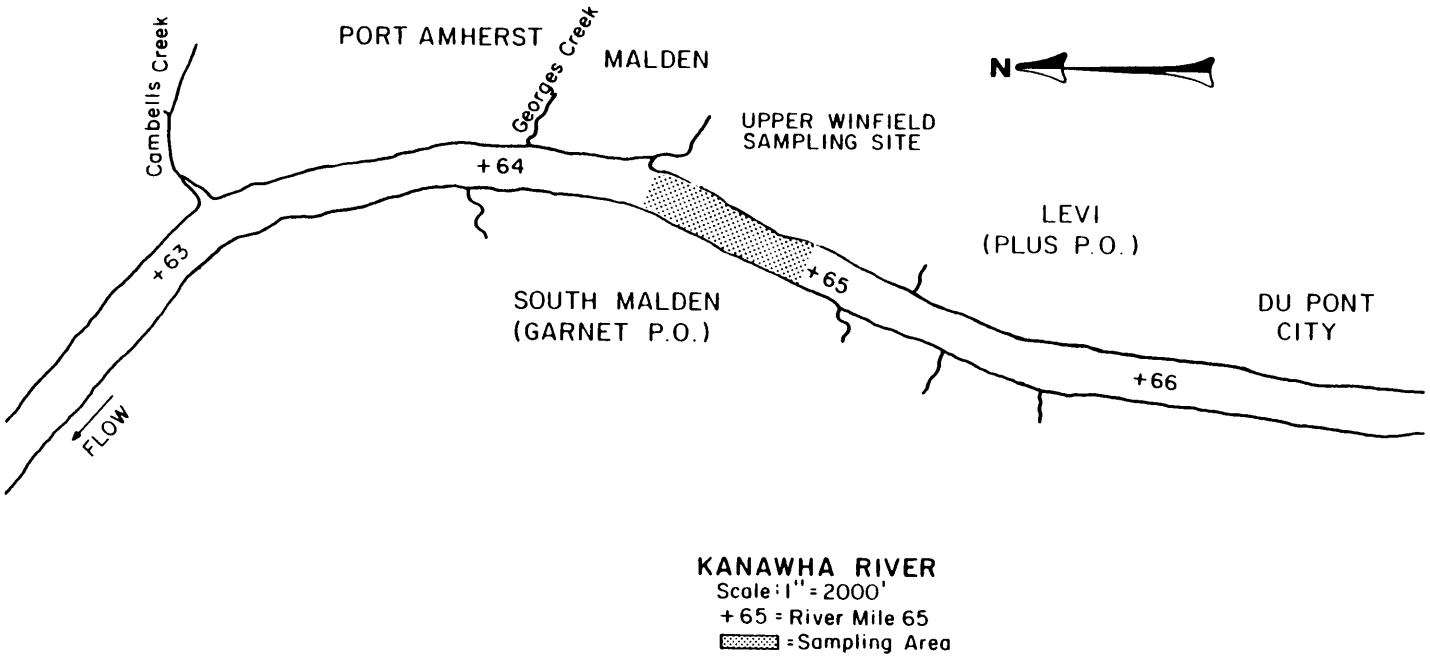

Figure 2. Location of the upper Winfield Pool sampling site (UW), Kanawha River.

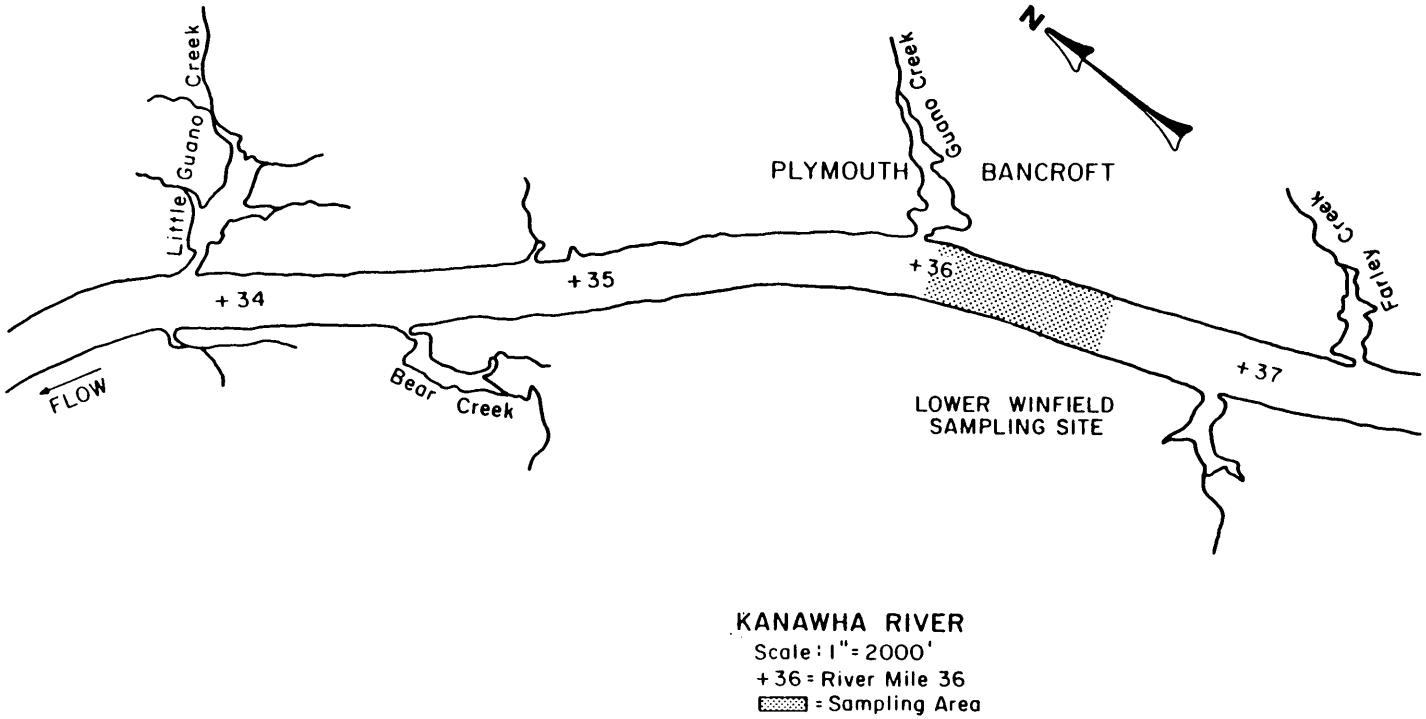

Figure 3. Location of the lower Winfield Pool sampling site (LW), Kanawha River.

is predominantly sand and silt. The river width at LW is approximately 225 m with a midchannel depth of approximately 9.4 m. Water depth does not change noticeably with discharge except during unusually large floods.

The shoreline zone at both sampling sites is characterized by overhanging riparian vegetation, occasional fallen trees extending out into the river, sunken and partially buried logs and woody debris, riprap, and an abundance of industrial and residential refuse. Due to the reduced velocities in this zone, the shoreline substrate is usually sand or silt, and, at LW, mixed with organic matter. A list of fishes known to inhabit the Winfield Pool is presented in Table 1.

Table 1. List of common adult fishes in the Winfield Pool, Kanawha River. Interpreted from catch composition of collections made in 1983 by the Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University.

Common name	Scientific name
Longnose gar	*Lepisosteus osseus*
Gizzard shad	*Dorosoma cepedianum*
Common carp	*Cyprinus carpio*
Emerald shiner	*Notropis atherinoides*
River shiner	*Notropis blennius*
Spotfin shiner	*Notropis spilopterus*
Mimic shiner	*Notropis volucellus*
Steelcolor shiner	*Notropis whipplei*
Bluntnose minnow	*Pimephales notatus*
Smallmouth buffalo	*Ictiobus bubalus*
Silver redhorse	*Moxostoma anisurum*
Golden redhorse	*Moxostoma erythrurum*
Shorthead redhorse	*Moxostoma macrolepidotum*
Channel catfish	*Ictalurus punctatus*
White bass	*Morone chrysops*
Pumpkinseed	*Lepomis gibbosus*
Bluegill	*Lepomis macrochirus*
Longear sunfish	*Lepomis megalotis*
Smallmouth bass	*Micropterus dolomieui*
Spotted bass	*Micropterus punctulatus*
Largemouth bass	*Micropterus salmoides*
White crappie	*Pomoxis annularis*
Sauger	*Stizostedion canadense*
Freshwater drum	*Aplodinotus grunniens*

METHODS

Larval Fish Distribution

Both Winfield sites were sampled six times, five sets from late May until August of 1983, and an additional set in early May 1984 (Table 2).

A total of 40 main channel samples were collected with bongo nets on each of the six sampling trips (Table 2). At UW, two samples were collected during daylight hours at each of six points in the river: near surface and near bottom at 20, 40, and 50% of distance across river from the right descending bank (Figure 4). At LW, two samples were collected during daylight hours at each of seven points in the river: near surface and near bottom at 20 and 40% of distances across river from the left descending bank, and near surface, near bottom, and middepth (4.5 m) at 50% of distance across river (Figure 4). A similar set of nocturnal samples was collected at LW to identify differences in spatial distribution between day and night (Table 2). The midriver sampling points (50% distance across river) were in the approximate sailing line of barge traffic.

Each sample was obtained by towing 0.5-m diameter bongo nets (0.5-mm mesh) upstream at a velocity of approximately 1 m/s for 5 min. Bridleless bongo nets were selected based on the large volume of water that can be sampled in a short time period (Bowles et al. 1978). They are more efficient at catching ichthyoplankton than bridled plankton nets of either 0.5-m or 1-m diameter (Marine Research Incorporated 1975, cited in Bowles et al. 1978). The contents of the paired nets were pooled to constitute one individual sample for each tow. A General Oceanics Model 2030 flowmeter mounted in one of the bongo nets recorded the volume of water filtered with each tow. The flowmeter did not alter the capture efficiency of

Table 2. Summary of sampling activities for analysis of larval fish distribution in the Kanawha River.

Dates	Site and Time	Number of samples	
		Bongo nets	Push nets
5/24-25/83	Lower Winfield Day	14	-
	Lower Winfield Night	14	-
	Upper Winfield Day	12	-
6/14-15/83	Lower Winfield Day	14	-
	Lower Winfield Night	14	-
	Upper Winfield Day	12	-
7/05-06/83	Lower Winfield Day	14	4
	Lower Winfield Night	14	4
	Upper Winfield Day	12	4
7/27-28/83	Lower Winfield Day	14	4
	Lower Winfield Night	14	4
	Upper Winfield Day	12	4
8/09-10/83	Lower Winfield Day	14	4
	Lower Winfield Night	14	4
	Upper Winfield Day	12	4
5/01-02/84	Lower Winfield Day	14	4
	Lower Winfield Night	14	4
	Upper Winfield Day	12	4
Total distribution samples		240	48

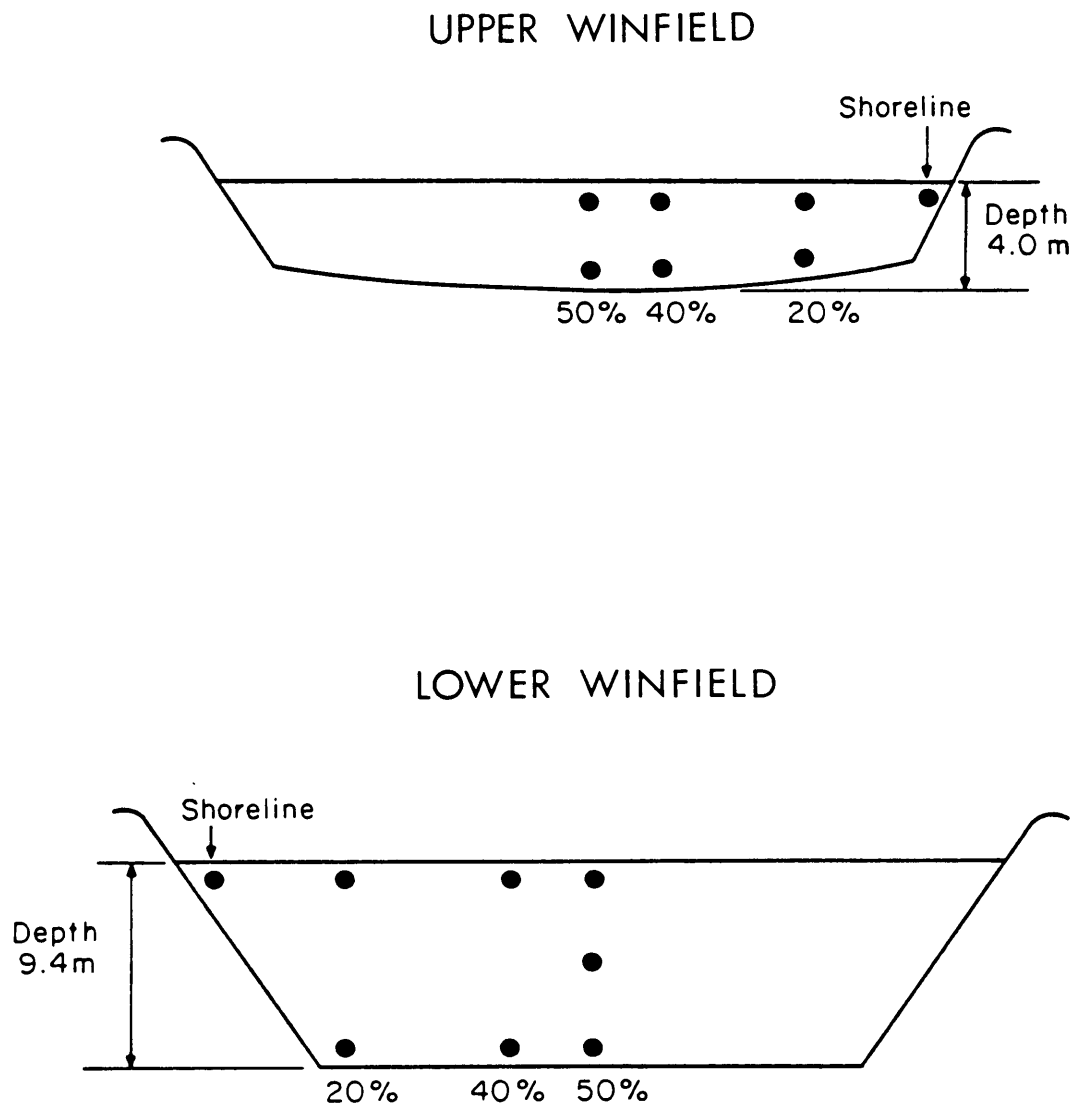

Figure 4. Design of sampling points in the river cross sections (descending views) at both sampling sites in the Winfield Pool, Kanawha River.

the net (Table 3). A mean of 121.9 m^3 of water (range: 100.6-154.0) was filtered by the pair of nets.

Towing depths were determined with a calibrated cable gauge (to measure the length of cable let out) and a clinometer. Depth (d) of the towed nets was determined from:

$$d = (\text{cosine } a)c - h$$

where a = angle of towing cable relative to the vertical axis

c = length of towing cable let out

h = height of cable attachment above water surface

Because these samples were to represent non-impacted larval fish distribution and densities, it was desirable to avoid any potential bias resulting from passage of tow boats. Therefore, the midriver distribution samples were collected no earlier than 90 min after the passage of a barge, and the 20 and 40% samples no earlier than 40 min after barge passage.

During the June 1983 sampling, numerous larvae were observed near the shoreline. The scheduled main channel sampling did not include the shoreline areas, but the apparent abundance of larval fish made sampling of this habitat desirable. Seining was impractical due to numerous submerged obstructions; bongo nets were similarly excluded because of the shallow water and obstructions.

An alternative sampling gear (push nets) was developed and employed beginning in early July 1983. Two WILDCO stream drift nets (mouth diameter 45 x 30 cm, 0.363-mm mesh) were mounted on a metal frame which extended out in front of a 5.2-m aluminum boat. This push net arrangement allowed sampling in water as shallow as 55 cm, and the small outboard-propelled craft could maneuver the nets around obstructions. While in fishing

Table 3. Results of paired comparisons (Wilcoxon Signed Ranks test) between the catch of Net 1 (containing flowmeter) and Net 2 (without flowmeter).

Gear type	Time	Replicates	Mean number of larvae		P-value
			Net 1	Net 2	
Bongo nets	Day	28	29.5	25.0	0.264
Bongo nets	Night	28	28.0	24.5	0.210
Push nets	Day	24	189.4	247.9	< 0.001
Push nets	Night	12	775.9	1022.8	0.002

position, the tops of the nets were approximately 5 cm below the water's surface. A WILDCO Model 39 A10 flowmeter mounted in one of the nets (Net 1) recorded the volume of water filtered during each sample. However, Net 1 was noticeably less efficient at capturing ichthyoplankton than the net without a flowmeter (Net 2) (Table 3). Therefore, only the contents of Net 2 were used to constitute a given sample.

A total of 12 shoreline samples were collected with push nets on each sampling trip from early July 1983 to May 1984 (Table 2). While the main channel bongo-net sampling was being carried out at a site, a second crew simultaneously collected four push-net samples along the shoreline (Figure 4). Beginning at the downstream end of the sampling site, as close to shore as possible, the push nets were lowered into the water and pushed upstream parallel to shore at a velocity of approximately 1 m/s for 5 min. The nets were then immediately raised, rinsed out, and the captured larvae preserved, providing the first sample. The remaining three samples were similarly collected, each beginning at the point along the shoreline where the previous sample terminated. Approximately 200 m of shoreline and a mean of 40.3 m^3 of water (range: 35.7-50.9) were sampled with each "push" sample.

Seven diurnal push-net samples were collected at the surface in the river concurrent with bongo-net sampling (two in early July at UW, three in late July at LW, and two in August at LW) to investigate differences in gear selectivity between bongo and push nets.

All samples were preserved in 5-10% buffered formalin (Taylor 1977) for subsequent counting, measurement, and identification in the laboratory. All larval fish were identified to the lowest practical taxonomic level using information and keys by Hogue et al. (1976) and Auer (1982).

Total lengths of larvae were measured with an ocular micrometer mounted in a stereo dissecting scope. If large numbers of a given taxon were present in a sample, a subsample

was taken by placing the larvae in a water-filled tray marked with a numbered grid pattern. The tray was agitated to disperse the larvae and then allowed to settle. A given grid square was selected with the aid of a random number table. The larva that had its eyeball within and nearest the upper left corner of the selected square was taken for the subsample. This procedure was repeated until a total of 30 larvae had been sampled. Cyprinids (excluding *Cyprinus carpio*) collected along the shoreline were an exception to this; their high abundance and variable size prompted me to collect a subsample size of 40 to insure adequate representation.

Densities of larvae were computed, and a logarithm transformation was used to normalize the data:

$$t = \log_e(y + 0.5)$$

where t = transformed data

y = number of larvae/100 m^3 of water

Analysis of variance (ANOVA) procedures were used to test if larval fish densities in the main channel samples varied with site (UW vs. LW), time (day vs. night), depth, and distance across river. T-tests were used to test if shoreline densities varied with site and time. To test if shoreline densities differed from main channel densities, one-way ANOVA tests were used. For these analyses, surface and bottom bongo-net samples were pooled to give four replicates at each distance across the main channel (20, 40 and 50% distance across river). This pooling increased standard deviation for those instances where surface and bottom samples differed substantially. If an ANOVA test indicated significant differences, a Duncan's Multiple Range test was used to determine which groups (shore, 20, 40, and 50% distance across river) differed.

The above tests were run on each taxonomic group and sampling date, if larvae were abundant enough. Due to the few replicates collected, I felt uncomfortable using a rejection level of 0.10 or 0.05; I opted instead for the conservative level of 0.01. My intent was to screen out artifacts of the data collection, and concentrate on the obvious distribution trends.

Barge-induced Mortality

Mortality resulting from direct physical damage of fish larvae in the vicinity of moving barges was investigated by comparison of mortality in samples collected prior to and immediately after barge passage. Any decreases in percent live larvae were to be attributed to barge impacts. Sampling was conducted during two time periods when larval fish densities were high ($> 15/100\ m^3$): 16-17 June, and 7-9 July 1983.

Samples were collected by towing twin bridleless 0.5-m diameter bongo nets (0.5-mm mesh) for 5 min at a speed of 85 cm/s. R. G. King (Ecological Analysts, Inc., personal communication) advised that towing velocities of 25-50 cm/s might be acceptable for this investigation. However, the boat used had a minimum speed of 70 cm/s. Several reconnaissance tows were made at 70, 76, 85, and 104 cm/s. The percent living larvae in each sample was determined, and based on the results, 85 cm/s appeared to yield adequate numbers of larvae per sample as well as relatively high percentage of living larvae.

Using the criteria described by King (1977) and Hergenrader et al. (1982), I planned to separate larvae immediately after collection into three groups: live, recently killed, and previously dead. King (1977) observed that sacrificed transparent larvae from the Missouri River became opaque within 1-2 h following death. G. F. Cada (Oak Ridge National

Laboratory, personal communication) advised that freshly killed larvae began to turn opaque within 15-30 min, usually starting at the head region; it took at least 1 h for the body to turn completely opaque. Unfortunately, this criterion of identifying recently killed larvae did not work on the Kanawha River because cyprinids and clupeids from the Kanawha River turned opaque immediately upon death or while dying, making identification of recently killed larvae impossible. Therefore, larvae were classified as live or dead. After sorting and counting, the larvae were preserved in 5-10% buffered formalin.

Initial sampling indicated a high variability in percent living larvae, thereby requiring more replicates than originally anticipated. This increase in samples required per site, combined with a time constraint, prompted a decision to concentrate efforts in the area where impacts were expected to be greatest: the sailing line (ANSP 1980). In June, a total 13 pre-passage and 10 post-passage samples were collected at three depths in the sailing line (near surface, middepth, and near bottom). A preliminary review of the June data indicated that even more replicates were needed. Therefore, efforts in July were directed at obtaining adequate replicates for the two upper depth strata (where barge propeller jet velocities are greatest). A total of 25 pre-passage and 16 post-passage samples were collected in July.

Pre-passage samples were collected at midriver between river km 55 and 59.5 (mortality sampling area) no less than 1 h following the passage of a barge. Each sample was sorted into live and dead larvae within 20 min of tow completion. When a barge entered the sampling area, a tow was made beginning approximately 100 m behind the tow-boat, and proceeding in the same direction of travel. Upon completion of the tow, the sample was rushed to the sorting crew for immediate separation. The sampling boat then caught up to the barge and collected another sample. Two or three samples could be collected in this way before the barge left the mortality sampling area. Seven samples containing < 15 larvae were discarded from analysis, leaving 11 pre-passage and 9 post-passage samples from June, and 24 pre-passage and 13 post-passage samples from July.

A two-way layout incorporating treatment (pre-passage vs post-passage) and depth was not recommended for either the June or July data because of the unbalanced sample sizes (J.B. Birch, Department of Statistics, Virginia Polytechnic Institute and State University, personal communication). As an alternative, each month's samples were pooled across depths and a Wilcoxon Rank Sum test (Hollander and Wolfe 1973) was employed to determine if survival differed between collections taken before and after barge passage. A decision level of 0.05 was used for these tests.

Laboratory Experiments

A literature search failed to find any previously conducted research applicable to achieving the objective of this portion of the study. Therefore, a new procedure was developed to subject larvae to three levels of high velocity water flow and turbulence. Two experimental chambers, each consisting of a glass aquarium (interior dimensions of 30-cm width, 75-cm length, 45-cm depth) divided into two compartments, were constructed (Figure 5). Larval fish were confined to Side A of the chamber by a divider constructed of 0.13-mm mesh Nitex netting stretched across a non-toxic plastic frame resting at a 60 degree angle from the horizontal axis. During operation, water entered Side A via two parallel inflow pipes that directed the high velocity water streams in such a manner as to "sweep" down parallel to the inclined divider, minimizing impingement of larvae against the divider while producing turbulent flow within Side A of the chamber. Water height was maintained at a fairly constant level by two 5.1-cm diameter PVC siphons connecting Side B with a constant-level-box equipped with two 7.8-cm diameter PVC spillways. During maximum flow conditions, the mean water level within Side A rose 4.5 cm above a resting water height of 25.5 cm.

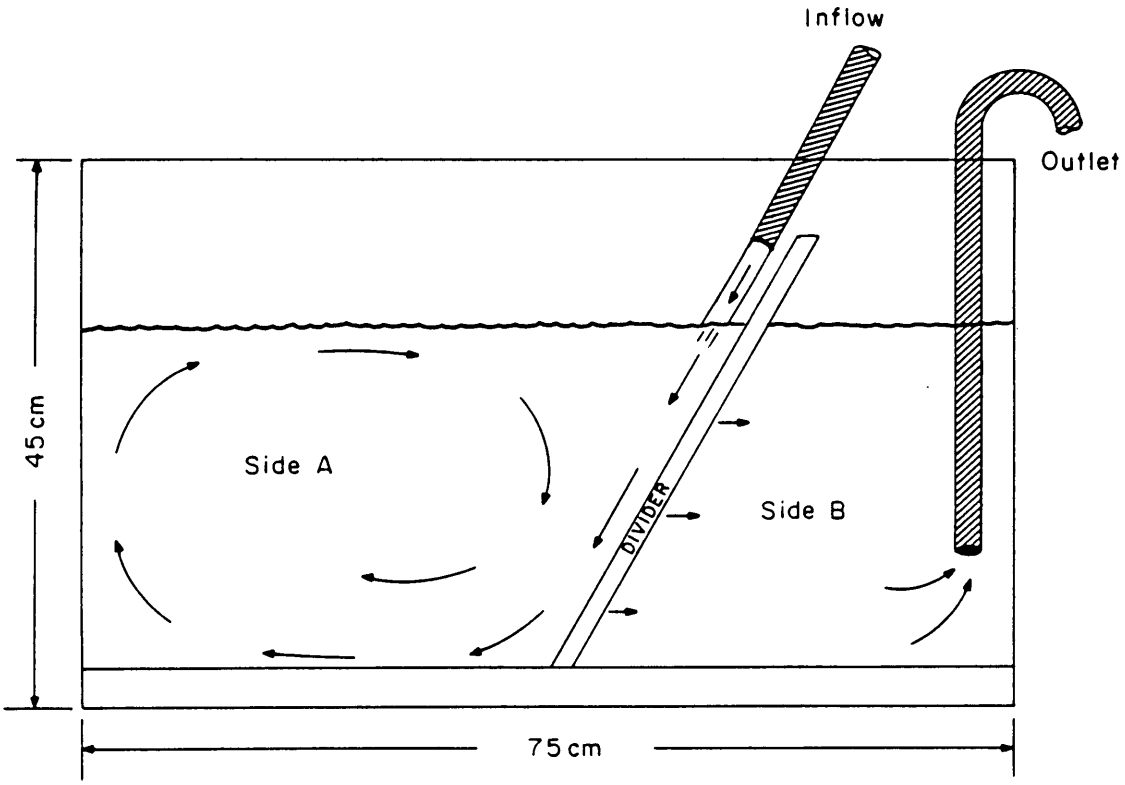

Figure 5. Profile of experimental chamber used to subject larval fish to high velocity water flows.

To eliminate the additional stress of changes in pH and temperature, water for the stress experiments was drawn from the same supply in which the larvae were held. All water was filtered to exclude stray larvae. A gasoline powered centrifugal pump (Homelite Model AP 320-1) supplied the required water pressure, and an adjustable gate valve regulated the flow of water to the chamber. All experiments were conducted in a shaded locality to avoid exposure of larvae to direct sunlight.

Three levels of turbulent high velocity flow were used to stress larval fish (Table 4). These flows were governed by the use of two sets of inflow pipes (0.9 and 1.3-cm inside diameter) and two inflow velocities (800 and 1000 cm/s). An inflow velocity of 1000 cm/s with the 1.3-cm inflow pipes was not possible due to limitations of the water pump.

Larval walleyes, carp (*Cyprinus carpio*), bluegills (*Lepomis macrochirus*), and channel catfish (*Ictalurus punctatus*) were subjected to the experimental flows within 2 d of swim-up. Walleye larvae were obtained from King and Queen State Fish Hatchery, Stephensville, Virginia, and experiments were conducted at the hatchery. Carp eggs and sperm were stripped from spawning adults collected from the Duck Pond, Blacksburg, Virginia, and fertilized eggs were reared in the laboratory. Recently hatched bluegill larvae were collected off nests in Bull Pond, Christiansburg, Virginia. Channel catfish yolk-sac larvae were obtained from Kurtz's Fish Hatchery, Elverson, Pennsylvania. Carp, bluegill, and channel catfish were reared in the laboratory until swim-up. Experiments involving these species were conducted at Cheatham Hall, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Six replicate experiments were run for each of the three flows and each species, except for two cases (Table 4). Bluegill differed, with nine replicates done for Treatment A (1000-cm/s inflow velocity, 0.9-cm pipes, 1.27-L/s discharge). Channel catfish were not subjected to Treatment B (800-cm/s inflow velocity, 0.9-cm diameter inflow pipes, 1.02-L/s discharge) because no mortality occurred at higher flows.

Table 4. Flows used within experimental chamber, and number of replicates for each species.

Treatment	Experimental conditions	Number of replicates			
		Bluegill	Walleye	Carp	Channel catfish
A	1000-cm/s inflow velocity 0.9-cm diameter inflow pipes 1.27-L/s discharge	9	6	6	6
B	800-cm/s inflow velocity 0.9-cm diameter inflow pipes 1.02-L/s discharge	6	6	6	0
C	800-cm/s inflow velocity 1.3-cm diameter inflow pipes 2.12-L/s discharge	6	6	6	6

For each replicate, the pump was started, the controlling valve opened to a predetermined setting, and at least 50 larvae were placed in Side A of the chamber (water level 25.5 cm) and allowed to disperse. Two ball valves (one per inflow pipe) were opened simultaneously, bringing the water flows to treatment level. The ball valves were closed simultaneously after 1 min, stopping the experimental treatment. Approximately 30 min later, the water level within the chamber was slowly lowered to 3.5 cm, and the chamber removed to a counting platform where the larvae remained undisturbed until 1 h had elapsed since exposure to the turbulence. The numbers of dead and live larvae were then counted. Larvae that did not respond to both the touch of forceps and immersion in 10% formalin were considered dead.

A control group was established for each replicate. At least 50 larvae were placed in the second experimental chamber for at least 1 h and subsequently examined for mortality.

To examine for an effect of sediment, paired experiments, with and without sediment, were conducted with bluegill and channel catfish larvae (Table 5). Two replicates of the experiments were made with bluegill larvae, with sediment concentrations of 220 mg/L added. Four replicates were conducted with channel catfish; two with 220 mg/L, and two with 880 mg/L of sediment. All of these experiments used the same flows as Treatment C (800-cm/s inflow velocity, 1.3-cm diameter inflow pipes, 2.12-L/s discharge). The sediment particles were 0.125-0.150 mm, and obtained from the New River, Montgomery County, Virginia. Weights of sediments were determined with an electronic balance after drying at 60 C for 25 h.

A Kruskal-Wallis test (Hollander and Wolfe 1973) was used to determine if mortality varied among species for Treatment A. A rank analogue of Fisher's Protected LSD (Koopmans 1987) was used to determine which pairs of species differed significantly. The same tests were used within species to determine if mortality varied with experimental treatment. A two sample test of proportions (Zar 1974) was used on each of the paired sediment experiments to determine if the addition of sediment influenced mortality of larvae. Decision level for all tests was 0.05.

Table 5. Number of paired replicates used in determining the effect of sediment on larval fish survival when subjected to experimentally created high velocity water flows.

Species	220 mg/L	880 mg/L
Bluegill	2	0
Channel catfish	2	2

RESULTS AND DISCUSSION

Larval Fish Distribution

Larvae were identified into 10 taxonomic groups (Tables 6-7). Clupeids were not identified below the family level, but were assumed to be predominantly gizzard shad (*Dorosoma cepedianum*) based on adult abundance. Of the several cyprinid species present, common carp was the only one that could be consistently identified to species. The majority of the remaining cyprinids were presumed to be emerald shiners (*Notropis atherinoides*) based on larval characteristics and adult abundance, although adult river (*N. blennius*), spotfin (*N. spilopterus*), and mimic (*N. volucellus*) shiners are common in the Winfield Pool. Adults of several Catostomidae species are common in the Winfield Pool, but only Ictiobinae larvae were collected. Separation of the genera *Ictiobus* and *Carpiodes* was not possible. Ictalurids were represented by one channel catfish collected at LW in late July. Centrarchids were identified to three lower taxa: sunfish (*Lepomis* spp.), crappie (*Pomoxis* spp.), and rock bass (*Ambloplites rupestris*). No black bass (*Micropterus* spp.) larvae were collected. Percidae were not identified below the family level because of extreme similarity in myomere counts and pigmentation (Auer 1982) and because of the presence of species whose larval forms remain to be described (e.g. *Percina copelandi* and *P. oxyrhyncha*). However, all percids collected in early May were likely *Stizostedion* spp. based on observed characteristics. Freshwater drum were common and easily identified to species.

Cyprinids (excluding carp) were the most abundant taxa followed by clupeids and freshwater drum (Tables 6-7). These three taxa composed nearly 98% of the 22,136 larvae collected. This was expected, as these three taxa are abundant in samples from the Ohio and

Table 6. Numbers of larval fish collected with bongo nets in the main channel of the Winfield Pool, Kanawha River. Percentages of column totals in parentheses.

Taxa	May 1-2	May 24-25	June 14-15	July 5-6	July 27-28	August 9-10	Total
Clupeidae	-	-	721 (50.8)	364 (16.3)	2 (9.1)	13 (6.7)	1,100 (28.3)
Cyprinus carpio	-	2 (9.1)	52 (3.7)	52 (2.3)	2 (9.1)	-	108 (2.8)
Cyprinidae (excluding *Cyprinus*)	-	3 (13.6)	442 (31.2)	828 (37.1)	14 (63.6)	149 (76.4)	1,436 (36.9)
Ictiobinae	-	4 (18.2)	48 (3.4)	4 (0.2)	-	1 (0.5)	57 (1.5)
Ictalurus punctatus	-	-	-	-	1 (4.5)	-	1 (<0.1)
Ambloplites rupestris	-	-	1 (0.1)	-	-	-	1 (<0.1)
Lepomis	-	-	7 (0.5)	6 (0.3)	2 (9.1)	-	15 (0.4)
Pomoxis	-	-	4 (0.3)	6 (0.3)	-	-	10 (0.3)
Percidae	3 (100.0)	13 (59.1)	14 (1.0)	11 (0.5)	-	1 (0.5)	42 (1.1)
Aplodinotus grunniens	-	-	118 (8.3)	934 (41.9)	1 (4.5)	30 (15.4)	1,083 (27.8)

Table 6. (Continued)

Taxa	May 1-2	May 24-25	June 14-15	July 5-6	July 27-28	August 9-10	Total
Unidentified	-	-	11 (0.8)	25 (1.1)	-	1 (0.5)	37 (1.0)
Total	3 (100.0)	22 (100.0)	1,418 (100.0)	2,230 (100.0)	22 (100.0)	195 (100.0)	3,890 (100.0)

Dash (-) indicates no larvae collected.

Table 7. Numbers of larval fish collected with push nets along the shoreline of the Winfield Pool, Kanawha River. Percentages of column totals in parentheses.

Taxa	May 1-2	May 24-25	June 14-15	July 5-6	July 27-28	August 9-10	Total
Clupeidae	-	*	*	782 (5.6)	291 (25.1)	24 (0.7)	1,097 (6.0)
Cyprinus carpio	-	*	*	47 (0.3)	-	-	47 (0.3)
Cyprinidae (excluding *Cyprinus*)	-	*	*	12,211 (88.1)	824 (71.0)	3,138 (97.9)	16,173 (88.6)
Ictiobinae	-	*	*	1 (<0.1)	-	-	1 (<0.1)
Ictalurus punctatus	-	-	-	-	-	-	-
Ambloplites rupestris	-	*	*	-	-	-	-
Lepomis	-	*	*	32 (0.2)	21 (1.8)	34 (1.1)	87 (0.5)
Pomoxis	-	*	*	3 (<0.1)	-	-	3 (<0.1)
Percidae	23 (100.0)	*	*	45 (0.3)	24 (2.1)	5 (0.2)	97 (0.5)
Aplodinotus grunniens	-	*	*	734 (5.3)	1 (0.1)	2 (0.1)	737 (4.0)

Table 7. (Continued)

Taxa	May 1-2	May 24-25	June 14-15	July 5-6	July 27-28	August 9-10	Total
Unidentified	-	*	*	2 (<0.1)	-	2 (0.1)	4 (<0.1)
Total	23 (100.0)	*	*	13,857 (100.0)	1,161 (100.0)	3,205 (100.0)	18,246 (100.0)

Dash (-) indicates no larvae collected.
Asterisk (*) indicates no samples taken.

Upper Mississippi Rivers (Holland and Sylvester 1983; Pearson and Krumholz 1984; Sheaffer and Nickum 1986). Total mean density of larval fish was 13.56/100 m^3 of water in the main channel samples, and 885.54/100 m^3 of water in the shoreline samples.

Larval fish were present on all sampling dates with highest densities in June and early July (Table 8). Main channel densities in early May, late May, and late July were too low for statistical analysis and identifying distribution trends. Densities were lower than expected in late May and late July, probably as a result of high river discharge (dilution of larvae as well as downstream flushing) and falling water temperatures (cessation of spawning, and delayed hatching) (Figure 6).

Densities in the main channel samples did not differ significantly ($P > 0.01$) with distance across river (20, 40, and 50%) for any taxonomic group, at any time. However, shoreline densities differed significantly ($P < 0.01$) from main channel densities 65.8% of the time tested for the six most common taxa (*Lepomis*, Percidae, common carp, Cyprinidae, Clupeidae, and freshwater drum). These differences are described in detail in the following taxa subsections.

The gear comparison samples collected in late July and August contained few larvae, and were not useful in comparing gear efficiency. The remaining two push-net samples (collected at UW in early July) had adequate numbers of cyprinids, clupeids, and freshwater drum to compare to bongo net catches (Table 9). Due to the few replicates, no statistical comparisons were attempted; all inferences were made from visually comparing the computed means.

Ictiobinae

Ictiobinae were present late May through August with peak densities in June (Table 8). Pearson and Krumholz (1984) reported that Ictiobinae densities in the Ohio River peak in May. The high discharge immediately prior to the late May sampling is likely responsible for the low densities observed then. Densities were too low to observe distribution patterns except in

Table 8. Mean densities (number/100 m^3) of larval fish collected in the main channel with bongo nets in the Winfield Pool, Kanawha River.

Taxa	May 1-2	May 24-25	June 14-15	July 5-6	July 27-28	August 9-10
Clupeidae	-	-	15.55	7.33	0.05	0.28
Cyprinus carpio	-	0.04	1.14	1.03	0.04	-
Cyprinidae	-	0.06	9.66	16.71	0.31	3.16
Ictiobinae	-	0.09	1.03	0.08	-	0.02
Ictalurus punctatus	-	-	-	-	0.02	-
Ambloplites rupestris	-	-	0.02	-	-	-
Lepomis	-	-	0.15	0.12	0.05	-
Pomoxis	-	-	0.09	0.12	-	-
Percidae	0.06	0.27	0.31	0.23	-	0.02
Aplodinotus grunniens	-	-	2.68	19.19	0.02	0.65
Unidentified	-	-	0.25	0.50	-	0.03
Total	0.06	0.45	30.86	45.31	0.49	4.16

Dash (-) indicates no larvae collected.

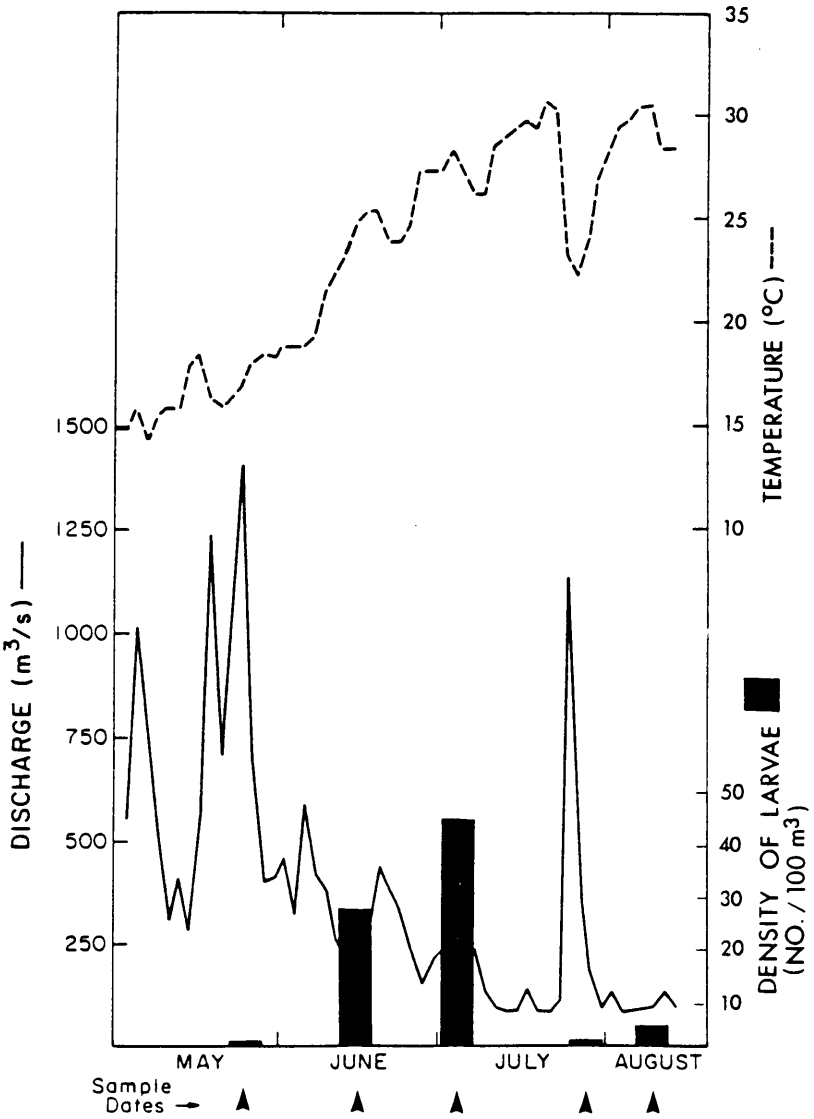

Figure 6. Discharge, temperature, and mean total density of larval fish in the Winfield Pool, Kanawha River, in 1983. Densities are for main channel samples only. Discharge and temperature data are from USGS records for the Charleston, West Virginia, gaging station.

Table 9. Mean densities (number/100 m^3) and lengths (mm) of larvae collected with bongo and push nets near the surface during daylight at Upper Winfield in early July.

	Clupeidae	Cyprinidae	*Aplodinotus grunniens*
Bongo net samples ($N = 6$)			
Mean density	3.62	2.39	11.31
Mean length	4.8	4.7	4.1
Push net samples ($N = 2$)			
Mean density	6.98	12.80	0.00
Mean length	4.9	5.6	-

June, when the only evident trend was higher abundance in the LW night samples than in the LW daylight collections ($P < 0.001$) (Figure 7). The mean length of Ictiobinae larvae did not differ between day (7.2 mm) and night (7.3 mm) at LW in June. A similar trend toward higher night densities has been observed in diel collections of quillback (*Carpiodes cyprinus*) from the Susquehanna River, Pennsylvania (Gale and Mohr 1978; Lathrop 1982).

Pflieger (1975) reported that little is known of the breeding habits of smallmouth buffalo (*Ictiobus bubalus*), the most abundant Ictiobinae in Winfield Pool; however, they reportedly spawn in shallows, scattering their eggs over the substrate, or on submerged or floating vegetation (Auer 1982). Sheaffer and Nickum (1986) found higher densities of Ictiobinae larvae in the main channel of the Upper Mississippi River than in the backwaters, indicating that this taxon may spawn primarily in the main channel. The lack of difference between UW and LW densities of Ictiobinae in June supports this idea because main channel habitats are abundant in both areas of the Winfield Pool.

Lepomis

Lepomis, though not abundant at any time, were present from June until August. Main channel densities were too low to discern any distribution patterns. The majority of sunfish larvae (85%) were captured along the shoreline, with significantly higher densities in the shoreline samples than in the main channel samples on several occasions (Figure 8): early July LW night ($P < 0.001$), late July LW day ($P = 0.009$), late July LW night ($P < 0.001$), and August UW day ($P < 0.001$). Sunfish from the shoreline had a mean length of 6.7 mm, while main channel larvae averaged 4.5 mm. *Lepomis* were absent in the early July gear comparison samples, so it is difficult to state from these results that sunfish larvae were more abundant in the littoral shoreline zone, or if the higher push net densities were just an artifact of greater gear efficiency. However, several authors have reported that in impounded rivers, sunfish larvae are more abundant in backwaters than in the main channel (Hess and Winger

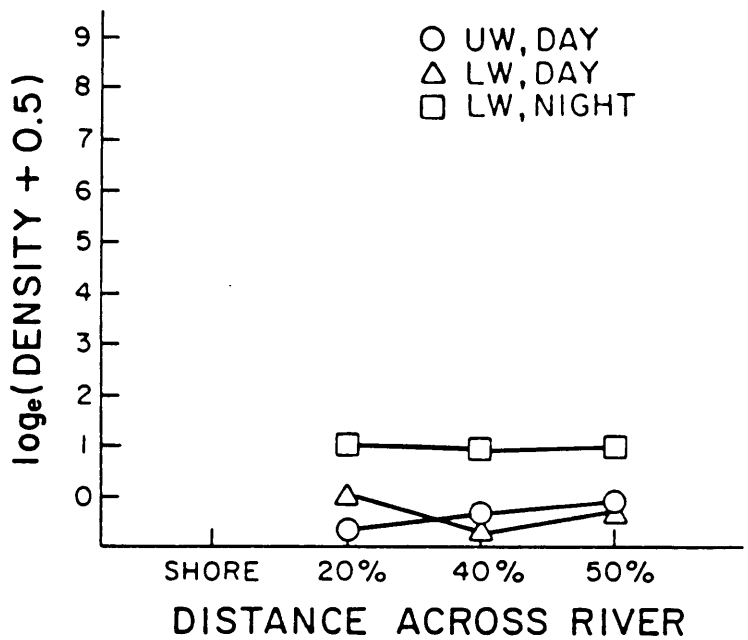

Figure 7. Horizontal distribution of larval Ictiobinae in the Winfield Pool, Kanawha River, in June, 1983.

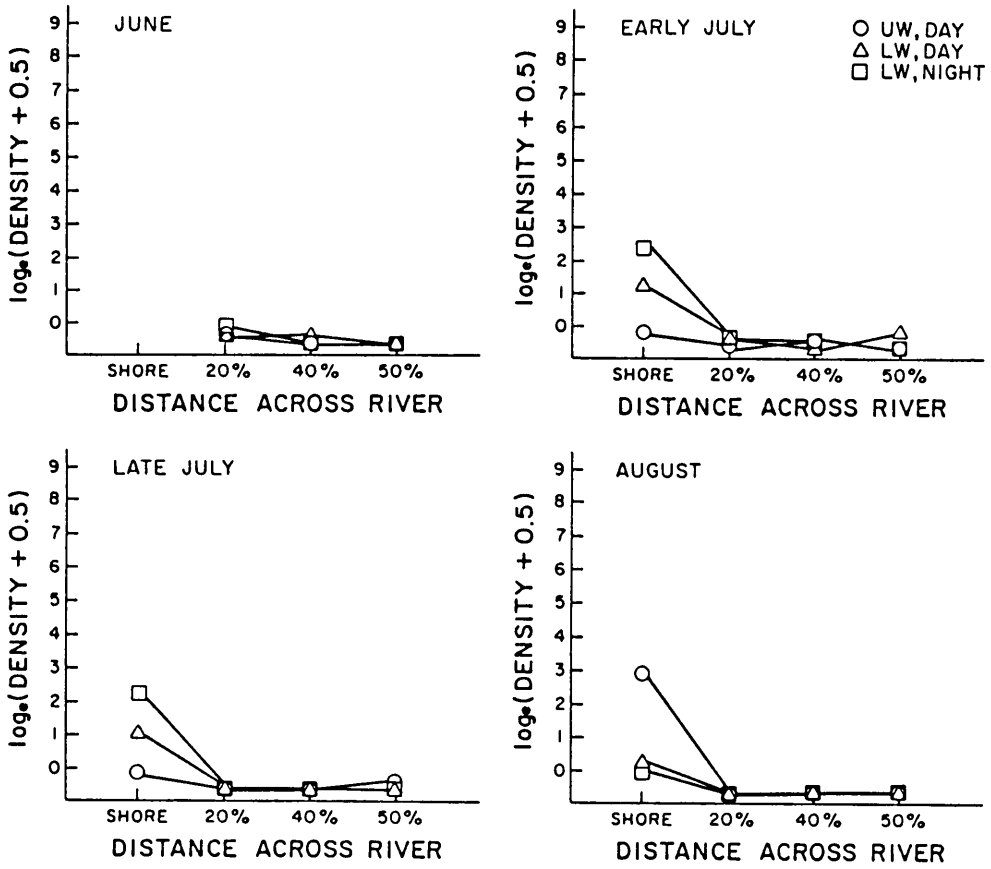

Figure 8. Horizontal distribution of larval sunfish in the Winfield Pool, Kanawha River, on selected sampling dates, 1983.

1976; Holland 1986b; Sheaffer and Nickum 1986), and Holland and Huston (1983) stated that bluegill larvae and juveniles are associated with littoral areas.

Lathrop (1982) reported higher catches of sunfish (*L. gibbosus/macrochirus*) larvae in nocturnal samples, but LW shoreline densities were not significantly higher at night on any sampling date. In early July, sunfish captured along the shore at LW tended to be larger at night than during daylight (mean length 7.5 and 5.8 mm, respectively). Size differences were not apparent in the late July or August samples.

Pearson and Krumholz (1984) stated that sunfish spawn most successfully in embayments of the Ohio River and proposed that the disturbances due to towboat wakes prevent spawning in most portions of the main channel. Therefore, I expected densities in the shoreline samples to be higher at LW than UW. Although mean densities appeared higher at LW than UW, in early and late July, the differences were not statistically significant. In August, shoreline densities were significantly higher at UW than LW ($P = 0.003$), the opposite of what I expected. The larvae captured at UW in August were relatively small (mean length 5.5 mm), indicating that they were from a late spawn. The higher abundance of sunfish larvae along the shoreline at UW indicates that *Lepomis* spawned successfully in the shallows of the mainstem at UW. One possible explanation for this is that the relatively light barge traffic of 8.5 tows/day at UW (USACE 1983) may not affect the spawning success of sunfish nesting along the shoreline to the degree that heavier traffic on the Ohio River might.

Pomoxis

Crappie were not abundant in the samples. Only 13 specimens were collected, 12 of which were captured at UW during daylight in June and early July. The greater abundance at UW suggests that the upper pool may contain better spawning habitat for crappie than the lower pool, despite its lack of embayments. Pearson and Krumholz (1984) indicated that embayments of the Ohio River were not important spawning habitat for crappie. In contrast,

Holland and Huston (1983) stated that crappie densities were generally higher in backwaters of the Upper Mississippi River than in the main channel, with significant drift from backwaters to the main channel occurring at dusk. However, the habitat characteristics of the backwaters of the Upper Mississippi River differ considerably from those of the Ohio River, which are similar to those of the Kanawha River (Nielsen et al. 1986). Crappie are guarding phytophils that can lay their eggs in water as deep as 6.1 m (Pflieger 1975; Holland and Huston 1983), which is considerably deeper than the waters other centrarchids use. The main channel at UW has water depths well within the range that crappie utilize, while most of the main channel at LW is too deep for this genus.

Percidae

Percids were the first larvae collected in the spring (the only taxon collected in early May) and were present until August. They were never abundant in the samples; however, higher densities may have been observed in late May if flooding had not occurred immediately prior to and during sampling (Figure 6). Main channel densities were too low to discern any vertical distribution patterns. The majority of percid larvae (70%) were collected along the shoreline, with significantly higher densities in the shoreline samples than in the main channel samples on several occasions (Figure 9): early May LW night ($P < 0.001$), early May UW day ($P = 0.004$), early July LW night ($P < 0.001$), and late July LW night ($P = 0.002$). Due to inadequate gear comparisons, I am unable to state if higher percid abundance in the shoreline samples is a result of actual distribution patterns, or if push nets are just more effective for capturing percid larvae than are bongo nets.

Diel and site variations in shoreline abundance of percids was evident in early-May only. Percid larvae were absent in the LW daylight shoreline samples, but were consistently present in the shoreline samples from LW at night, and UW during daylight. All larvae collected in the early May shoreline samples were late yolk-sac larvae, with no size difference between sites (mean lengths of 8.2 and 8.6 mm for UW and LW, respectively). It seems unlikely that percid

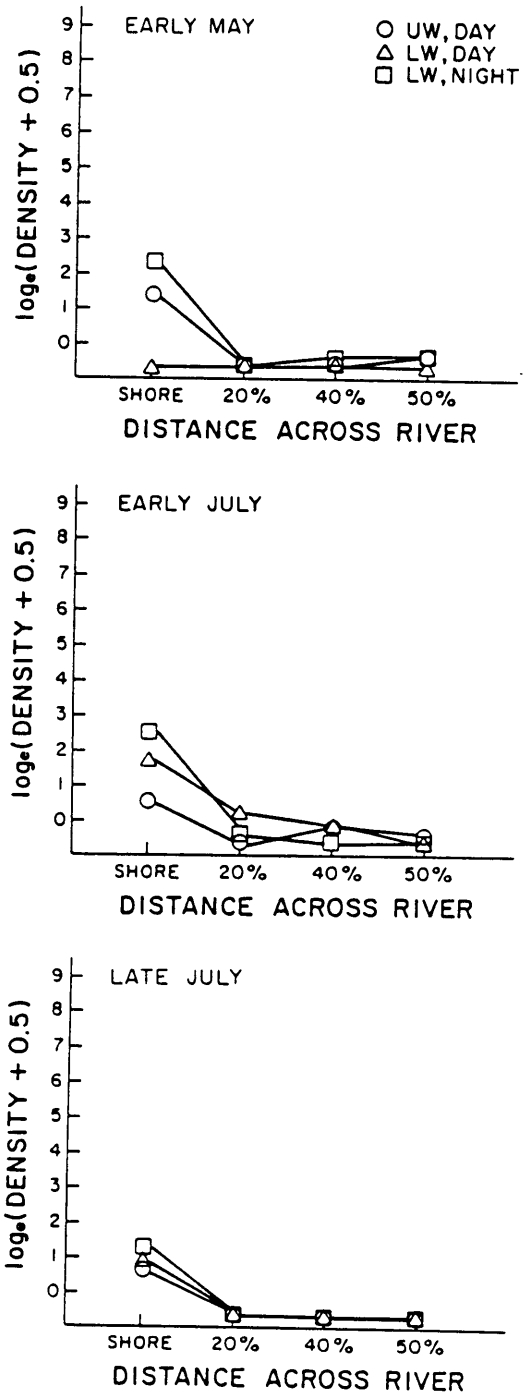

Figure 9. Horizontal distribution of larval Percidae in the Winfield Pool, Kanawha River, on selected sampling dates, 1983 and 1984.

larvae at similar developmental stages would exhibit different diel patterns of shoreline use at the two sites. Therefore, I speculate that early-spawned percid larvae (probably *Stizostedion*) were more abundant at UW than LW, and more vulnerable to capture (or more abundant) at night. Priegel (1970, cited in Gale and Mohr 1978) reported a similar increase in walleye drift catch at night.

Little is known about the distribution and ecology of most larval percids (Holland and Huston 1983); however, spawning habits are known for the walleye and sauger (*S. canadense*). Spawning generally occurs over rock or gravel substrates in shallows 6-37 cm deep (shoreline or shoals). Based on personal observations during field work, UW appears to have more habitat of this type than LW, especially immediately downstream of the Marmet Dam.

Cyprinus carpio

Common carp were present from late May to late July, with highest densities in June and early July (Table 8). In June, carp were absent from the daylight main channel samples at LW, yet were a consistent component at night and at UW during daylight (Figure 10). The observed catch indicates a higher abundance at UW than LW, and less gear avoidance (or higher abundance) at night. In early July, daylight main channel densities of carp did not differ significantly between UW and LW, but catch was still higher at night at LW ($P = 0.001$). Lathrop (1982) reported a similar trend towards higher larval carp catch at night in the Susquehanna River. No carp were captured along the shoreline during daylight in early July at either UW or LW; however, they were common in the nocturnal shoreline samples at LW, with densities significantly higher than the main channel samples ($P < 0.001$). The mean length of carp larvae did not differ substantially between UW and LW, day and night, or shoreline and main channel samples in either June (mean length 6.6 mm) or early July (mean length 7.3 mm).

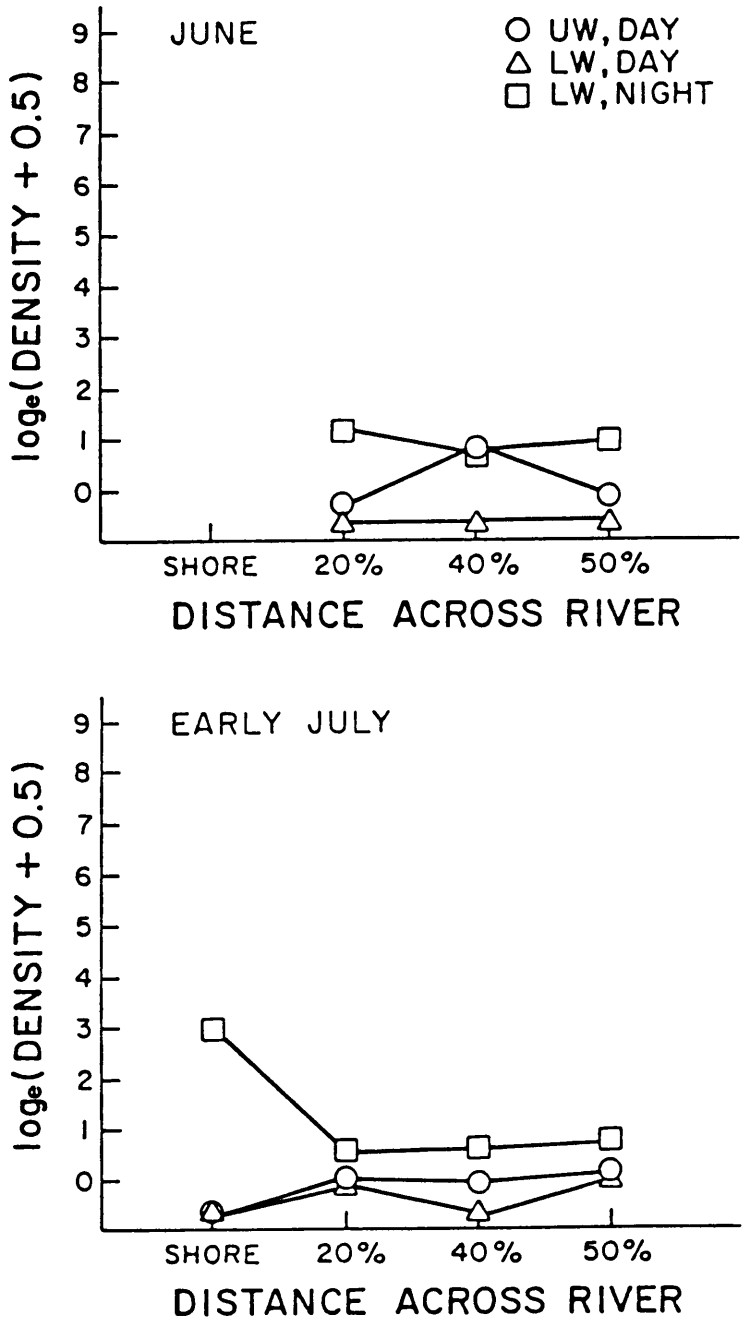

Figure 10. Horizontal distribution of larval common carp in the Winfield Pool, Kanawha River, on selected sampling dates, 1983.

Densities of carp in UW main channel samples did not differ significantly with depth in either June or early July. However, main channel catch did vary with depth at LW (Table 10). In June, carp were absent from daylight LW main channel samples, but present at night, with significantly higher densities near the surface ($P = 0.002$). In early July at LW during daylight, carp were absent from the surface samples, while present in the bottom samples. At night, carp were present in both surface and bottom samples at LW, with no significant difference in densities. The mean length of carp larvae did not differ substantially with depth at either site, for either sampling period.

Cyprinidae

Cyprinids, the most abundant taxon collected (80% of the total catch), were present late May to August, with highest densities in June and early July (Table 8). Most cyprinids (92%) were captured along the shoreline (Tables 6-7). Densities in the shoreline samples were significantly higher than the main channel samples ($P < 0.001$) on all occasions when both habitats were sampled (early July to August) (Figure 11). Holland and Sylvester (1983) observed a similar trend in larval cyprinid daylight distribution in the Upper Mississippi River, with this taxon displaying some "preference" for littoral areas, but Sheaffer and Nickum (1986) reported that at night, larval emerald shiner densities in the Upper Mississippi River did not differ between main channel and backwater samples. In the Kanawha River samples, larval cyprinids were more abundant in the littoral zone (shoreline) during both day and night.

Emerald shiners have been classified as pelagophils (Balon 1975; Pearson and Krumholz 1984; Holland 1986b), and their abundance in main channel samples from numerous river systems confirms this. However, the high abundance of cyprinid larvae in the shoreline samples (most of which were presumably emerald shiners) suggests that cyprinid larvae concentrate (actively or passively) in the shoreline zone. Although the push nets appear over five times more effective than bongo nets at catching cyprinid larvae (Table 6), greater gear efficiency can not account wholly for the extreme differences in densities between main

Table 10. Mean densities (number/100 m^3) of larval common carp in main channel samples in June and early July, Winfield Pool, Kanawha River. UW = Upper Winfield site; LW = Lower Winfield site.

	June			Early July		
	UW Day	LW Day	LW Night	UW Day	LW Day	LW Night
Main channel surface	0.31	-	3.48	0.40	-	2.44
Main channel bottom	2.04	-	1.16	0.93	0.96	1.88

Dash (-) indicates no larvae collected.

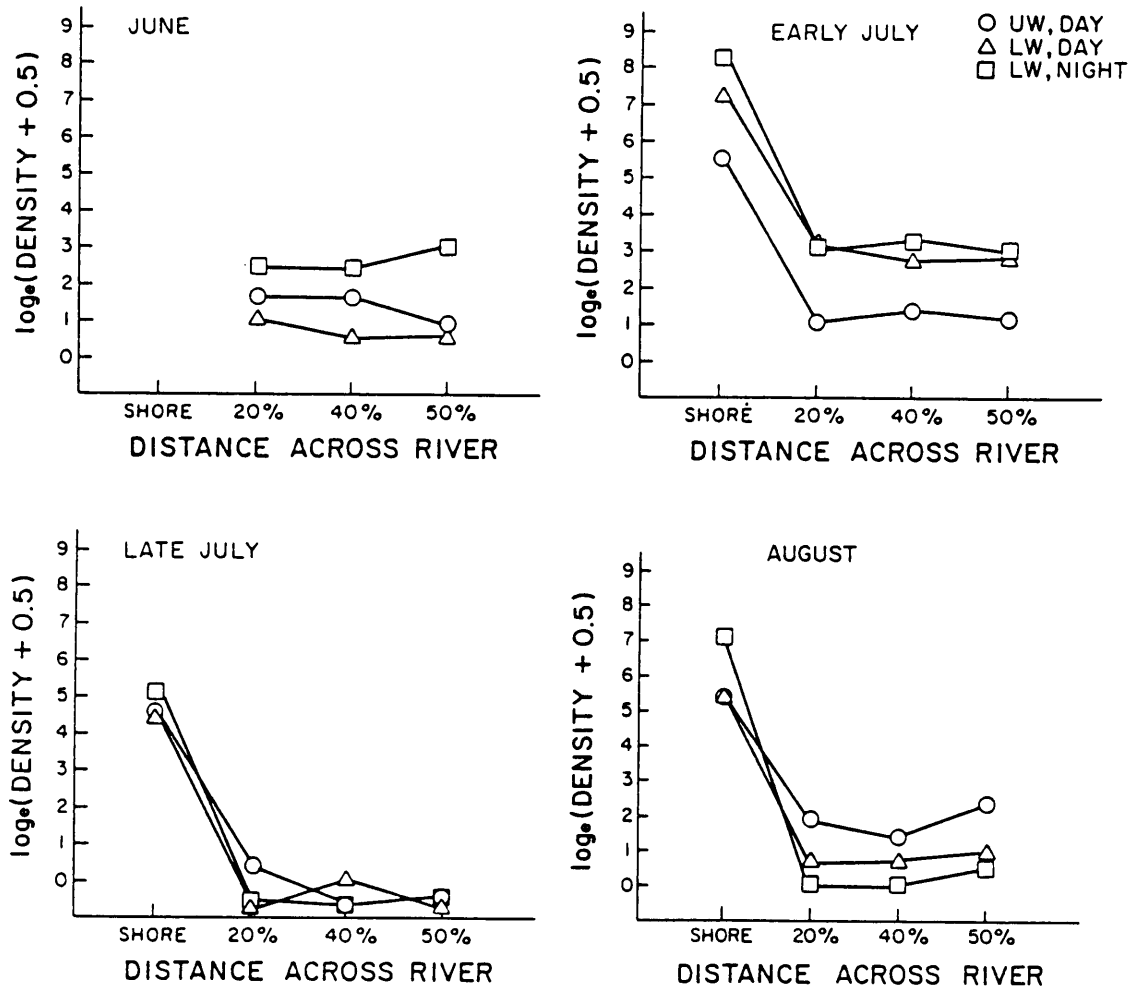

Figure 11. Horizontal distribution of larval Cyprinidae in the Winfield Pool, Kanawha River, on selected sampling dates, 1983.

channel and shoreline samples. The minimum difference between mean densities of cyprinids was observed in August at UW, when shoreline densities were 56 times higher than main channel densities. The mean length of cyprinids collected along the shore usually exceeded that of cyprinids from main channel samples (Table 11), but gear comparison samples provided evidence that the push nets are more effective than the bongo nets at capturing older cyprinid larvae (Table 9).

Cyprinid abundance and size data indicate that while spawning occurs at both sites, conditions may become suitable earlier at UW than LW. Flooding in late May 1983 probably delayed most cyprinid spawning until June, when main channel densities were significantly higher at UW than LW ($P = 0.003$). Main channel cyprinids from both sites were similar in size at this time (Table 11). By early July, main channel densities of cyprinids at LW surpassed those at UW ($P < 0.001$). Again, main channel larvae from both sites were similar in size. Flooding in late July resulted in low catches, and densities at both were similar. By the August sampling period, when discharge and water temperatures had returned to expected levels, main channel densities were higher at UW than LW ($P = 0.007$). The main channel cyprinids collected in August at LW tended to be larger than those in corresponding samples at UW, or from collections made in June or early July (Table 11). While spawning appears to have resumed at UW after the late July flood, the lower abundance and greater size of main channel cyprinids at LW suggests that less spawning was occurring there and most of the larvae present had drifted downstream from upstream spawning sites or were earlier spawned and resident there.

In early July, shoreline densities of cyprinids were significantly higher at LW than UW ($P < 0.001$), as in the main channel samples (Figure 11), and cyprinids collected along the shore tended to be larger at LW than UW. This size difference may indicate transport of young pelagic yolk-sac larvae from the more lotic upstream UW to the more lentic LW, where they

Table 11. Mean lengths (mm) of larval Cyprinidae (excluding common carp) in distribution samples collected from Winfield Pool, Kanawha River. UW = Upper Winfield site; LW = Lower Winfield site.

	June			Early July			Late July			August		
	UW Day	LW Day	LW Night	UW Day	LW Day	LW Night	UW Day	LW Day	LW Night	UW Day	LW Day	LW Night
Main channel surface	4.7	5.1	4.6	4.7	4.9	4.7	7.5	6.1	6.3	4.6	5.7	9.1
Main channel bottom	4.7	4.8	4.8	4.6	4.7	4.6	8.2	5.8	7.3	4.7	5.6	6.4
Shoreline	*	*	*	5.3	6.7	6.4	9.4	7.8	8.2	7.8	6.7	8.0

Asterisk (*) indicates no samples taken.

develop and then congregate in the shore zone. In late July and August, cyprinid shoreline densities did not differ between sites.

Diel differences in cyprinid catch at LW were significant only on two occasions; nocturnal densities were higher than daylight densities for both the August shoreline samples, and the June main channel samples ($P < 0.001$ for both) (Figure 11). Another trend in distribution of cyprinids in the main channel occurred in June only, when main channel densities at LW were significantly higher near the bottom than surface during both day and night ($P < 0.001$ for both) (Table 12). This is opposite of vertical trends of emerald shiner catch in the Upper Mississippi River (Sheaffer and Nickum 1986). Because of the differences between mean densities in the June surface and bottom samples (9.5X and 5.4X higher in the bottom samples during day and night, respectively), it is doubtful that this is an artifact of sampling. However, no adequate explanation for this conflict in findings is apparent. In my June samples, a variety of larval cyprinid taxa were present (though not identified), but larvae whose characteristics resembled published descriptions of emerald shiners were the most common. By early July, and through the remainder of the summer, samples were strongly dominated by these "emerald shiner" larvae, yet vertical trends still did not agree with the findings of Sheaffer and Nickum (1986).

Clupeidae

Clupeids, a relatively abundant taxon, were present from June until August, with highest densities during June (Table 8). During peak densities (in June), the only apparent distribution trend was that clupeids at LW were concentrated near middepth during daylight (one-way ANOVA on the LW midriver samples only: $P = 0.006$). Mean length in June was just over 5 mm (Table 13). Significant differences in vertical distribution at LW were also observed in early July, when clupeids were more abundant at surface than bottom during daylight ($P < 0.001$), but just the opposite at night ($P = 0.009$) (Table 14). Mean lengths of clupeids in early July samples were approximately 5 mm, except for in the LW nocturnal surface samples which

Table 12. Mean densities (number/100 m^3) of larval Cyprinidae (excluding common carp) in main channel samples in June, Winfield Pool, Kanawha River. UW = Upper Winfield site; LW = Lower Winfield site.

	June		
	UW Day	LW Day	LW Night
Main channel surface	3.07	0.54	7.07
Main channel bottom	6.16	5.11	37.80

Table 13. Mean lengths (mm) of larval Clupeidae in distribution samples collected from Winfield Pool, Kanawha River. UW = Upper Winfield site; LW = Lower Winfield site.

	June			Early July			Late July			August		
	UW Day	LW Day	LW Night	UW Day	LW Day	LW Night	UW Day	LW Day	LW Night	UW Day	LW Day	LW Night
Main channel surface	5.3	5.3	5.2	4.8	4.9	6.0	-	12.1	-	7.3	8.6	-
Main channel bottom	5.1	5.1	5.2	4.9	5.4	5.2	14.2	-	-	8.0	-	9.6
Shoreline	*	*	*	4.8	5.2	8.6	15.3	12.6	13.9	9.9	-	9.4

Dash (-) indicates no larvae collected.
Asterisk (*) indicates no samples taken.

Table 14. Mean densities (number/100 m^3) of larval Clupeidae in main channel samples in June and early July, Winfield Pool, Kanawha River. UW = Upper Winfield site; LW = Lower Winfield site.

	June			Early July		
	UW Day	LW Day	LW Night	UW Day	LW Day	LW Night
Main channel surface	6.39	11.68	20.14	3.62	27.31	1.98
Main channel bottom	6.56	8.99	12.76	3.87	4.77	5.73

tended to be larger (6.0 mm). Several authors have reported similar vertical trends in clupeid abundance, with highest densities near the surface and middepth during day, but more even (Tuberville 1979; Holland and Sylvester 1983; Holland 1986b) or higher densities near the bottom (Graser 1979) at night. Densities were too low in LW main channel samples in late July and August to discern any vertical distribution trends. Vertical trends were not apparent at UW on any sampling dates, and may be related to the more lotic characteristics or shallower depth found there.

Several authors have reported that gizzard shad larvae are more abundant in backwater than in main channel habitats and, thus, the adults presumably spawn there (Hergenrader et al. 1982; Gallagher and Conner 1983; Holland 1986b; Sheaffer and Nickum 1986). Swimming patterns of the young larvae, however, make them subject to transport by currents into the main channel (Holland 1986b). I anticipated higher densities of clupeids at LW than UW because of the greater abundance of backwaters in the lower end of Winfield Pool, but abundance did not differ between sites in June. However, in early July, daylight densities were significantly higher at LW in both main channel and shoreline samples ($P < 0.001$ for each) (Figure 12). Clupeids captured during daylight at both sites averaged approximately 5 mm in length for both main channel and shoreline samples in June and early July (Table 13). Clupeids were common in the daylight shoreline samples in late July, and densities were not significantly higher at LW than UW ($P = 0.028$). Mean lengths were in excess of 12 mm. In August, clupeids were essentially absent from the LW daylight samples (one specimen); at UW, 11 larvae were collected in the main channel, and they were common in the shore samples. The size of these clupeids indicated they were probably spawned in late July or early August (Table 13).

Clupeids used the shoreline zone extensively, as indicated by the numerous times shoreline densities significantly exceeded those in the main channel (Figure 12): early July during daylight at both sites; late July at both sites during daylight and at LW at night; and

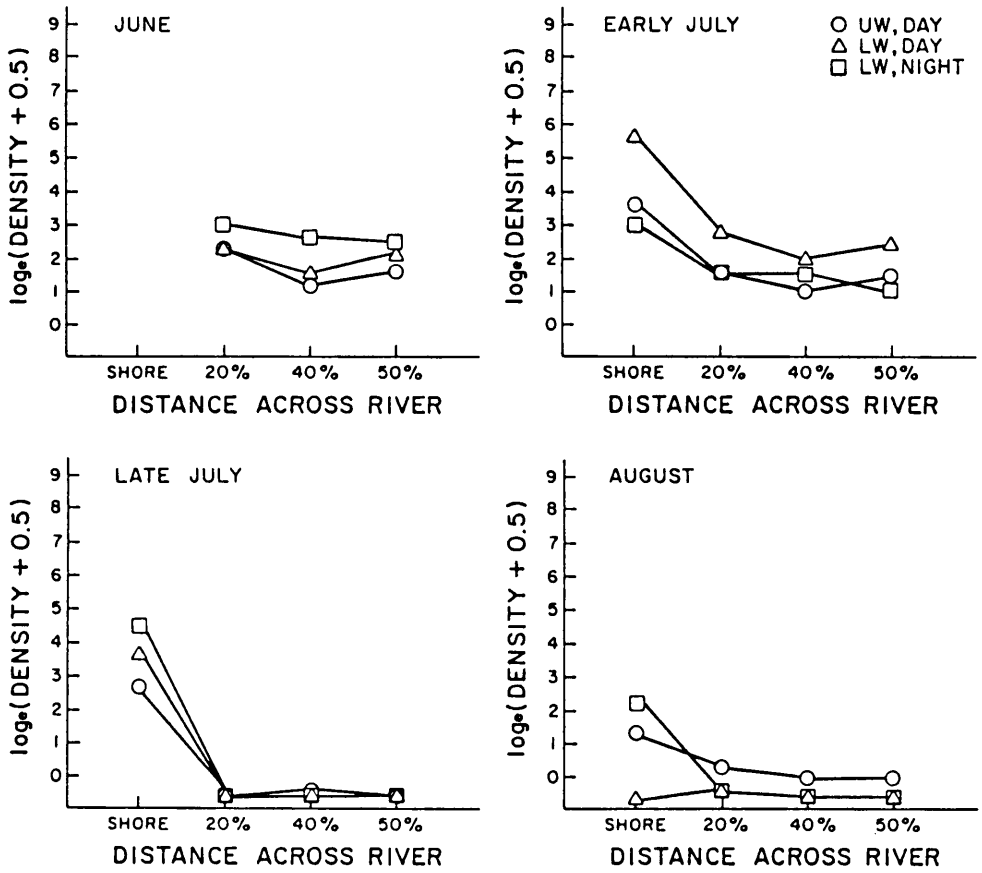

Figure 12. Horizontal distribution of larval Clupeidae in the Winfield Pool, Kanawha River, on selected sampling dates, 1983.

August at LW at night ($P < 0.001$ for all). Gallagher and Conner (1983) found push nets more effective for capturing gizzard shad than towed nets. The limited gear comparisons at UW in early July confirm this result (Table 9), but greater gear efficiency (2X) can not account wholly for the high densities in the shoreline samples (minimum significant difference in mean densities: 10X at UW in early July). The high abundance in the littoral shoreline zone is similar to the high densities found in backwaters of other river systems (Gallagher and Conner 1983; Holland 1986b; Sheaffer and Nickum 1986).

Diel differences in clupeid catch were apparent in early July main channel samples at LW, with significantly higher densities during day than at night ($P < 0.001$) (Figure 12). At night at LW, clupeids captured in the main channel near the bottom were similar in size to those collected during daylight (mean lengths < 6 mm), but clupeids near the surface and along the shore tended to be somewhat larger (Table 13). Graser (1979) reported a similar diel variation in catch of clupeids (day exceeding night), with the nocturnal decline attributable to a 14-fold decrease in catch of small larvae (< 5 mm). Tuberville (1979) observed such a trend, but only for clupeids less than 10 mm in length; for larger larvae, the reverse was observed (night exceeding day). In late July, clupeid catch along the shore did not differ significantly between day and night, even though mean lengths exceeded 10 mm. High turbidity due to flood flows may have reduced daylight net avoidance, or altered clupeid distribution (Matthews 1984). In August, clupeids were not captured along the shore at LW during daylight, but they were relatively abundant in the night samples. The mean length of these clupeids was 9.4 mm, and visibility was much better than in late July.

Aplodinotus grunniens

Freshwater drum were present from June to August, with peak densities occurring in early July (Table 8). Main channel densities in late July and shoreline densities in late July and August were too low to identify distribution trends. Densities differed between sites only in June, when main channel densities were higher at UW than LW ($P < 0.001$) (Figure 13).

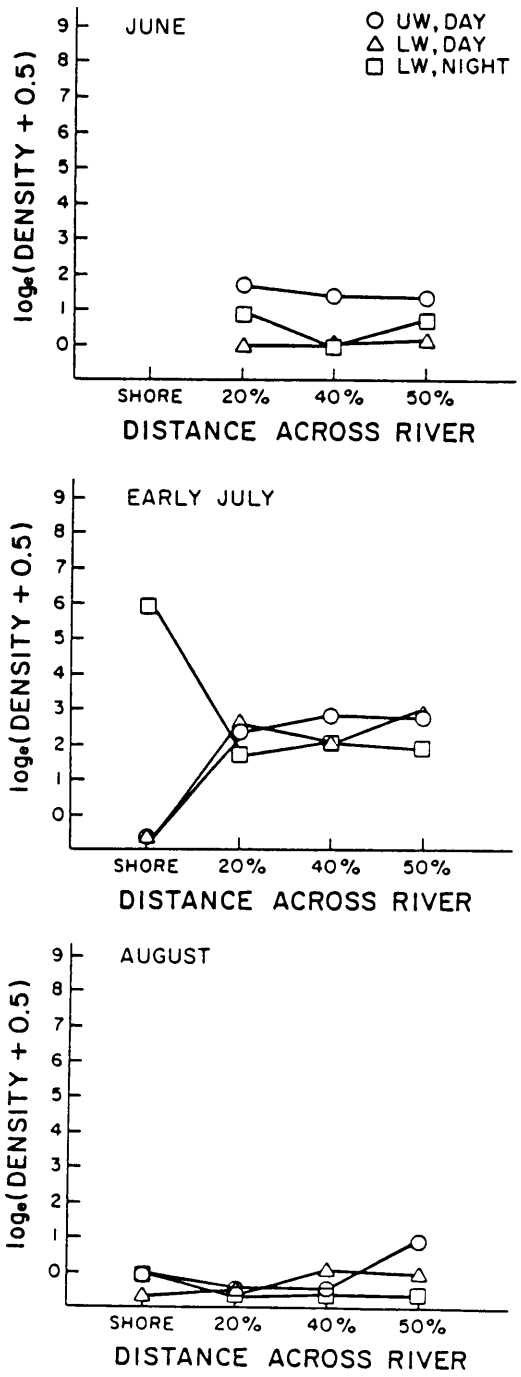

Figure 13. Horizontal distribution of larval *Aplodinotus grunniens* in the Winfield Pool, Kanawha River, on selected sampling dates, 1983.

Holland and Sylvester (1983) found evidence that freshwater drum larvae accumulate in the lentic waters immediately above navigation dams on the Upper Mississippi River. I observed no such trend in freshwater drum catch in my samples; however, my lower site was several kilometers upstream of Winfield Dam.

Diel differences in main channel densities at LW were not significant except in August ($P < 0.001$), when freshwater drum were captured during daylight, but absent at night. Diel differences in shoreline catch were obvious in early July. Although freshwater drum were abundant in the daylight main channel samples at both sites in early July, they were absent from the daylight shoreline samples. At night, however, shoreline densities at LW far exceeded main channel densities ($P < 0.001$). Freshwater drum larvae captured along the shoreline in early July tended to be larger than freshwater drum collected in the main channel samples (Table 15). Nearly all larvae captured along the shore had well-developed eyes, a large mouth, and had begun exogenous feeding (food items in gut), while most freshwater drum from the main channel were yolk-sac larvae. Gallagher and Conner (1983) and Holland and Sylvester (1983) reported freshwater drum to be essentially absent from daylight backwater and shoreline collections, but abundant in night collections. Gallagher and Conner (1983) also reported that their nocturnal backwater samples contained less than 10% protolarvae (young larvae lacking distinct median fin rays or spines).

In the June main channel samples, freshwater drum were more abundant near the bottom than near the surface during both day and night: LW day ($P < 0.001$), LW night ($P = 0.003$), and UW day ($P = 0.003$) (Table 16). A similar trend was evident in August during daylight: LW day ($P = 0.003$) and UW day ($P = 0.010$). During peak abundance in early July, densities in the near bottom samples were not significantly higher than in the near surface samples. Freshwater drum appeared very abundant in the two daylight middepth samples collected at LW in early July; however, densities in these samples did not differ significantly from surface and bottom at the 0.01 level (one-way ANOVA on the LW midriver samples only: $P = 0.038$).

Table 15. Mean lengths (mm) of larval freshwater drum in distribution samples collected from Winfield Pool, Kanawha River. UW = Upper Winfield site; LW = Lower Winfield site.

	June			Early July			Late July			August		
	UW Day	LW Day	LW Night	UW Day	LW Day	LW Night	UW Day	LW Day	LW Night	UW Day	LW Day	LW Night
Main channel surface	4.5	-	3.2	4.1	4.5	4.5	-	4.2	-	4.8	-	-
Main channel bottom	4.7	3.9	4.3	4.2	4.7	4.5	-	-	-	4.6	5.6	-
Shoreline	*	*	*	-	-	5.6	-	-	8.5	5.0	-	6.5

Dash (-) indicates no larvae collected.
Asterisk (*) indicates no samples taken.

Table 16. Mean densities (number/100 m^3) of larval freshwater drum in main channel samples in June, early July, and August, Winfield Pool, Kanawha River. UW = Upper Winfield site; LW = Lower Winfield site.

	June			Early July			August		
	UW Day	LW Day	LW Night	UW Day	LW Day	LW Night	UW Day	LW Day	LW Night
Main channel surface	2.02	-	0.44	11.31	12.79	7.08	0.14	-	-
Main channel bottom	9.31	2.27	3.52	24.85	24.42	15.73	2.56	1.45	-

Dash (-) indicates no larvae collected.

Holland and Sylvester (1983) reported similar findings, with main channel freshwater drum densities highest near bottom during day, but more equally dispersed at night. Holland (1986b) reported that in the Upper Mississippi River, freshwater drum protolarvae occur primarily in surface waters during both day and night due to their buoyancy (oil globule in yolk sac), but older larvae are found near bottom during day, and migrate upward at night. It is interesting to note that in the Kanawha River samples, mean lengths did not appear to differ with depth and time (Table 15).

Gear selectivity for freshwater drum was evident in the limited comparisons done at UW during daylight in early July. Surface bongo-net samples consistently contained freshwater drum larvae (mean length 4.1 mm), but push-nets samples contained none (Table 9). Gallagher and Conner (1983) noted a similar trend in catch between surface collections made with 0.5-m push nets and a 1.0-m plankton net towed behind a boat. They attributed the observed differences to a greater concentration of freshwater drum larvae at a depth of 50-100 cm. Although the bongo nets used in this study were 0.5-m in diameter, the manner in which they were towed resulted in them sampling a greater depth stratum than that which the push nets sampled.

It is unlikely, however, that the absence of freshwater drum in the daylight shoreline samples in early July was due to gear selectivity (freshwater drum larvae distributed below the depths sampled by the push nets). R.W. Flanders (Geo-Marine, personal communication) observed the following freshwater drum distribution trend while employing a gear type that sampled shoreline habitats thoroughly: high densities of ichthyoplankton were captured along the Ohio River shoreline during daylight using a beach seine, but freshwater drum larvae were scarce in these collections, despite abundance in towed net samples from the main channel. Therefore, I speculate that freshwater drum postlarvae (post-absorption of yolk sac) are abundant in the shoreline zone at night, but move offshore to deeper depths during daylight.

Other Taxa

Only one rock bass larva was collected during sampling, and it was in a relatively late larval stage. Similarly, only one channel catfish was captured. Scarcity of these species was expected, as they tend to be uncommon in ichthyoplankton samples from other navigable rivers (Gallagher and Conner 1983; Holland and Sylvester 1983; Pearson and Krumholz 1984).

Summary

The mean peak density of larval fish (all species combined) observed in this study (45.31/100 m^3) was within the ranges reported for the upper two-thirds of the Ohio River (Pearson and Krumholz 1984). However, peak densities were not observed until early July 1983 in the Kanawha River, while peak densities in the Ohio River occur in May and June (Pearson and Krumholz 1984). The flood that occurred in late May 1983 appears to have negatively affected larval fish abundance in the late spring.

Larval fish species composition in the Winfield Pool of the Kanawha River is similar to that of the Ohio River, with species having pelagic larvae being the most abundant: cyprinids (majority presumed to be emerald shiners), clupeids (primarily gizzard shad), and freshwater drum. Larval species compositions were very similar at UW and LW, except for crappies, which were more abundant at the upper site. Percidae, common carp, Cyprinidae, and freshwater drum were more more abundant at UW than LW at the onset of their spawning seasons, but as their seasons progressed, densities at LW equalled (Percidae, common carp, and freshwater drum) or exceeded (Cyprinidae) those at UW.

In general, the taxa that were common in the main channel were even more abundant along the shoreline. Differential gear efficiency may be responsible for at least some of the differences between shoreline (push nets) and main channel (bongo nets) catch, but the evidence overwhelmingly indicates that the shoreline is an important nursery area for larval fish in the the Winfield Pool of the Kanawha River. Shoreline samples usually had densities

several times higher than main channel samples (significantly higher in 25 out of 41 comparisons). This trend was observed during both day and night for sunfish, clupeids, percids, and cyprinids. Common carp and freshwater drum were essentially absent from the daylight shoreline samples, but at night, their densities were significantly higher in the shoreline samples than in the main channel samples. Heavy use of shoreline habitat was not evident for Ictiobinae or crappie.

The benefits of utilizing the shoreline zone are at least two-fold for larval fish. First, water velocities in the shoreline zone of the Kanawha River are noticeably slower than in the main channel. By remaining along the shoreline, larvae can reduce, if not halt, their downstream movement with little energy expenditure. Second, the shallow littoral habitats along the shore may contain higher concentrations of prey than the main channel. Western (1984) reported that cladocerans were much more abundant along the shoreline than in the main channel of the Kanawha River, and cladocerans were a prey item in the digestive tracts of larval fish collected as bycatch during zooplankton sampling.

Vertical differences were apparent for several taxa at the more lentic site, LW. Freshwater drum were generally more abundant near the bottom at LW, especially during daylight. Common carp displayed a similar pattern, tending to be more abundant in the bottom samples during daylight, but equally dispersed or near the surface at night. Cyprinids were more abundant near the bottom during both day and night in June, but showed no vertical preferences on other sampling dates. Clupeids were more abundant at middepth or near the surface during daylight, while being equally dispersed or near the bottom at night. Vertical differences may occur with other taxa (e.g. Percidae, *Lepomis*) but densities were too low to test. Vertical trends in larval abundance were not evident at UW except for freshwater drum, which showed the same preference for the bottom of the river at UW as at LW. The shallower depth and more lotic nature of UW may restrict some larvae from exhibiting vertical patterns observed in the deeper and more lentic LW.

The reasons for vertical trends in larval fish catch are not wholly understood, and may vary between larval stages. Holland (1986b) stated that recently hatched freshwater drum are abundant near the surface due to the buoyant oil globule in their yolk sacs, but older larvae become photophobic, moving to deep waters during daylight. Balon (1975) related some phototactic responses to oxygen requirements: recently hatched pelagophils (e.g. freshwater drum, emerald shiners) lack well-developed respiratory organs, and their surface orientation maintains the young larvae in the well-oxygenated surface waters during early development. For older larvae that have begun exogenous feeding, phototactic response may be an adaptation related to feeding. Zooplankton exhibit diel vertical migrations, moving down during daylight and back up at night (Wetzel 1975). Observed vertical trends in larval fish catch may result from larvae interacting with prey (zooplankton) movements and the minimum light required for feeding. In addition, reduced avoidance of sampling gear may occur at greater (and darker) depths, biasing catch.

Diel changes in catch varied with species and sampling date, but the general trends were that nocturnal densities either equalled (14 of 25 comparisons) or exceeded (10 of 25 comparisons) those of daylight samples. Clupeids were an exception to this. In early July, diel variations in clupeid catch were similar to those reported by Graser (1979), with daylight densities exceeding those at night. It is not clearly understood to what extent these observed diel differences in catch were influenced by changes in gear avoidance, vertical microdistribution patterns (Gallagher and Conner 1983), and diel movements of larvae between the main channel and the shoreline habitats.

Due to higher catch rates in twilight and night samples, Holland and Sylvester (1983) concluded that direct impacts associated with barge passage may be greatest at night. I disagree with their logic, believing that observed diel variations in catch are caused by diel changes in gear avoidance and inadequacies in sampling design, as the larval fish must be present somewhere within the river system at all times. Many ichthyoplankton distribution

investigations, including Holland and Sylvester (1983) and this study, have employed discrete depth sampling with plankton nets. While useful in identifying vertical distribution patterns, discrete depth sampling often fails to adequately sample all of the water column effectively. If a given species of larvae were concentrated at middepth during the day, and only near-bottom and near-surface samples were collected, then the species would be under-represented in the daylight collections. A change in the distribution of the larvae at night (to near-surface or near-bottom) would make the larvae more susceptible to the sampling regime, thereby, appearing more abundant at night. However, reduced gear avoidance in dim light makes me suspect that at night, larvae may also exhibit less avoidance of an approaching hull, and may be more vulnerable to entering the hull shear field.

Barge-induced Mortality

The percentage of live larvae in pre-passage and post-passage samples did not differ at the 0.05 level for either June or July (Table 17). In June, when samples were dominated by small clupeid larvae (Figure 14), mean survival following barge passage appeared to decline, but the difference was not significant at the 0.05 level ($P = 0.074$). In July, clupeids were replaced by freshwater drum and cyprinids as the dominant components (Figure 14). Survival following barge passage at this time appeared to exceed pre-passage survival, but the difference was not significant at the 0.05 level ($P = 0.123$). The mean sizes of larvae were similar in the June and July sampling periods. It is difficult to speculate on how the change in species composition may have affected the results, but Morgan et al. (1976), as well as this study, found that mortality following exposure to simulated navigation-related stresses can vary among species.

Table 17. Two-sided Wilcoxon Rank Sum tests on barge-induced larval fish mortality data.

	June		July	
	Before	After	Before	After
Number of tows:	11	9	21	13
Mean # of larvae/tow:	55.4	44.0	38.7	28.5
Standard deviation (# of larvae):	50.7	21.6	24.9	15.9
Mean % live larvae:	31.9	18.3	21.5	31.0
Standard deviation (% live):	14.9	16.2	14.3	20.4
P-value:	0.074		0.123	

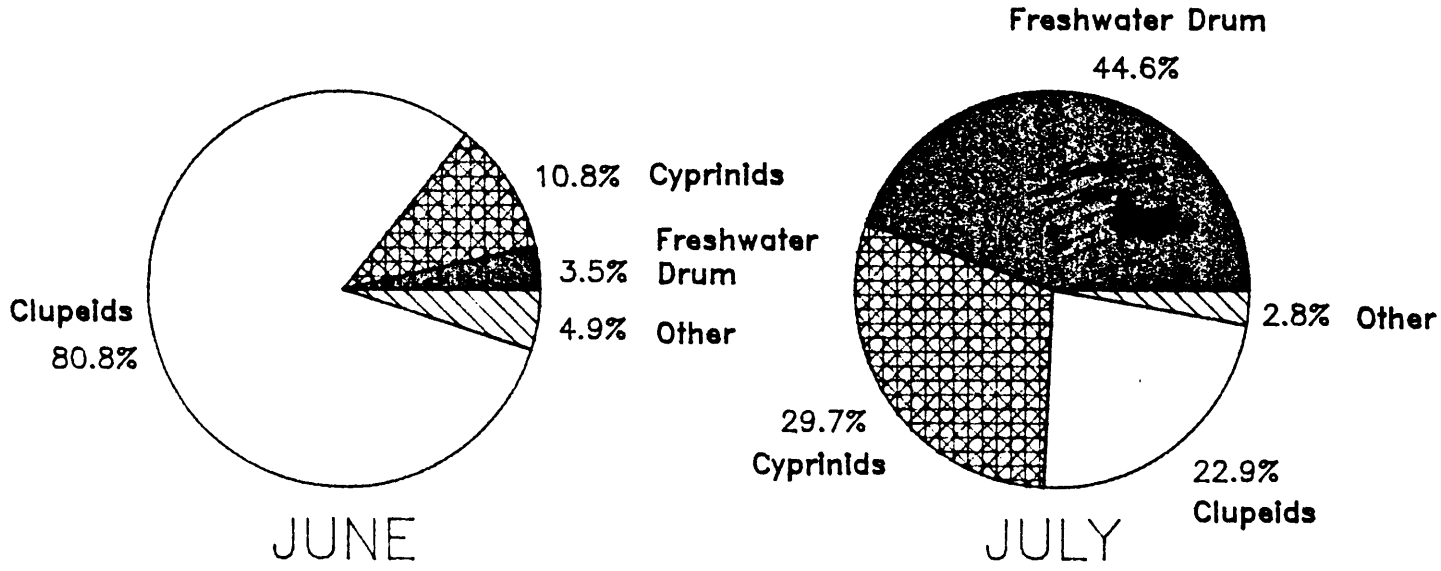

Figure 14. Species composition at the LW sampling site in the Winfield Pool, Kanawha River, during daylight barge mortality sampling.

My inability to document barge-related direct mortality of larval fish is similar to the findings of Holland (1986a). Although a significant increase in the percentage of damaged freshwater drum eggs following barge passage (mean increase of 14%) was observed by Holland (1986a), a similar trend for larvae was not evident. Four explanations for these findings may be plausible. First, barges may not kill or damage significant numbers of larvae. Morgan et al. (1976) reported that striped bass larvae could survive shear forces better than eggs, but eggs and larvae of white perch both had survival rates similar to those of striped bass eggs. Unfortunately, similar information for species common to the Mississippi River drainage is not available. Second, Holland (1986a) suggested that the mixing of non-impacted larvae with impacted larvae within the barge wake may dilute the damaged larvae to an imperceptible percentage. This implies that larvae have a lower barge-associated mortality than eggs; otherwise Holland (1986a) would not have found a significant increase of damaged eggs following barge passage. Third, enormous and variable handling mortality associated with plankton nets may have masked any differences in survival. Fourth, the sampling methodology used in this study (towed plankton nets), as well as by Holland (1986a), may have an additional shortcoming in assessing barge-associated mortality of larvae. Avoidance of nets by larvae is believed to be triggered by visual clues and pressure waves moving ahead of towed nets. The pre-passage samples were collected in relatively calm water, whereas the post-passage samples were collected in the turbulent wake of barges. Turbidity levels may increase following barge passage, reducing visibility, and the turbulence within the wake may disguise the pressure waves of an oncoming net. Reduced avoidance capability could result in a higher percentage of live larvae being captured than if the water's physical conditions matched those existing when the pre-passage samples were taken.

Laboratory Experiments

Mortality due to experimentally created high velocity water flows varied among species (Table 18). For Treatment A (1,000-cm/s inflow velocity), bluegills exhibited significantly higher mortality (20.12%) than all other species ($P < 0.001$ for all), common carp (0.25%) and walleyes (0.35%) did not differ significantly ($P = 0.334$), and channel catfish did not exhibit any mortality. For Treatments B and C (800-cm/s inflow velocities), bluegills exhibited approximately 6% mortality, but the remaining species essentially had none (Table 18). No mortality was observed in the controls. All four species exhibited positive rheotaxis and increased swimming effort in response to water flows, as well as signs of stress immediately following exposure.

Channel catfish (mean length 14.5 mm) were the most robust larvae, with no fatalities observed in any of the experiments. Due to lack of fatalities, channel catfish were excluded from statistical analysis. After exposure, all channel catfish showed signs of stress (reduced swimming and accelerated gill ventilation); some even lay resting on the bottom of the tank or attached to the water surface film. After 15 min, all were swimming about normally. The addition of sediments (up to 880 mg/L) did not decrease catfish survival (100% in all experiments) or alter the stress behavior exhibited (all fish recovered within 15 min).

Walleyes (mean length 8.2 mm) had 100% survival in each of the 800-cm/s inflow velocity experiments (Treatments B and C). Immediately after exposure to these flows, larvae exhibited reduced swimming, with 10-50% of the individuals resting on the bottom of the tank. After 1 h, no larvae had died and more than 99% were swimming normally. Following exposure to 1,000-cm/s inflow velocities (Treatment A) the majority of walleyes (> 50%) lay on the bottom of the tank. After 1 h, a mean mortality of 0.35% had occurred and an additional

Table 18. Mortality of larval fish subjected to experimental turbulent high velocity water flows. Asterisk (*) indicates no experiments conducted.

	Experimental Treatment		
	A[1]	B[2]	C[3]
Bluegill			
Mean % mortality	20.12	6.10	6.00
Standard deviation	11.87	1.54	1.61
Walleye			
Mean % mortality	0.35	0.00	0.00
Standard deviation	0.40	-	-
Common carp			
Mean % mortality	0.25	0.00	0.06
Standard deviation	0.28	-	0.14
Channel catfish			
Mean % mortality	0.00	*	0.00
Standard deviation	-		-

[1] 1000-cm/s inflow velocity, 0.9-cm diameter inflow pipes, 1.27-L/s discharge.

[2] 800-cm/s inflow velocity, 0.9-cm diameter inflow pipes, 1.02-L/s discharge.

[3] 800-cm/s inflow velocity, 1.3-cm diameter inflow pipes, 2.12-L/s discharge.

4.47% (mean) were not swimming properly or were obviously injured. Most of the walleyes that died were missing all or a portion of their yolk sac.

Common carp (mean length 6.6 mm) exhibited a mean mortality of 0.25% in the 1,000-cm/s experiments (Treatment A). For the 800-cm/s experiments, mean mortality was 0.06% (one fatality out of 1,569) for Treatment C, and no mortality in Treatment B. In all three sets of experiments, all carp exhibited reduced swimming, and most either rested on the bottom or attached to the surface film immediately following exposure. After 1 h, nearly all (mean > 99% for all three levels of flow) had recovered.

Bluegills (mean length 5.6 mm) exhibited the highest mortality rates, which varied significantly with water velocity ($P = 0.001$). Mortality in the 1,000-cm/s experiments (mean of 20.13%) was significantly higher ($P < 0.002$) than in either set of 800-cm/s experiments (6.10% mean mortality for Treatment B; 6.00% mean mortality for Treatment C), which did not differ from each other ($P = 0.436$) despite the difference in water volumes pumped through the stress chamber. All bluegills exhibited signs of stress immediately following exposure to water flows (resting on the bottom or attached to the water surface film). After 1 h, numerous larvae still appeared in an unhealthy condition (e.g. sporadic swimming, difficulty remaining upright, resting on the bottom). Removing or counting the ailing bluegill larvae was impractical because of their small size and the numbers involved, but I estimated that at least 40% of the surviving larvae in all replicates of all treatments had not recovered after 1 h. Many of the dead bluegill larvae had a damaged yolk sac, gut tract, or eye. The presence of 220 mg/L of sediment increased bluegill mortality significantly (Run #1, $P = 0.004$; Run #2, $P = 0.003$). The mean difference in percent mortality between runs with and without sediment was 12.87% (Table 19). These results indicate that the presence of suspended sediments can increase mortality levels in fragile species subjected to high velocity water flows.

Table 19. Results of paired experiments to test for effects of sediment on bluegill mortality when subjected to high velocity flows.

	Replicate #1		Replicate #2	
	With sediment	Without sediment	With sediment	Without sediment
Percent mortality:	19.05	7.14	20.43	6.59
Number of larvae in sample:	84	140	93	91
Difference in percent mortality:	11.90		13.84	
P-value:	0.004		0.003	
Mean difference in percent mortality:	12.87			

The procedures employed in this study were relatively effective at achieving the specified objective. Relative mortality rates of different species of larval fish were easily determined, but relating the observed mortality rates to conditions in the field is difficult, as flow patterns within the experimental chamber were not analyzed. Measurements of velocities throughout the chamber would be difficult due to complex turbulent flows, requiring injection of dye and high speed photography. Larval fish mortality varied with inflowing velocity and not with the volume of water passing through the chamber, suggesting that the major cause of mortality was associated with the inflowing jets of water and not impingement against the Nitex divider. Physical damage to larvae was observed, but it was impossible to determine if the damage resulted from exposure to the forces within the water flows, or from abrasive contact with the sides of the chamber or Nitex divider. Further investigations using the methods employed in this study would be useful in identifying species with high susceptibility to barge-associated impacts.

A possible correlation appeared during this experiment: the smallest larvae tested (bluegill) had the lowest survival, while the largest larvae (channel catfish) had 100% survival. Carp and walleye (intermediate in size) had some mortality but considerably less than that experienced by bluegill. Future research should investigate this possible relationship to determine if size of larvae is negatively correlated with mortality resulting from high velocity flows.

Hochstein and Adams (1985) reported that the highest velocities resulting from towboats will normally occur in the midchannel region (sailing line) and in shallow water along the shoreline. Equations presented in their paper predict that propeller jet velocities for a 5,500-horsepower towboat with twin 183-cm props may exceed 650 cm/s within a radial distance of 91.5 cm of the propeller axis. However, as radial distance doubles, maximum propeller jet velocity decreases by 50%. This limits the high velocities of the prop wash to a narrow zone within the river cross section. Hochstein and Adams (1985) predicted that these

midchannel velocities were sufficient to increase temporarily suspended sediments, especially in shallow portions of the river. Their predictions of tow-generated diverging waves indicate maximum wave heights of 30.5 cm, which will create bottom velocities of 290, 119, and 31 cm/s at depths of 15.2, 30.5, and 61 cm respectively, as they break along the shoreline. Hochstein and Adams (1985) predict that wave action will not significantly increase suspended sediments, but their predictions are based on bottom wave velocities occurring at a depth of 61 cm. They failed to discuss what the bottom wave velocities occurring in water less than 61 cm will do to suspended sediment concentrations. These higher velocities will likely increase suspended sediments temporarily. There is a need for future field research to identify changes in suspended solids along the shoreline resulting from barge-generated waves.

It is impossible to say to what extent conditions in the stress chamber simulate the forces larvae in a river may be exposed to; however, inflow velocities were 800 cm/s and higher in the stress chamber. These far exceed those predicted for the shoreline, but are not much higher than potential propeller jet velocities. Based on survival rates observed in the stress chamber, it is likely that some direct mortality will occur for small pelagic yolk-sac larvae entrained through the propellers or subjected to high velocity propeller wash, especially if abrasive suspended sediments are present (high ambient river velocities or tow operation in shallow water). Direct mortality along the shoreline is likely to be negligible except in the very shallow edges less than 15.2-cm deep. Larval fish distribution data show the shoreline to be an important nursery habitat in the Kanawha River. However, all shoreline distribution samples were collected from areas where water depth exceeded 55 cm; the use of habitats less than 15.2 cm in depth is unknown at present and deserves further study.

CONCLUSIONS

The results of this study indicate that the shoreline zone is an important nursery area for larval fish in the Winfield Pool of the Kanawha River. Larval fish were concentrated along the shoreline, with densities of up to two orders of magnitude higher than in the main channel (nocturnal sampling at LW in early July). Species composition along the shoreline was similar to that in the main channel.

Neither this study nor Holland (1986a) found evidence of significant increases in larval fish mortality in the sailing line following barge passage. If high levels of mortality (or damage) of larvae had occurred, it is likely that at least some increase would have been observed, as with the increase in damaged freshwater drum eggs observed by Holland (1986a). However, towed plankton nets (used in this study) do not appear to be well suited for this type of investigation due to high and variable capture-related mortality.

Based on the results of this study, I feel there is a high potential for barge-associated impacts to larval fish along the shoreline. This conflicts with the conclusions of ANSP (1980), who considered the zone of greatest potential impacts to be in the sailing line, and adverse impacts along the shore to be insignificant. Granted, the sailing line is the zone of greatest potential sources of mortality (hull shear, entrainment through the propulsion mechanism, and high velocity flows associated with the prop wash), but larval fish are concentrated along the shoreline, while more dispersed in the main channel. Every barge that passes first creates a drawdown that may dewater shallow areas along the shore. Simulated dewaterings equivalent to eight barge passages per day resulted in significant direct larval fish mortality (Holland 1987). Following drawdown, barge-created waves break along the shoreline. Based on the wave predictions of Hochstein and Adams (1985) and the results of the experimental chamber portion of this study, wave-associated velocities along the Kanawha River shoreline

may be sufficient to kill fragile larvae occupying depths less than 15.2 cm (velocities >290 cm/s). Unfortunately, the use of such habitats (depth <15.2 cm) by larval fish in the Kanawha River was not examined in this study.

Indirect mortality was not addressed by this study but bears mentioning. Wave action may dislodge young yolk-sac larvae from nest sites (e.g. centrarchids) or attachment sites (e.g. common carp), making them subject to predation. Another potential indirect impact became evident during the laboratory experiments. All four species of larvae used in the experimental chamber portion of this study exhibited positive rheotaxis in response to high velocity flows. Their rapid swimming efforts against the flows exhausted the larvae, with most laying on the bottom or attached to the water-surface film for several minutes until they recovered. Not only would the larvae be more prone to predation at this time, but the energy expenditure of these swimming efforts may affect growth, and ultimately, survival.

Overcoming the gaps in our understanding of larval fish ecology and navigation-related impacts will be a challenge. Due to high larval fish abundance in shoreline habitats, it seems logical that future research efforts should begin there. Use of very shallow areas (0-50 cm) subject to drawdowns and wave-associated high velocities should be determined for both eggs and larvae. This goal should not be restricted to river shoreline habitats, but should include backwaters (subject to drawdowns). Examination of prey distribution patterns may be useful in understanding why fish larvae occur where they do. The experimental chamber developed in this study would prove useful in determining if a negative correlation exists between size of larvae and mortality resulting from exposure to high velocities.

Although studies investigating direct mortality along the shoreline could be carried out either in the field or laboratory, investigations into direct mortality out in the sailing line would be difficult. Conditions in the vicinity of a barge (hull shear, entrainment through the propulsion mechanism, and exposure to the prop wash) would be difficult to duplicate in the

laboratory; therefore, the alternative is to attempt another field study. The challenges of effectively sampling prior to and after barge passage are frustrating. Large volumes of water must be sampled (insuring enough larvae per sample) in a manner resulting in a very low handling mortality. Conventional plankton nets sample large volumes of water, but handling mortality is relatively high (e.g. this study). Algae blooms may complicate matters by entangling larvae, making removal of live specimens difficult (L.E. Holland, U.S. Fish and Wildlife Service, personal communication). Until an effective methodology can be worked out, the question of barge-related mortality in the sailing line will remain unanswered.

REFERENCES

ANSP (Academy of Natural Sciences of Philadelphia). 1980. Analysis of the effect of tow traffic on the biological components of the Ohio River. Academy of Natural Sciences of Philadelphia, Philadelphia, Pennsylvania.

Auer, N.A., editor. 1982. Identification of larval fishes of the Great Lakes Basin with emphasis on the Lake Michigan drainage. University of Michigan, Ann Arbor, Michigan.

Balon, E. 1975. Reproductive guilds of fishes: a proposal and definition. Journal of the Fisheries Research Board of Canada 32: 821-864.

Bhowmik, N.G., M. Demissie, and C. Guo. 1982. Waves generated by river traffic and wind on the Illinois and Mississippi River. Research Report Number 167, Water Resources Center, University of Illinois, Urbana, Illinois.

Bowles, R.R., J.V. Merriner, and J. Boreman. 1978. Factors affecting accuracy of ichthyoplankton samples used in power plant entrainment studies. U. S. Fish and Wildlife Service, FWS/OBS 76/20.7.

Cada, G.F. and G.L. Hergenrader. 1978. An assessment of sampling mortality of larval fishes. Transactions of the American Fisheries Society 107: 269-274.

Clady, M.D. 1976. Influence of temperature and wind on the survival of early stages of yellow perch, *Perca flavescens*. Journal of the Fisheries Research Board of Canada 33: 1887-1893.

Embree, W.N., E.A. Friel, F.M. Taylor, and T.A. Ehlke. 1984. Water resources data for West Virginia, water year 1983. U.S. Geological Survey Water-Data Report WV-83-1. U.S. Geological Survey, Charleston, West Virginia.

Gale, W.F., and H.W. Mohr, Jr. 1978. Larval fish drift in a large river with a comparison of sampling methods. Transactions of the American Fisheries Society 107: 46-55.

Gallagher, R.P., and J.V. Conner. 1983. Comparison of two ichthyoplankton sampling gears with notes on microdistribution of fish larvae in a large river. Transactions of the American Fisheries Society 112: 280-285.

Graser, L.F. 1979. Spatio-temporal distribution of clupeid larvae in Barkley Reservoir. Pages 120-138 *in* R.D. Hoyt, editor. Proceedings of the third symposium on larval fish. Western Kentucky University, Bowling Green, Kentucky.

Hergenrader, G.L., L G. Harrow, R.G. King, G.F. Cada, and A.B. Schlesinger. 1982. Larval fishes in the Missouri River and the effects of entrainment. Pages 185-223 *in* L.W. Hesse, G.L. Hergenrader, H.S. Lewis, S.D. Reetz, and A.B. Schlesinger, editors. The middle Missouri River. A collection of papers on the biology with special reference to power station effects. The Missouri River Study Group, Norfolk, Nebraska.

Hess, T.B., and P.V. Winger. 1976. The occurrence and distribution of larval fish in the Cumberland River. Proceedings of the Annual Conference Southeastern Association of Game and Fish Commissioners 30: 295-310.

Hochstein, A.B., and C.E. Adams, Jr. 1985. An assessment of environmental effects of tow movements in the Winfield Pool, Kanawha River. U.S. Army Corps of Engineers, Huntington District, Huntington, West Virginia.

Hogue, J.J., Jr., R. Wallus, and L.K. Kay. 1976. Preliminary guide to the identification of larval fishes in the Tennessee River. Technical Note B19, Tennessee Valley Authority, Norris, Tennessee.

Holland, L.E. 1986a. Effects of barge traffic on distribution and survival of ichthyoplankton and small fishes in the upper Mississippi River. Transactions of the American Fisheries Society 115: 162-165.

Holland, L.E. 1986b. Distribution of early life history stages of fishes in selected pools of the upper Mississippi River. Hydrobiologia 136: 121-130.

Holland, L.E. 1987. Effect of brief navigation-related dewaterings on fish eggs and larvae. North American Journal of Fisheries Management 7: 145-147.

Holland, L.E., and M.L. Huston. 1983. A compilation of available literature on the larvae of fishes common to the upper Mississippi River. U.S. Fish and Wildlife Service, La Crosse, Wisconsin.

Holland, L.E., and J.R. Sylvester. 1983. Distribution of larval fishes related to potential navigation impacts on the upper Mississippi River, pool 7. Transactions of the American Fisheries Society 112: 293-301.

Hollander, M., and D.A. Wolfe. 1973. Nonparametric statistical methods. John Wiley and Sons, Inc., New York, New York.

Johnson, F.H. 1961. Walleye egg survival during incubation on several types of bottom in Lake Winnibigoshish, Minnesota and connecting waters. Transactions of the American Fisheries Society 90: 312-322.

King, R.G. 1977. Entrainment of Missouri River fish larvae through Fort Calhoun Station. Pages 45-46 *in* L.D. Jensen, editor. Fourth national workshop on entrainment and impingement. Ecological Analysts, Inc., Melville, New York.

Koopmans, L.H. 1987. Introduction to contemporary statistical methods, 2nd edition. Duxbury Press, Boston, Massachusetts.

Kramer, R.H., and L.L. Smith, Jr. 1962. Formation of year classes in largemouth bass. Transactions of the American Fisheries Society 91: 29-41.

Lathrop, B.F. 1982. Ichthyoplankton density fluctuations in the lower Susquehanna River, Pennsylvania, from 1976 through 1980. Pages 28-36 *in* C.F. Bryan, J.V. Conner, and F.M. Truesdale, editors. Proceedings of the fifth annual larval fish conference. Louisiana Cooperative Fisheries Research Unit, Louisiana State University, Baton Rouge, Louisiana.

Marine Research Incorporated. 1975. Entrainment investigations and Cape Cod Bay ichthyoplankton study: June-August, 1975. (unpublished manuscript)

Matthews, W.J. 1984. Influence of turbid inflows on vertical distribution of larval shad and freshwater drum. Transactions of the American Fisheries Society 113: 192-198.

Miller, K.D., and R.H. Kramer. 1971. Spawning and early life history of largemouth bass (*Micropterus salmoides*) in Lake Powell. Pages 73-83 *in* G.E. Hall, editor. Reservoir fisheries and limnology. Special Publication Number 8, American Fisheries Society, Washington, D.C.

Morgan, R.P., II, R.E. Ulanowicz, V.J. Rasin, Jr., L.A. Noe, and G.B. Gray. 1976. Effects of shear on eggs and larvae of striped bass, *Morone saxatilis* and white perch, *M. americana*. Transactions of the American Fisheries Society 105: 149-154.

Nielsen, L.A., R.J. Sheehan, D.J. Orth. 1986. Impacts of navigation on riverine fish production in the United States. Polish Archives of Hydrobiology 33: 277-294.

Pearson, W.D., and L.A. Krumholz. 1984. Distribution and status of Ohio River fishes. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Pflieger, W.L. 1975. The fishes of Missouri. Missouri Department of Conservation, Jefferson City, Missouri.

Priegel, G. 1970. Reproduction and early life history of the walleye in the Lake Winnebago region. Wisconsin Department of Natural Resources Technical Bulletin 45, Madison, Wisconsin.

Rupp, R.S. 1965. Shore-spawning and survival of eggs of the American smelt. Transactions of the American Fisheries Society 94: 160-168.

Sheaffer, W.A., and J.G. Nickum. 1986. Backwater areas as nursery habitats for fishes in pool 13 of the upper Mississippi River. Hydrobiologia 136: 131-139.

Sparks, R.E. 1975. Possible biological impacts of wave wash and resuspension of sediments caused by boat traffic in the Illinois River. Appendix J of supplement, environmental statement, volume III: biological appendices - animals. Locks and dams number 26 (replacement), upper Mississippi River Basin, Mississippi River, Alton, Illinois, Missouri and Illinois. U.S. Army Corps of Engineers, St. Louis, Missouri.

Taylor, W.R. 1977. Observations on specimen fixation. Proceedings of the Biological Society of Washington 90: 753-763.

Tuberville, J.D. 1979. Vertical distribution of ichthyoplankton in upper Nickajack Reservoir, Tennessee, with a comparison of three sampling methodologies. Pages 185-203 *in* R.D. Hoyt, editor. Proceedings of the third symposium on larval fish. Western Kentucky University, Bowling Green, Kentucky.

UMRBC (Upper Mississippi River Basin Commission). 1982. Comprehensive master plan for the management of the upper Mississippi River system. Upper Mississippi River Basin Commission, Minneapolis, Minnesota.

USACE (U.S. Army Corps of Engineers). 1983. Kanawha River navigation study, reconnaissance report and appendices. U.S. Army Corps of Engineers, Huntington District, Huntington, West Virginia.

VPISU (Virginia Polytechnic Institute and State University). 1985. Development and application of an energy flow model to analyze impacts of navigation changes on the

Kanawha River in West Virginia. Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Western, L.G. 1984. Distribution of Rotifera and Cladocera in a regulated river system. Master's thesis. Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Wetzel, R.G. 1975. Limnology. W.B. Saunders, Philadelphia, Pennsylvania.

Wright, T.D. 1982. Potential biological impacts of navigation traffic. Environmental and Water Quality Operation Studies Miscellaneous Paper E-82. U.S. Army Corps of Engineers, Mobile District, Mobile, Alabama.

Zar, J.H. 1974. Biostatistical analysis. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

APPENDICES

Appendix 1. Mean densities (number/100 m^3) of larval fish collected in the main channel with bongo nets during daylight at the Upper Winfield site, Kanawha River.

Taxa	May 1-2	May 24-25	June 14-15	July 5-6	July 27-28	August 9-10
Clupeidae	-	-	6.48	3.75	0.08	0.79
Cyprinus carpio	-	-	1.17	0.67	-	-
Cyprinidae	-	-	4.62	3.76	0.52	6.78
Ictiobinae	-	0.08	0.23	-	-	0.07
Ictalurus punctatus	-	-	-	-	-	-
Ambloplites rupestris	-	-	-	-	-	-
Lepomis	-	-	0.08	0.08	0.08	-
Pomoxis	-	-	0.31	0.34	-	-
Percidae	0.06	0.07	0.30	0.21	-	-
Aplodinotus grunniens	-	-	5.67	18.08	-	1.35
Unidentified	-	-	0.47	0.21	-	-
Total	0.06	0.14	19.32	27.08	0.68	8.98

Dash (-) indicates no larvae collected.

Appendix 2. Mean densities (number/100 m^3) of larval fish collected in the main channel with bongo nets during daylight at the Lower Winfield site, Kanawha River.

Taxa	May 1-2	May 24-25	June 14-15	July 5-6	July 27-28	August 9-10
Clupeidae	-	-	22.47	14.23	0.06	0.06
Cyprinus carpio	-	0.12	-	0.53	0.06	-
Cyprinidae	-	0.12	2.98	18.80	0.33	2.48
Ictiobinae	-	0.12	0.42	0.06	-	-
Ictalurus punctatus	-	-	-	-	-	-
Ambloplites rupestris	-	-	-	-	-	-
Lepomis	-	-	0.24	0.17	0.07	-
Pomoxis	-	-	-	-	-	-
Percidae	-	0.53	0.56	0.43	-	0.06
Aplodinotus grunniens	-	-	0.97	28.50	0.06	0.69
Unidentified	-	-	0.11	0.63	-	0.08
Total	-	0.89	27.75	63.33	0.58	3.37

Dash (-) indicates no larvae collected.

Appendix 3. Mean densities (number/100 m^3) of larval fish collected in the main channel with bongo nets at night at the Lower Winfield site, Kanawha River.

Taxa	May 1-2	May 24-25	June 14-15	July 5-6	July 27-28	August 9-10
Clupeidae	-	-	16.39	3.49	-	0.06
Cyprinus carpio	-	-	2.24	1.85	0.06	-
Cyprinidae	-	0.06	20.65	25.72	0.12	0.75
Ictiobinae	-	0.06	2.32	0.16	-	-
Ictalurus punctatus	-	-	-	-	0.07	-
Ambloplites rupestris	-	-	0.07	-	-	-
Lepomis	-	-	0.12	0.11	-	-
Pomoxis	-	-	-	0.06	-	-
Percidae	0.11	0.17	0.07	0.06	-	-
Aplodinotus grunniens	-	-	1.82	10.83	-	-
Unidentified	-	-	0.19	0.61	-	-
Total	0.11	0.28	43.87	42.91	0.25	0.81

Dash (-) indicates no larvae collected.

Appendix 4. Mean densities (number/100 m^3) of larval fish collected near shore with push nets during daylight at the Upper Winfield site, Kanawha River.

Taxa	May 1-2	May 24-25	June 14-15	July 5-6	July 27-28	August 9-10
Clupeidae	-	*	*	39.24	16.82	5.75
Cyprinus carpio	-	*	*	-	-	-
Cyprinidae	-	*	*	273.08	130.21	385.06
Ictiobinae	-	*	*	-	-	-
Ictalurus punctatus	-	*	*	-	-	-
Ambloplites rupestris	-	*	*	-	-	-
Lepomis	-	*	*	0.65	0.60	19.65
Pomoxis	-	*	*	1.93	-	-
Percidae	5.92	*	*	2.64	4.49	3.10
Aplodinotus grunniens	-	*	*	-	-	0.65
Unidentified	-	*	*	0.65	-	1.35
Total	5.92	*	*	318.20	152.12	415.58

Dash (-) indicates no larvae collected.
Asterisk (*) indicates no samples taken.

Appendix 5. Mean densities (number/100 m^3) of larval fish collected near shore with push nets during daylight at the Lower Winfield site, Kanawha River.

Taxa	May 1-2	May 24-25	June 14-15	July 5-6	July 27-28	August 9-10
Clupeidae	-	*	*	341.04	42.70	-
Cyprinus carpio	-	*	*	-	-	-
Cyprinidae	-	*	*	1,708.71	110.41	230.55
Ictiobinae	-	*	*	-	-	-
Ictalurus punctatus	-	*	*	-	-	-
Ambloplites rupestris	-	*	*	-	-	-
Lepomis	-	*	*	5.17	3.91	1.20
Pomoxis	-	*	*	-	-	-
Percidae	-	*	*	9.15	5.92	-
Aplodinotus grunniens	-	*	*	-	-	-
Unidentified	-	*	*	-	-	-
Total	-	*	*	2,064.06	162.94	231.75

Dash (-) indicates no larvae collected.
Asterisk (*) indicates no samples taken.

Appendix 6. Mean densities (number/100 m^3) of larval fish collected near shore with push nets at night at the Lower Winfield site, Kanawha River.

Taxa	May 1-2	May 24-25	June 14-15	July 5-6	July 27-28	August 9-10
Clupeidae	-	*	*	32.47	127.71	9.98
Cyprinus carpio	-	*	*	25.67	-	-
Cyprinidae	-	*	*	4,551.82	278.56	1,416.80
Ictiobinae	-	*	*	0.57	-	-
Ictalurus punctatus	-	*	*	-	-	-
Ambloplites rupestris	-	*	*	-	-	-
Lepomis	-	*	*	11.56	9.14	1.30
Pomoxis	-	*	*	-	-	-
Percidae	9.47	*	*	13.28	4.58	-
Aplodinotus grunniens	-	*	*	402.61	0.64	0.61
Unidentified	-	*	*	0.48	-	-
Total	9.47	*	*	5,038.47	420.62	1,428.69

Dash (-) indicates no larvae collected.
Asterisk (*) indicates no samples taken.

Appendix 7. Mean densities (number/100 m^3) of larval Clupeidae collected from the Winfield Pool, Kanawha River, by date and location.

Location/time	May 1-2	May 24-25	June 14-15	July 5-6	July 27-28	August 9-10
50% Surface						
Upper/Day	-	-	4.00	3.62	-	1.22
Lower/Day	-	-	8.59	27.70	-	-
Lower/Night	-	-	15.29	1.10	-	-
50% Mid-depth						
Upper/Day	*	*	*	*	*	*
Lower/Day	-	-	95.29	3.35	-	-
Lower/Night	-	-	16.01	1.33	-	-
50% Bottom						
Upper/Day	-	-	6.45	4.59	-	-
Lower/Day	-	-	9.12	3.74	-	-
Lower/Night	-	-	12.52	5.53	-	-
40% Surface						
Upper/Day	-	-	2.70	2.80	-	1.20
Lower/Day	-	-	2.63	12.02	0.43	-
Lower/Night	-	-	19.08	2.74	-	-
40% Bottom						
Upper/Day	-	-	4.33	3.23	0.46	-
Lower/Day	-	-	10.31	4.39	-	-
Lower/Night	-	-	11.13	5.86	-	-
20% Surface						
Upper/Day	-	-	12.47	4.45	-	0.99
Lower/Day	-	-	23.81	42.21	-	0.40
Lower/Night	-	-	26.04	2.10	-	-

Appendix 7. (Continued)

Location/time	May 1-2	May 24-25	June 14-15	July 5-6	July 27-28	August 9-10
20% Bottom						
Upper/Day	-	-	8.91	3.79	-	1.30
Lower/Day	-	-	7.54	6.17	-	-
Lower/Night	-	-	14.63	5.80	-	0.41
Shoreline						
Upper/Day	-	*	*	39.24	16.82	5.75
Lower/Day	-	*	*	341.04	42.70	-
Lower/Night	-	*	*	32.47	127.71	9.98

Dash (-) indicates no larvae collected.
Asterisk (*) indicates no samples taken.

Appendix 8. Mean densities (number/100 m^3) of larval *Cyprinus carpio* collected from the Winfield Pool, Kanawha River, by date and location.

Location/time	May 1-2	May 24-25	June 14-15	July 5-6	July 27-28	August 9-10
50% Surface						
Upper/Day	-	-	-	0.41	-	-
Lower/Day	-	-	-	-	-	-
Lower/Night	-	-	4.07	3.02	-	-
50% Mid-depth						
Upper/Day	*	*	*	*	*	*
Lower/Day	-	0.39	-	0.83	-	-
Lower/Night	-	-	1.77	-	-	-
50% Bottom						
Upper/Day	-	-	1.83	1.14	-	-
Lower/Day	-	-	-	1.64	-	-
Lower/Night	-	-	0.89	1.42	-	-
40% Surface						
Upper/Day	-	-	0.92	-	-	-
Lower/Day	-	-	-	-	-	-
Lower/Night	-	-	2.14	3.93	0.44	-
40% Bottom						
Upper/Day	-	-	3.36	1.25	-	-
Lower/Day	-	0.43	-	-	0.45	-
Lower/Night	-	-	0.85	0.40	-	-
20% Surface						
Upper/Day	-	-	-	0.80	-	-
Lower/Day	-	-	-	-	-	-
Lower/Night	-	-	4.24	0.38	-	-

Appendix 8. (Continued)

Location/time	May 1-2	May 24-25	June 14-15	July 5-6	July 27-28	August 9-10
20% Bottom						
Upper/Day	-	-	0.92	0.41	-	-
Lower/Day	-	-	-	1.23	-	-
Lower/Night	-	-	1.75	3.81	-	-
Shoreline						
Upper/Day	-	*	*	-	-	-
Lower/Day	-	*	*	-	-	-
Lower/Night	-	*	*	25.67	-	-

Dash (-) indicates no larvae collected.
Asterisk (*) indicates no samples taken.

Appendix 9. Mean densities (number/100 m^3) of larval Cyprinidae (excluding *Cyprinus carpio*) collected from the Winfield Pool, Kanawha River, by date and location.

Location/time	May 1-2	May 24-25	June 14-15	July 5-6	July 27-28	August 9-10
50% Surface						
Upper/Day	-	-	0.88	2.01	0.45	9.75
Lower/Day	-	-	0.39	9.89	-	3.74
Lower/Night	-	-	10.72	18.88	0.42	0.84
50% Mid-depth						
Upper/Day	*	*	*	*	*	*
Lower/Day	-	-	3.90	7.29	-	1.68
Lower/Night	-	-	9.92	16.28	-	-
50% Bottom						
Upper/Day	-	-	4.14	6.92	-	10.63
Lower/Day	-	-	4.35	29.42	-	1.71
Lower/Night	-	-	50.46	26.66	-	1.31
40% Surface						
Upper/Day	-	-	3.59	2.84	-	3.62
Lower/Day	-	0.42	-	17.43	1.30	0.80
Lower/Night	-	-	6.75	26.86	-	1.33
40% Bottom						
Upper/Day	-	-	9.14	5.09	-	3.77
Lower/Day	-	-	5.98	15.90	0.99	4.64
Lower/Night	-	-	20.77	27.60	-	-
20% Surface						
Upper/Day	-	-	4.75	2.33	2.19	6.37
Lower/Day	-	0.43	1.24	26.14	-	1.58
Lower/Night	-	0.39	3.75	11.83	-	1.34

Appendix 9. (Continued)

Location/time	May 1-2	May 24-25	June 14-15	July 5-6	July 27-28	August 9-10
20% Bottom						
Upper/Day	-	-	5.21	3.35	0.48	6.51
Lower/Day	-	-	5.00	25.50	-	3.20
Lower/Night	-	-	42.17	51.95	0.42	0.43
Shoreline						
Upper/Day	-	*	*	273.08	130.21	385.06
Lower/Day	-	*	*	1,708.71	110.41	230.55
Lower/Night	-	*	*	4,551.82	278.56	1,416.80

Dash (-) indicates no larvae collected.
Asterisk (*) indicates no samples taken.

Appendix 10. Mean densities (number/100 m^3) of larval Ictiobinae collected from the Winfield Pool, Kanawha River, by date and location.

Location/time	May 1-2	May 24-25	June 14-15	July 5-6	July 27-28	August 9-10
50% Surface						
Upper/Day	-	-	-	-	-	-
Lower/Day	-	-	-	-	-	-
Lower/Night	-	-	1.95	-	-	-
50% Mid-depth						
Upper/Day	*	*	*	*	*	*
Lower/Day	-	-	0.42	-	-	-
Lower/Night	-	-	2.60	-	-	-
50% Bottom						
Upper/Day	-	-	0.92	-	-	0.43
Lower/Day	-	-	0.87	-	-	-
Lower/Night	-	-	2.23	-	-	-
40% Surface						
Upper/Day	-	-	-	-	-	-
Lower/Day	-	0.42	-	-	-	-
Lower/Night	-	-	3.83	-	-	-
40% Bottom						
Upper/Day	-	0.45	0.48	-	-	-
Lower/Day	-	-	-	0.39	-	-
Lower/Night	-	-	0.85	0.40	-	-
20% Surface						
Upper/Day	-	-	-	-	-	-
Lower/Day	-	-	0.36	-	-	-
Lower/Night	-	0.39	2.09	0.34	-	-

Appendix 10. (Continued)

Location/time	May 1-2	May 24-25	June 14-15	July 5-6	July 27-28	August 9-10
20% Bottom						
Upper/Day	-	-	-	-	-	-
Lower/Day	-	0.42	1.30	-	-	-
Lower/Night	-	-	2.71	0.40	-	-
Shoreline						
Upper/Day	-	*	*	-	-	-
Lower/Day	-	*	*	-	-	-
Lower/Night	-	*	*	0.57	-	-

Dash (-) indicates no larvae collected.
Asterisk (*) indicates no samples taken.

Appendix 11. Mean densities (number/100 m^3) of larval *Lepomis* collected from the Winfield Pool, Kanawha River, by date and location.

Location/time	May 1-2	May 24-25	June 14-15	July 5-6	July 27-28	August 9-10
50% Surface						
Upper/Day	-	-	-	-	0.47	-
Lower/Day	-	-	-	0.35	0.46	-
Lower/Night	-	-	-	-	-	-
50% Mid-depth						
Upper/Day	*	*	*	*	*	*
Lower/Day	-	-	0.87	-	-	-
Lower/Night	-	-	-	-	-	-
50% Bottom						
Upper/Day	-	-	-	-	-	-
Lower/Day	-	-	-	0.42	-	-
Lower/Night	-	-	-	-	-	-
40% Surface						
Upper/Day	-	-	-	-	-	-
Lower/Day	-	-	-	-	-	-
Lower/Night	-	-	-	-	-	-
40% Bottom						
Upper/Day	-	-	-	0.45	-	-
Lower/Day	-	-	0.43	-	-	-
Lower/Night	-	-	-	0.40	-	-
20% Surface						
Upper/Day	-	-	-	-	-	-
Lower/Day	-	-	-	0.42	-	-
Lower/Night	-	-	0.41	-	-	-

Appendix 11. (Continued)

Location/time	May 1-2	May 24-25	June 14-15	July 5-6	July 27-28	August 9-10
20% Bottom						
Upper/Day	-	-	0.46	-	-	-
Lower/Day	-	-	0.41	-	-	-
Lower/Night	-	-	0.43	0.40	-	-
Shoreline						
Upper/Day	-	*	*	0.65	0.60	19.65
Lower/Day	-	*	*	5.17	3.91	1.20
Lower/Night	-	*	*	11.56	9.14	1.30

Dash (-) indicates no larvae collected.
Asterisk (*) indicates no samples taken.

Appendix 12. Mean densities (number/100 m^3) of larval *Pomoxis* collected from the Winfield Pool, Kanawha River, by date and location.

Location/time	May 1-2	May 24-25	June 14-15	July 5-6	July 27-28	August 9-10
50% Surface						
Upper/Day	-	-	0.46	0.81	-	-
Lower/Day	-	-	-	-	-	-
Lower/Night	-	-	-	-	-	-
50% Mid-depth						
Upper/Day	*	*	*	*	*	*
Lower/Day	-	-	-	-	-	-
Lower/Night	-	-	-	-	-	-
50% Bottom						
Upper/Day	-	-	-	0.38	-	-
Lower/Day	-	-	-	-	-	-
Lower/Night	-	-	-	-	-	-
40% Surface						
Upper/Day	-	-	-	0.39	-	-
Lower/Day	-	-	-	-	-	-
Lower/Night	-	-	-	-	-	-
40% Bottom						
Upper/Day	-	-	-	0.45	-	-
Lower/Day	-	-	-	-	-	-
Lower/Night	-	-	-	-	-	-
20% Surface						
Upper/Day	-	-	0.44	-	-	-
Lower/Day	-	-	-	-	-	-
Lower/Night	-	-	-	-	-	-

Appendix 12. (Continued)

Location/time	May 1-2	May 24-25	June 14-15	July 5-6	July 27-28	August 9-10
20% Bottom						
Upper/Day	-	-	0.94	-	-	-
Lower/Day	-	-	-	-	-	-
Lower/Night	-	-	-	0.44	-	-
Shoreline						
Upper/Day	-	*	*	1.93	-	-
Lower/Day	-	*	*	-	-	-
Lower/Night	-	*	*	-	-	-

Dash (-) indicates no larvae collected.
Asterisk (*) indicates no samples taken.

Appendix 13. Mean densities (number/100 m^3) of larval Percidae collected from the Winfield Pool, Kanawha River, by date and location.

Location/time	May 1-2	May 24-25	June 14-15	July 5-6	July 27-28	August 9-10
50% Surface						
Upper/Day	0.33	0.39	-	-	-	-
Lower/Day	-	0.37	-	-	-	-
Lower/Night	-	0.38	-	-	-	-
50% Mid-depth						
Upper/Day	*	*	*	*	*	*
Lower/Day	-	-	0.45	-	-	-
Lower/Night	-	-	-	-	-	-
50% Bottom						
Upper/Day	-	-	0.92	0.39	-	-
Lower/Day	-	-	1.74	-	-	0.44
Lower/Night	0.37	-	-	-	-	-
40% Surface						
Upper/Day	-	-	-	0.41	-	-
Lower/Day	-	0.79	-	1.35	-	-
Lower/Night	-	-	-	-	-	-
40% Bottom						
Upper/Day	-	-	-	0.45	-	-
Lower/Day	-	-	0.86	-	-	-
Lower/Night	0.38	-	-	-	-	-
20% Surface						
Upper/Day	-	-	0.86	-	-	-
Lower/Day	-	1.69	-	0.81	-	-
Lower/Night	-	0.39	-	-	-	-

Appendix 13. (Continued)

Location/time	May 1-2	May 24-25	June 14-15	July 5-6	July 27-28	August 9-10
20% Bottom						
Upper/Day	-	-	-	-	-	-
Lower/Day	-	0.85	0.84	0.82	-	-
Lower/Night	-	0.41	0.46	0.44	-	-
Shoreline						
Upper/Day	5.92	*	*	2.64	4.49	3.10
Lower/Day	-	*	*	9.15	5.92	-
Lower/Night	9.47	*	*	13.28	4.58	-

Dash (-) indicates no larvae collected.
Asterisk (*) indicates no samples taken.

Appendix 14. Mean densities (number/100 m^3) of larval *Aplodinotus grunniens* collected from the Winfield Pool, Kanawha River, by date and location.

Location/time	May 1-2	May 24-25	June 14-15	July 5-6	July 27-28	August 9-10
50% Surface						
Upper/Day	-	-	1.72	11.46	-	0.41
Lower/Day	-	-	-	19.09	-	-
Lower/Night	-	-	0.44	9.67	-	-
50% Mid-depth						
Upper/Day	*	*	*	*	*	*
Lower/Day	-	-	-	87.91	-	0.47
Lower/Night	-	-	0.89	7.37	-	-
50% Bottom						
Upper/Day	-	-	7.35	31.11	-	6.80
Lower/Day	-	-	2.60	30.08	-	1.71
Lower/Night	-	-	4.46	4.82	-	-
40% Surface						
Upper/Day	-	-	0.92	9.63	-	-
Lower/Day	-	-	-	7.28	-	-
Lower/Night	-	-	-	10.86	-	-
40% Bottom						
Upper/Day	-	-	11.06	33.79	-	0.43
Lower/Day	-	-	2.13	16.02	-	2.08
Lower/Night	-	-	1.67	16.34	-	-
20% Surface						
Upper/Day	-	-	3.43	12.83	-	-
Lower/Day	-	-	-	11.99	0.42	-
Lower/Night	-	-	0.87	0.71	-	-

Appendix 14. (Continued)

Location/time	May 1-2	May 24-25	June 14-15	July 5-6	July 27-28	August 9-10
20% Bottom						
Upper/Day	-	-	9.52	9.66	-	0.44
Lower/Day	-	-	2.07	27.15	-	0.57
Lower/Night	-	-	4.44	26.03	-	-
Shoreline						
Upper/Day	-	*	*	-	-	0.65
Lower/Day	-	*	*	-	-	-
Lower/Night	-	*	*	402.61	0.64	0.61

Dash (-) indicates no larvae collected.
Asterisk (*) indicates no samples taken.

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