Abundance of Fishes in the Navigation Channels of the Mississippi and Illinois Rivers and Entrainment Mortality of Adult Fish Caused by Towboats

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Preface

The work reported herein was conducted as part of the Upper Mississippi River - Illinois Waterway (UMR-IWW) System Navigation Study. The information generated for this interim effort will be considered as part of the plan formulation process for the System Navigation Study.

The UMR-IWW System Navigation Study is being conducted by the U.S. Army Engineer Districts of Rock Island, St. Louis, and St. Paul under the authority of Section 216 of the Flood Control Act of 1970. Commercial navigation traffic is increasing, and in consideration of existing system lock constraints, will result in traffic delays that will continue to grow in the future. The system navigation study scope is to examine the feasibility of navigation improvements to the Upper Mississippi River and Illinois Waterway to reduce delays to commercial navigation traffic. The study will determine the location and appropriate sequencing of potential navigation improvements on the system, prioritizing the improvements for the 50-year planning horizon from 2000 through 2050. The final product of the System Navigation Study is a Feasibility Report which is the decision document for processing to Congress.

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Abstract

Expansion of the capacity of the Upper Mississippi River System to support commercial navigation is being deliberated. This proposed expansion created the need to develop information on potential effects of commercial navigation on fishes of the Upper Mississippi River System. Our study objectives were to: 1) quantify the distribution and abundance of early life stages of fish for later incorporation into models of losses of adult-fish equivalents, production foregone and recruitment foregone; 2) develop methods to estimate abundance and entrainment mortality of juvenile and adult fishes in navigation channels; 3) estimate abundance of juvenile and adult fishes in the navigation channels of Pool 26 of the Mississippi River and in the lower Illinois River; and 4) estimate entrainment mortality of juvenile and adult fishes per unit distance of towboat travel.

Total densities of larval fishes in the navigation channels generally did not exceed 3 fish/m^3 and tended to be greater in the lower Illinois River than in nearby Pool 26 of the Mississippi River. Larvae of common carp *Cyprinus carpio* and catostomids predominated in May but in June were replaced by clupeids, primarily gizzard shad *Dorosoma cepedianum*. Finally, freshwater drum *Aplodinotus grunniens* larvae predominated ichthyoplankton drift in late June and early July. Total minimal densities of fish longer than 10 cm total length averaged 157 and 177 fish/ha during 1996 and 1997, respectively, in the lower Illinois River, and 109 and 55, respectively in Pool 26 of the Mississippi River. The assemblage of these larger fishes was dominated by freshwater drum, gizzard shad, channel catfish *Ictalurus punctatus*, and smallmouth buffalo *Ictiobus bubalus*. Additionally, shovelnose sturgeon *Scaphirhynchus platorhynchus* were

common in the upper portion of Pool 26, but totally absent from the Illinois River. The core assemblage of larval fish taxa and larger fish species present in Pool 26 of the Mississippi River and in the lower Illinois River was similar between years, but substantial variability in seasonal timing of appearance and in observed density of these fishes in the navigation channel exists. However, due to the short duration of the study, we cannot determine the potential magnitude of year-to-year changes in the density and seasonal appearance of fishes in the navigation channel, leaving substantial uncertainty as to how representative our estimates of entrainment losses might be.

Our results from 41 entrainment samples suggest that an average of 9.5 adult gizzard shad are killed or seriously injured by entrainment through towboat propellers per kilometer of tow travel, with an 80% confidence interval of 3.8-22.8 adult fish/km of tow travel. The utility of this estimate is limited by the substantial width of the confidence interval and the short duration of the study, which included only one fall-winter period. We observed entrainment kills only during the fall and early winter of 1996, suggesting a seasonal effect, but lack of seasonal replication leaves this uncertain. Because gizzard shad were the only species observed killed in the entrainment sampling, this estimate also represents the total kill for all species within the entrainment sampling design. However, in 110 ambient samples, which were conducted to estimate abundance of live fish, we also observed fresh entrainment kills of one adult smallmouth buffalo and one adult shovelnose sturgeon. This result is entirely plausible because rarer entrainment kills might go undetected in 41 entrainment samples, but show up in the more numerous ambient samples. The ambient samples were more numerous because, given the prevailing traffic rates and logistic constraints, approximately 2-3 ambient samples can be completed for each entrainment sample. We developed a statistical method to estimate the entrainment mortality rate for shovelnose sturgeon and smallmouth buffalo from the combined entrainment and ambient samples. These ancillary entrainment mortality estimates for shovelnose sturgeon and smallmouth buffalo are each 2.4 adult fish/km of tow travel, with 80% confidence intervals of 0-6.0 fish/km of tow travel. This ancillary mortality estimator is shown to be essentially unbiased. Because the confidence intervals for these species include zero, we believe that it is reasonable to conclude only that entrainment mortality cannot be eliminated as an important component of their dynamics in the navigation channels of the Upper Mississippi River System. The ancillary estimates create a paradox because there are now two estimates of the total entrainment mortality rate for all species combined. The first is the estimate of 9.5 fish/km from the entrainment sampling, which is unbiased within that sampling design. The second is the sum of entrainment-sampling estimate plus the ancillary estimates for shovelnose sturgeon and smallmouth buffalo. This second augmented mortality estimate is 14.3 adult fish/km of tow travel with an 80% confidence interval of 0-26.7 fish/km of tow travel.

Introduction

Large rivers of the United States are managed by multiple agencies for multiple uses, including commercial navigation. On the Upper Mississippi River System, commercial traffic consists largely of tows which, for the purposes of this report, we define as a propulsion vessel called towboat pushing one or more freight containers called barges. Towboats entrain large volumes of water through their propellers, which may exceed 2.5 m in diameter. Fish that pass through those propellers may be injured or killed by shear stress, impact or pressure changes. Although mortality of eggs and larval fishes that pass through power plant cooling systems is well known (Hesse et al. 1982; Englert and Boreman 1988), less is known about effects of hydropower turbines (Cada 1990), and very little is known about mortality of early life stages of riverine fishes caused by entrainment through towboat propellers. Larval fish are present across all aquatic areas of the Upper Mississippi and the Illinois Rivers, including the navigation channels (Holland and Sylvester 1983; Holland-Bartels et al. 1995), and are therefore at risk of entrainment through towboat propellers. Holland (1986) studied short-term changes in distribution and catch of early-life stages of fish associated with towboat passage in Pools 7 and 8 of the Mississippi River and noted significant damage to eggs, but found no consistent effects on catches of age-0 and small adult fishes. Odom et al. (1992) attempted to estimate entrainment mortality of larval fishes by deploying plankton nets before and after barge-passage, but concluded that net- and handling-induced mortality may have masked any effects of towboats.

Mortality of larger fish caused by entrainment through towboat propellers has not previously been quantified, but has been reported anecdotally. In large open channels many fish may escape entrainment by avoiding oncoming tows. For instance, some fishes avoid large vessels in the marine environment (Neproshin 1978; Misund and Aglen 1992; Soria et al. 1996). Furthermore, Todd et al. (1989) observed radio-tagged channel catfish *Ictalurus punctatus* move in response to oncoming towboats in the Illinois River. Lowery et al. (1987) used hydroacoustic sensing to monitor the responses of fishes to tow passages in the Cumberland River and found that some moved away from passing tows. The strength of this avoidance reaction seemed to vary with direction of tow travel (up- versus downbound) and whether or not the barges were loaded. However, some fish may not avoid entrainment. The magnitude, seasonal timing and spatial variation in tow-induced entrainment mortality of large riverine fishes is completely unknown.

An expansion of commercial navigation capacity is being considered for the Mississippi and Illinois rivers above Lock and Dam 26 near St. Louis, Missouri. Estimates of entrainment mortality and effects on fish populations are needed by decision makers including the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service. The goals of this study in Pool 26 of the Mississippi River and in the lower Illinois River were to: 1) quantify the distribution and abundance of early life stages of fish for later incorporation into models of losses of adult-fish equivalents, production foregone and recruitment foregone; 2) develop methods to estimate abundance and entrainment mortality of juvenile and adult fishes in navigation channels of large rivers; 3) estimate abundance of juvenile and adult fishes in the navigation channels; and 4) estimate entrainment mortality of juvenile and adult fishes per unit distance of towboat travel.

Methods

With the exception of additions and modifications described below, methods of sampling and data management conformed to Long Term Resource Monitoring protocols (Gutreuter et al. 1995). Water temperature, Secchi depth, and surface current velocity were measured and recorded before each fish sampling event. Surface current velocity was measured at 30-cm depth by using a Marsh-McBirney™ Flow-Mate 2000 current meter. All names of fishes used in this report (Appendix A) conform to Robins et al. (1991).

Larval fish sampling.

We collected larval fishes every other week during May 1-August 1, 1996 at up to 10 main channel sites (River Miles 203.2, 207.1, 211.2, 213.6, 215.7, 223.0, 225.8, 230.5, 233.5, and 240.2) on the Mississippi River and four sites (River Miles 4.5, 9.3, 13.5, and 18.7) on the Illinois River. All sampling sites were located in the center of the navigation channel and chosen such that the risk of a towboat appearing suddenly from around a blind bend was minimized. Sampling occurred in an upstream direction with paired 1-m diameter, 500-μm mesh ichthyoplankton nets mounted from a boom attached to the bow of a boat and pushed near the surface of the water alongside the boat at speeds of 1.0-1.5 m/s relative to the water. Speeds and water volumes strained by the plankton net were measured using a General Oceanics flow meter suspended in the mouth of the net. Each push lasted about 10 minutes (exact time recorded in seconds by stopwatch), after which larval fishes and drifting debris were preserved in 10% formalin or 95%

ethanol. Sampling throughout a 24-hour period was not conducted, as originally planned, because two crew leaders were not available during 1996.

In 1997, larval fish sampling occurred in five locations, one on the lower Illinois River at River Mile 13.5, two on the Mississippi River above its confluence with the Illinois River at River Miles 223.0 and 233.5, and two on the Mississippi River below its confluence with the Illinois River at River Miles 208.5 and 215.7. These locations were selected so that 1) they were sites used in 1996 or 2) spatial distribution of larvae across main channel, side channel, and backwater habitats could be assessed. We followed a sampling protocol similar to that in 1996 at these sites, except that we 1) also sampled side channel and backwater sites, 2) sampled all sites for about 8 minutes instead of 10 minutes to reduce the volume of extraneous debris and speed sample processing, and 3) sampled backwater sites with a 0.5-m diameter ichthyoplankton net due to their lack of depth compared to main channel and side channel sites.

All fishes were identified, following the keys of Auer (1982) and Holland-Bartels et al. (1990), to the lowest possible taxonomic category (most often to family or genus) given the amount of time needed to process and count samples. As many as 100 larval fish of each taxon were randomly selected from each net tow within a paired sample and their individual total lengths were measured to the nearest 0.1 mm total length (TL) by using a drawing tube attached to a microscope and a computerized digitizing program. To estimate abundance of larval fishes at each sampling site and date, we used the simple mean density from the two paired nets.

Sampling small and 'adult' fishes by trawling.

We used bottom trawls to sample fishes in the navigation channels. Bottom trawls were chosen because most channel-dwelling fishes of the Upper Mississippi River System are primarily epibenthic in their vertical distribution. Further, we sought to measure the quantity of fish that might be killed by entrainment through towboat propellers, which presented particular problems. This study was conducted under the philosophy that where uncertainty was unavoidable or where assumptions were required, we would choose strategies that would reasonably avoid underestimation of impact. Fish killed by entrainment, and particularly those severed by propellers might have ruptured gas bladders and be negatively buoyant, tending to settle to the bottom. Therefore sampling high in the water column might tend to underestimate impacts, and so we sampled the water immediately above the bottom.

We sampled small (2.5-15.0 cm TL) primarily epibenthic fishes in the navigation channel by using a beam trawl (described below). The beam trawl was deployed at up to eight sites (from among River Miles 203.2, 207.1, 211.2, 213.6, 215.7, 223, 227.1, 233.5, and 238.2) on Pool 26 and three sites (River Miles 5.5, 9.3, and 13.5) on the lower Illinois River. The beam trawl was deployed approximately 45 m behind the trawler and towed upstream at speeds of approximately 4 km/h (2.5 mi/h) relative to the ground for a nominal duration of 10 minutes in July when small fishes were relatively common and for 20 minutes in September when many of these fishes had grown to larger sizes and were likely less vulnerable to the gear. A General Oceanics flowmeter was placed in the mouth of the net to determine the amount of water passing through the net mouth. All fishes ≥ 2.5 cm were identified, measured, weighed, and immediately released, whereas small fishes < 2.5 cm were identified in the laboratory.

We used a rockhopper bottom trawl (described below) to sample 'adult' fish, here loosely defined as fish longer than 10 cm TL, in the navigation channel. Sampling occurred during August-December 1996 and March-October 1997 as equipment, weather, and flow rates permitted. The primary criterion used to select sampling sites within the larger study areas was that we required an unobstructed view of the navigation channel in both directions so that we would not be surprised by the sudden approach of a tow and could maintain an unobstructed view of tows in the area. Regular sampling sites in Pool 26 were located at River Miles 203.2, 207.2, 213.6, and 215.7, 223.0, 227.2, 230.5, 233.5, and 238.2 during 1996. We sampled at River Miles 211.2 and 225.8 once during the process of site selection, but did not include these sites as part of our regular sampling. Sampling sites during 1997 were the same as for 1996, except that the site at 230.5 was dropped after we lost a net there during April sampling and that sampling occasionally was done at river mile 240.2. Sampling sites in the Illinois River were located at River Miles 5.5, 9.3, 13.5, and 18.7 during both 1996 and 1997. We sampled at River Mile 16.5 only once during 1996. Our goal was to sample all of the sites listed above within a one-week time frame before starting another cycle of sampling.

We distinguish two types of trawling used in this study. We define ambient sampling as trawling done primarily to estimate ambient abundance of live fish in the navigation channel and to measure the background drift of injured and dead fish in the navigation channel. We define entrainment sampling as trawling conducted behind specific tows to estimate mortality of fish caused by entrainment through the propellers of towboats. Entrainment sampling also produces useful information on abundance of live fish. We will also show that ambient samples can contain information that is useful to estimation of entrainment mortality. Due to time constraints, we performed entrainment sampling using only the rockhopper bottom trawl.

The sampling methods described below apply to both ambient and entrainment sampling. The rockhopper trawl was deployed approximately 30 m behind the trawler and towed at speeds of approximately 4 km/h (2.5 mi/h) relative to the ground for a nominal duration of 20 min. During 1997, when river conditions were favorable, an acoustic trawl monitoring system (see below) was used to measure the dimensions of the net mouth opening during trawling. This information permitted quantitative estimation of the numbers of fish per square meter of river bottom. All fishes collected were identified, measured, weighed, and immediately released.

In situ forensic examination of wounded and dead fish.

For both ambient and entrainment sampling, we examined fish for injuries and recorded the characteristics of dead fish. We first determined the position of any wounds on the body, scoring wound position as some combination of dorsal, ventral, anterior, and posterior on the body of the fish. If no obvious wound was found on a fish, scoring for wound position was left blank. We then estimated the age of the wound as 1) *fresh*, defined as an obvious fresh wound with no signs of clotting; 2) *recent*, a wound less than one day old, still a fresh-looking wound, but clotting had begun; 3) *old*, a wound older than 24 h, including healed scars or wounds clearly not recently made; and 4) wound marks on a dead, decomposing fish. If a fish was dead when we brought it on board, we also estimated the time of death as 1) *very recent*, within 1 h, gill filaments still red and eyes clear; 2) *recent*, within several hours, gill filaments pink, eyes clouded; or 3) *not recent*, over several hours dead, gill filaments white/grey, eyes cloudy, body stiff. Finally, we determined whether the wound could have been caused by a propeller. If a wound was cleanly cut, particularly if that wound was fresh in the presence of tow traffic, we assumed a propeller could have caused the wound. If not, we assumed that the cause could reasonably have been something other than a towboat propeller. When sampling behind towboats, we assumed that all fresh wounds that were consistent with injury by propeller were caused by the preceding towboat.

Trawling vessel.

The trawling vessel used in this study is based on a Munson Hammerhead™ aluminum hull that is 7.31-m (24-ft) long and has a beam of 2.74 m (9 ft). A 0.61-m fantail afterdeck extends the total length to 7.92 m (26 ft). The trawler is powered by a 415-hp engine and the outdrive unit has a single 0.5-m (19.75 in) diameter propeller having a pitch of 0.48 m (19 in) or 3.26:1. The afterdeck is equipped with a custom aluminum trawling gantry supporting a pair of trawling blocks suspended approximately 0.5 m above the surface of the water. Accessory gear includes

Raytheon marine radar. This trawler is small and light enough to be transported on a conventional boat trailer yet has some advanced trawling and safety features.

The trawling system consists of two trawling winches, an accessory net handling winch and accessory controls designed manufactured and installed by Rapp-Hydema US, Seattle, Washington, nets and net-monitoring gear. Each trawling winch contained approximately 100 m of 6.4-mm (0.25 in) diameter galvanized steel combination wire. The trawling gantry, winches and cable were designed to sustain a total load of approximately 9 kN (2,000 lbs force). The hydraulic system was designed to maximize safety. When the trawl is under tow, the trawling winches are constantly active and the trawl is held in position by balancing the drag on the net with the pressure exerted by the winches. Therefore the winches automatically release cable when the net snags on an immovable object, thus preventing sudden and violent stops. In addition, the trawling winches are equipped with an emergency release that can be activated by the pilot to allow the winch drums to spool freely in the event of a severe snag. These features are critical in river trawling because of the frequency and severity of snags, the added difficulty of trawling in current, and the presence of commercial navigation. Trawl cable lengths are monitored by a Rapp-Hydema EMS 2000™ Warp Counter.

On the recommendations of a trawling expert, and based on our own preliminary tests, we conducted all trawling in the upstream direction to minimize risks to safety. Trawling upriver allows easier release of tension when snagged because it only requires reduction of throttle speed. Further, proper expansion of the doors and trawl, and therefore capture efficiency, relies on the speed of the trawl relative to the water. In the presence of current, obtaining a particular speed relative to the water requires lower speed relative to the ground when traveling upstream than when traveling downstream. Therefore trawling upstream results in less violent deceleration on immovable snags than does trawling downstream.

Rockhopper bottom trawl.

We used a four-seam "Tomcod" high-rise rockhopper bottom trawl (Figure 1) designed and manufactured by Wilcox Marine Supply, Mystic, Connecticut. Rockhopper trawls are designed to ride over the top of small obstacles and thereby reduce the frequency of snagging. The footrope of our nets had a length of 10.2 m (33.33 ft) and a headrope length of 8.0 m (26.25 ft). Mesh of the trawl mouth and cod end consisted of #21 nylon twine with a bar-measure mesh size of 2.54 cm (1 in); stretch-measure is 2x bar measure. The rockhopper consisted of 7.6-cm (3- in) diameter "cookies" cut from truck tire tread salvage threaded on the footrope and 25-cm (10-in) diameter cookies spaced approximately every 61 cm (2 ft) between the 7.6-cm diameter cookies. Four 20-cm (8-in) diameter spherical trawl floats were equally spaced along the length of the headrope. The length of the cod end was approximately 2.4 m (8 ft), and the total length from the wings to the cod end was approximately 10.7 m (35 ft). The paired "V" doors were constructed of steel and measured 96 cm (38 in) long by 69 cm (27 in) high, and were attached to the trawl wings by 9.1-m (30-ft) long "straight leg" ground cables of 0.63-cm (0.25-in) galvanized steel combination wire.

The trawler was equipped with a Netmind™ (Northstar Technical Inc., Vancouver, British Columbia, Canada) hydroacoustic trawl monitoring system that provides a continuous stream of measurements of the distance between trawl wings (Figure 1) and the distance from the headrope to the bottom for the rockhopper bottom trawl. The Netmind system consists of a paravane receiver that is towed over the port side of the trawler, a trawl monitor that displays net dimensions, wingspread master and slave sensors that are placed in net pockets at the forward end of each wing, and a trawl height sensor that is attached to the headrope at the midpoint between the wings. When the sensors were installed in the net, one additional 20-cm (8-in) diameter spherical trawl float was attached at the position of the headrope sensor, as per manufacturer's specifications, to make that sensor neutrally buoyant. Wingspread sensors require no such buoyancy compensation. In tests, coefficients of mean variation of headrope height measurements were not greater than 3.6% and those for wingspread measurements were not greater than 1.7% (Table 1). Mean bias never exceeded 4.3 cm (0.14 ft). Because of the high cost of the sensors relative to the cost of rockhopper trawls, sensors were deployed in a subsample of the trawl samples to reduce the risk of loss. Despite that care, one set of sensors was lost with a trawl that became snagged under severe and threatening conditions.

Beam trawl.

We used a beam (frame) trawl manufactured by Wilcox Marine Supply, Mystic, Connecticut, to sample small fishes. This trawl consisted of a heavy aluminum alloy frame containing bottom skids and a net made from 3.2-mm (0.125-in) "Ace" nylon mesh. This beam trawl has a rectangular opening when towed over level bottom that is 2.44 m (8 ft) wide and 1.52 m (5 ft) high, and has a surface area of 3.71 m^2 (40 ft^2).

Measurement of rockhopper bottom trawl dimensions and estimation of areas swept.

Estimation of density (number/hectare) and biomass (kg/hectare) of epibenthic fish requires measurement of the bottom area swept A_b by the trawl. Estimation of entrainment mortality also requires estimation of volume strained by the rockhopper trawl. In turn, we required measurements of the wingspread of the rockhopper trawl and estimates of the surface area of the mouth of the trawl A_m in the plane perpendicular to the direction of the trawler.

Measurements from the Netmind™ acoustic trawl monitoring system were recorded at approximately 1-min intervals during the course of 18 trawl hauls. For hauls of full duration of 20-min, this yielded 20 sets of recordings. The durations of some hauls were abbreviated because of snags or development of hazards. Further, signal interference or other factors occasionally caused measurements of headrope height and wingspread to be missed. In total, we obtained 265 recordings of headrope height and 258 recordings of wingspread during normal trawling operations.

To estimate A_m, the surface area of the projection of the mouth of the rockhopper trawl onto the vertical plane perpendicular to the towing direction, we modeled that projection of the mouth as the top half of an ellipse having semi-major axis $0.5w$ and semi-minor axis h (Figure 1). The area of any ellipse is given by $\pi d_1 d_2$, where d_1 and d_2 are the lengths of the semi-minor and semi-major axes, respectively (Mc Lenaghan and Levy 1996). Therefore the area of our trawl mouth A_m is given by

$$A_m = \frac{\pi}{4} h w. \tag{1}$$

For the 18 rockhopper bottom trawl hauls that were monitored by using the Netmind™ system, we computed the bottom area swept A_b as the product of the length of the trawl haul and the mean wingspread from measurements recorded during the particular haul. Similarly, we estimated mouth areas A_m as the means of areas computed from the individual measurements taken at 1-min intervals during the particular haul. For the hauls that were not monitored with the Netmind™ system, we computed the bottom area swept A_b as the length of the haul times the mean wingspread from all 258 measurements obtained during the 18 monitored hauls. Similarly, we estimated mouth areas of unmonitored hauls as the mean of the 258 areas computed from the 18 monitored hauls.

We measured the lengths of 41 trawl hauls by using the differences between radar measurements of a prominent stationary object made at the start and finish of the haul. From these we computed the mean and variance of trawl speed. The lengths of unmeasured trawl hauls were obtained as the product of trawl time and mean speed. The variances of these lengths were obtained as the products of the variance of speed and time squared (Hogg and Craig 1970).

Statistical analyses of trawl catches.

Let C_{ijkm} denote the number of fish of a species caught in trawl sample m from year i, pool j, and segment k within pool j. To examine pattern in the trawl catch data, we began with the conventional catch equation $C = fqN$, where q is the catchability coefficient, f is fishing effort (min), and N is abundance (Ricker 1975). Our goal here was not to estimate q and N, but rather to formulate a statistical model for effects of year, pool, location and month on catch that is consistent, in general form, with the conventional catch equation. Thus, the conventional catch equation provides the basis for our statistical model of catch given by

$$C_{ijkm} = f \exp(\lambda_0 + y_i + p_j + l_{j(k)} + \beta_1 t + \beta_2 t^2 + \beta_3 t^3) \tag{2}$$

where we model qN by

$$qN = \exp(\lambda_0 + y_i + p_j + l_{j(k)} + \beta_1 t + \beta_2 t^2 + \beta_3 t^3) \tag{3}$$

where λ_0 is a parameter for the overall mean effect on the logarithmic scale, y_i is the effect of year i, p_j is the effect of pool j, $l_{j(k)}$ is the effect of longitudinal zone l nested within pool j, t is the effect of time measured as month of the year, and the $\beta_1 ... \beta_3$ are parameters for the linear, quadratic and cubic effects of time, respectively. We model qN in equation (3) as an exponential function because the later, consistent with qN, is multiplicative in that $\exp(X_1 + X_2) = \exp(X_1)\exp(X_2)$.

The Poisson distribution, given by

$$f(\mathbf{C}|\mu) = \frac{\exp(-\mu)\ \mu^{C_{ijk}}}{C_{ijk}!}, \tag{4}$$

where **C** is the vector of catches C_{ijk} and μ is the distribution mean, serves as the starting point for our assumed probability distribution for catch. The Poisson distribution is appropriate for integer-valued random variables such as C whenever variance is equal to the mean μ. This constraint on variance is too restrictive for catch data, and we relax it by assuming that $\mathrm{Var}(C_{ijk}) = \varphi\mu$, where φ is a multiplicative overdispersion parameter. This distribution reduces to the conventional Poisson distribution when $\varphi \equiv 1$. For $\varphi > 1$ **C** is said to be overdispersed, which is a manifestation of a clumped spatial distribution of fish. The negative binomial distribution, which has the variance function $\mathrm{Var}(C_{ijk}) = \mu + \varphi\mu^2$ (Lawless 1987), is a viable alternative to this overdispersed Poisson but is numerically somewhat more difficult to fit and would be unlikely to yield important differences in inference. We modeled mean catch μ as

$$\mu = f\exp(\lambda_0 + y_i + p_j + l_{j(k)} + \beta_1 t + \beta_2 t^2 + \beta_3 t^3) \tag{5}$$

based on equation (2). The linear predictor η corresponding to the logarithmic link function, which is cannonical for the Poisson distribution (McCullagh and Nelder 1989), is given by

$$\eta = \log(\mu) = \log(f) + \lambda_0 + y_i + p_j + l_{j(k)} + \beta_1 t + \beta_2 t^2 + \beta_3 t^3, \qquad (6)$$

which can be viewed as an extension of an analysis of covariance to the overdispersed Poisson distribution with offset $\log(f)$. Such Poisson 'regression' models have become standards for the analysis of count data (Frome et al. 1973; Koch et al. 1986; Dean and Lawless 1989; Fay and Feuer 1997), and Smith et al. (1991) used an overdispersed Poisson regression model to identify patterns of abundance of Atlantic cod *Gadus morhua*. We fitted equation (5) to the overdispersed Poisson distribution by using maximum quasilikelihood estimation (McCullagh and Nelder 1989) in the generalized linear model formalism. These models were fitted by using the SAS GENMOD procedure (SAS Institute 1997). We used likelihood ratio chi-square tests to assess the statistical significance of model parameters.

The previous analysis assumes that catches are mutually independent across time and space. Because trawl samples were taken from particular areas through time, it is reasonable to expect that trawl catches may not be mutually independent, but rather may be serially correlated. To include this possibility, we also modeled the catches (equation 2) as realizations of an overdispersed Poisson distribution including a first-order autoregressive process [AR(1)] , and fitted this model by using population-averaged generalized estimating equations (Zeger et al.

1988). We fitted these models using the SAS GENMOD procedure (SAS Institute 1997) and assessed the statistical significance of model parameters based on normal-theory Z scores.

For some species, the Newton-Raphson iterations for maximization of the quasilikelihood or the iterative generalized estimating equation algorithms failed to converge with certainty because the estimated Hessian matrix (matrix of second derivatives of the log likelihood) was not positive definite. For these cases we assumed the model given by

$$\log\left(\frac{C}{f} + 1\right)_{ijkm} = \lambda_0 + y_i + p_j + l_{j(k)} + \beta_1 t + \beta_2 t^2 + \beta_3 t^2 + \xi_{ijkm}, \qquad (7)$$

where we assume the ξ_{ijkm} follow a Gaussian (normal) distribution having mean zero and variance σ^2, and fitted it using ordinary least-squares estimation. This Gaussian errors model in log[(C/*f*) + 1] implies that catch per unit effort *C*/*f* follows a lognormal distribution.

Estimation of density and biomass of live fish the navigation channels.

We estimated the density (number per unit area) of fishes by dividing the catch from each sample by the bottom area swept by the trawl A_b. We emphasize that this is a minimal estimate of density because some unknown fraction of live fish avoid capture by the trawl.

Biomass is the mass of live fish per unit area. For some fish, we made measurements of individual mass (g) in the field by using a spring-loaded scale. We measured individual lengths (mm) of all fish captured. For fish for which we measured only length L, we estimated mass W by using the conventional weight-length equation

$$W = 10^{a} L^{b} \tag{8}$$

(Anderson and Gutreuter 1983). We used estimates of *a* and *b* (Table 2) obtained from ordinary least-squares regressions of $\log_{10} W$ on $\log_{10} L$ using data obtained by the Long Term Resource Monitoring Program of the Upper Mississippi River System (Gutreuter et al. 1995). Biomass was computed as total mass divided by bottom area swept by the trawl A_b. This provides a minimal estimate of actual biomass because some unknown fraction of live fish avoid the trawl or are not retained in it.

Estimation of Entrainment Mortality of Adult Fish.

We estimated entrainment mortality of ‘adult’ fishes by using the rockhopper bottom trawl. Herein, ‘adult’ is used to refer to fish large enough to be retained in the 2.54-cm mesh of the trawl, and does not necessarily reflect reproductive maturity. Our goal was to produce estimates of the numbers of fish killed by entrainment through the propellers per unit distance of towboat travel. The original plan also prescribed estimating entrainment mortality of ‘small’ fishes by using the beam trawl. Time and logistic difficulties created by delays in the start of the studies precluded entrainment sampling using the beam trawl. However, the rockhopper trawl proved successful in capturing some small fishes including silver chub and speckled chub.

The original study plan prescribed tentative use of a large barrier net to strain wounded and dead adult fish that might have been entrained by towboat propellers. The plan was to deploy the barrier net behind passing towboats and hold it in fixed position for approximately 10 minutes. This prescription was tentative because it had never been tried in a large river. This approach required resolution of at least three critical problems. First, holding a large net in place in current, and particularly in the presence of commercial and recreational boat traffic presented significant safety hazards and difficulties. Second, as of the time of the initiation of our sampling, a means to equate the time that the strainer net was deployed to an equivalent distance of towboat travel had not been developed. This conversion would require modeling the downstream velocity distribution of entrained particles relative to the velocity of the towboat. Instead, the original plan was to release dead test fish at several distances along the towboat sailing line upstream of the barrier net and count the fraction retained over some tow distance. However this method would not have provided a useful equivalence between time and distance traveled because tow distance and straining efficiency would be completely confounded. Third, the straining (retention and retrieval of dead fish) efficiency of this passive barrier was unknown. Given the short duration of our study, our safety concerns, the difficulty of conversion from time to distance, our need to conduct several types of untried sampling, and realization that simplification was possible, we concluded that entrainment sampling using the barrier net should be abandoned.

We proposed the following modification to the Corps of Engineers, and it was accepted. Because trawling is an active gear, it is possible to follow the sailing line of towboats and strain any dead fish. If we retraced the sailing line of tows with the trawls, we could safely assume that the distance trawled was exactly equivalent to distance traveled by the towboat regardless of the relative speeds of the towboat, trawler and water. This approach vastly simplified the problem of estimation of entrainment mortality per unit distance of towboat travel. Further, although trawling is hazardous, we believed that it could be done more reliably in the presence of variable current, water elevation and navigation traffic than could the deployment of a large fixed barrier net. Henceforth, we refer to this as entrainment sampling.

We conducted entrainment sampling behind both up- and downbound tows. When conducting entrainment trawling behind a towboat, the boat's name, direction of travel (upstream or downstream), and configuration of barges (number empty or loaded) was recorded. We also recorded the initial distance of our trawler behind the towboat as the trawler entered the visible towboat propeller wash and the final distance from our trawler at the end of our 20-min sampling run. Distances were determined by radar. The total distance, over the ground, traveled by the trawler was also measured as the difference between radar measurements of a prominent fixed feature. These measurements allowed us to derive the speeds of the towboat and trawler relative to the ground. Initial distances behind downbound towboats could not be measured reliably because the trawling gantry tended to interfere with the radar signal. Preliminary modeling of the distribution and velocity of water in the propeller jets indicated that complete vertical mixing of entrained water could be assumed at following distances greater than 100-150 m (E. R. Holley, Department of Civil Engineering, University of Texas, personal communication). We typically entered the towboat wake 250-350 m behind the towboat as it passed, and then followed the towboat track by a combination of visual observations of disturbed water from the towboat propellers and keeping the towboat itself directly in front of our trawler if both vessels were traveling upstream.

The trawler traveled slower than the towboats and therefore the following distances behind upbound tows increased during each entrainment sample. We were confident that the trawler operator could always successfully track the sailing line of the keel of upbound towboats to within 27.5 m, or equivalently, could stay within a 55-m wide strip centered on the sailing line of the towboat keel. In straight reaches of the Upper Mississippi River System, the navigation channel is approximately 90-m wide (Wilcox 1993), and therefore our assumed 55-m wide sampling strip spans approximately 60% of the width of the navigation channel. However, for downbound tows, the trawler and towboat traveled in opposite directions and distances between the trawler and tows became large. Because the trawler operator could not watch downbound towboats during these entrainment samples, we were confident that the trawler could follow the sailing line of the keel of the towboat only to within 37.5 m, or within a 75-m wide strip centered on the sailing line of the keel. The width of this strip is approximately 82% of the width of the navigation channel in straight reaches of the Upper Mississippi River System.

It is both necessary and reasonable to assume that our entrainment sampling approximates simple random sampling of towboat transit events with replacement. Simple random sampling with replacement would be guaranteed only if (a) we could have developed a complete list of towboat transits through our sampling areas during this study and then sampled from that list randomly and with replacement, or (b) we remained on the water continuously and selected passing towboats by using a random binary decision rule. Approach (a) is impossible and approach (b) is infeasible. Rather, we sought to sample behind every towboat that happened to pass while we worked in the sampling area. Given the prevailing traffic, we expected to encounter an average of approximately three towboats per 6-h sampling day. Towboats that passed while completing another sample or when equipment failed were not sampled. Based on logistic constraints and prevailing traffic, we expected to be able to sample behind no more than one towboat for every 2-3 ambient trawl samples. We made no attempt to either select or avoid particular towboats, except that we avoided sampling a few downbound tows early in the study when we were developing our technique and later when testing newly repaired gear. Therefore we rely on the unknown stochastic processes that generate the prevailing towboat traffic, coupled with our haphazard selection of towboats for entrainment sampling, to approximate simple random sampling with replacement. Our entrainment sampling was with replacement because it was possible to sample a particular towboat on more than one occasion. In fact, there were instances where we sampled a particular towboat more than once, for example when one was by chance encountered at different sampling locations.

Our goals were to estimate the total number of fish killed per unit distance in the ith entrainment sample, $i = 1,...,41$, and the average of the total number killed per unit distance over all 41 entrainment samples. Our original hope was to estimate the averages of total kills for each combination of propeller type (Kort nozzle and open), direction of towboat travel and river, but the short study duration and resulting limited sampling precluded estimation in this finer partitioning of the data. We estimated entrainment mortality in the *i*th entrainment sample as the number of freshly killed or mortally wounded fish observed in that sample divided by the probability of detection g_i of killed fish (Thompson and Seber 1994). Let k_{hi} denote the *observed* number of kills of species *h* attributed to the leading towboat in the *i*th entrainment sample. Let $k_{\cdot i}$ denote the number of observed kills of all species combined in the *i*th entrainment sample. Let l_i denote the distance traveled by the towboat during collection of the *i*th sample, which is equal to the distance trawled. Then, $\hat{\tau}_{0hi} = k_{hi}/l_i$ is an unbiased estimate of the *observed* kills of species *h* per unit distance of towboat travel, and $\hat{\tau}_{0\cdot i} = k_{\cdot i}/l_i$ is the corresponding estimate of species totals. In our sampling, detection of kills is imperfect; that is we observed only the fraction g_i of the total number of fish killed by the towboat. Therefore, an estimate of the *total* kills of species *h* per unit distance of towboat travel in the *i*th entrainment sample is

$$\hat{\tau}_{hi} = \frac{\hat{\tau}_{0hi}}{\hat{g}_i}, \tag{9}$$

and an estimate of the total kills for all species per unit distance of towboat travel is

$$\hat{\tau}_{\cdot i} = \frac{\hat{\tau}_{0\cdot i}}{\hat{g}_i}, \tag{10}$$

where $\hat{g}_i$ is an estimate of g_i. In random sampling with replacement, the estimated numbers of fish of species h that are killed per unit distance, averaged over all n = 41 entrainment samples, is

$$\hat{\tau}_h = \frac{1}{n}\sum_{i=1}^{n} \hat{\tau}_{hi}, \tag{11}$$

and the average total kills per unit distance for all species combined is

$$\hat{\tau}. = \frac{1}{n}\sum_{i=1}^{n} \hat{\tau}._i \tag{12}$$

(Thompson and Seber 1994). When the $\hat{g}_i$ are stochastically independent, the variance of $\hat{\tau}_h$ is given by

$$\hat{V}(\hat{\tau}_h) = \sum_{i=1}^{n} \frac{(\hat{\tau}_{hi} - \hat{\tau}_h)^2}{n(n-1)} \tag{13}$$

and a corresponding variance estimator applies for $\hat{V}(\hat{\tau}.)$ (Thompson and Seber 1994). The corresponding standard errors are given by the square roots of these variances. This variance $\hat{V}(\hat{\tau}.)$ is inversely proportional to sample size n, and therefore the corresponding standard error decreases at rate $1/\sqrt{n}$ as n increases. Therefore precision increases, as usual, with sample size.

Estimation of probabilities of detection, or sampling efficiencies, g_i.

The original study plan prescribed estimation of the probability of detection by in situ efficiency estimation using marked test fish carcasses. For this approach, probability of detection is the capture efficiency of these test fish. In a preliminary sample, we scattered 400 test fish behind a passing towboat, but detected none of them yielding a probability of detection of 0. This result is not useful because it yields implausibly infinite expansions for the total number of fish killed. This attempt may have failed, in part, because the test fish were scattered in the jets behind the propellers for lack of a way to actually entrain them through the propellers. This may have resulted in inadequate mixing of the test fish in the jets. Further, examination of results of the DIFFLAR model (Holley 1999), which was developed to estimate the fraction of larval fish entrained by one towboat that are also entrained by a second following towboat, indicated that concentrations of entrained particles varied along cross-sectional transects, and with distance behind the tow. Different towboat configurations also produced different distributions. This spatial heterogeneity and tow-specific variation may also help explain our failed attempt at in situ estimation of efficiency.

We recognized that intermediate results in the original DIFFLAR model could be used to estimate detection probabilities because the spatial distribution of killed fish is isomorphic with the distribution of water that has passed through the propellers. After consultation with members of the Modeling and Integration Study Team (MIST) and Corps of Engineers project managers, we adopted that approach, and E. R. Holley developed the modified DIFFLAR2 which produced the desired intermediate output values from which to estimate g_i.

DIFFLAR2 is a two-dimensional model that computes numerical solutions of the velocity and mass concentration distribution c_i of the towboat propeller wash. The flows from the propellers are modeled as co-flowing jets. The end of the region of jet flow is determined based on a tolerance for the ratio of velocity in the jet to ambient river current velocity. After jet velocities decrease below this threshold, ambient diffusion, forced only by the flow of the river, is used to model the concentration distribution. The solution is a Gaussian (normal) probability density function with parameters determined completely by river, barge and water characteristics. The model treats the river channel as a series of strips parallel to the sailing line, and computes the fraction of water in each strip that was entrained through the propellers of a towboat some specified distance in front of the imaginary transect. From these results and the depth of the channel, DIFFLAR2 computes the fraction of previously entrained water, per m^2 of cross section, that passes through an imaginary vertical plane across the channel along a imaginary transect perpendicular to the sailing line at some particular distances lateral to the sailing line and behind the towboat. Holley (1999) gives a thorough technical description of this model. Our estimates of detection probabilities $\hat{g}_i$ are given by

$$\hat{g}_i = \hat{c}_i \hat{A}_{mi}, \tag{14}$$

where $\hat{c}_i$ is the estimated fraction or concentration of entrained water per m^2 in the zone of the *i*th sample and $\hat{A}_{mi}$ is the estimated projection of the surface area (m^2) of the mouth A_m of the rockhopper trawl in the *i*th sample.

The accuracy of the DIFFLAR model was tested in a 122-m long towing tank at the Hydraulics Laboratory of the U.S. Army Corps of Engineers Waterways Experiment Station (Holley 1999). The tank represented a channel having a full-scale depth of 4.88 m. Current velocities were measured at 20, 40, 60 and 80% depth using acoustic Doppler velocity meters positioned in the cross section of the tank. The tank was equipped with a scale-model towboat that represents a barge 258.2 m long and 32.0 m wide and operating with two propellers. The distribution of mass is computed from momentum flux, which is in turn computed from the velocity distribution. Therefore velocity, which is far easier to measure than mass concentration, can be used to assess the accuracy of the DIFFLAR model. See Holley (1999) for details of the DIFFLAR model and this test. In the ranges of distances x (m) behind the towboat in this test, the velocities computed by the DIFFLAR model agreed well with the depth-averaged measured current velocities (Figure 2). The sailing line of the towboat was at transverse distance 308.7 m. Note that at small following distances x, the increased velocities due to the tow are concentrated near the sailing line, and the velocity increases are increasingly distributed across the channel as x increases (Figure 2).

We used DIFFLAR2 to estimate the g_i by using the following model input (our complete input files for the DIFFLAR2 model are given in Appendix F). We used 0.0001 for the convergence tolerance and 1 m for the longitudinal distance increment for numerical integration of momentum (Holley 1999). We set the threshold for the end of the jet region as 0.2 (S. Maynord, Hydraulics Laboratory, U.S. Army Corps of Engineers Waterways Experiment Station, personal communication). We computed the mass concentration distribution of the propeller wash, c_i, over a 200-m wide swath of the river. Although the main channel (navigation channel and main channel borders) was always wider than this, preliminary computations demonstrated that DIFFLAR2 was totally insensitive to variation beyond this width. We specified computation of mass concentration in $m = 40$ strips (5-m wide) within this 200-m wide swath. We used 0.03 for our value of Manning's coefficient, and used 0.4 for the dimensionless ambient transverse diffusion coefficient. We used 0.052 for the spreading coefficient for co-flowing jets. The trawler always traveled slower than the leading tow. Therefore we computed mass concentration profiles, c_{ikm}, for towboats with sailing lines on the 21st strip, at distances behind the tow x_k, $k = 1,...,4$. These four following distances bounded and equally divided the range of following distances in the entrainment sample.

For upbound towboats, we computed the speed relative to the ground as the sum of the measured trawler speed over the ground and the distance gained by the tow during the entrainment sample divided by the trawl duration. Tow speed relative to the water was obtained as the sum of current velocity and tow velocity over the ground. Where trawler speeds over the ground were not measured, including all entrainment samples behind downbound towboats, the speed of tows relative to the water was taken as 9.55 km/h (6.5) mi/h for the Mississippi River and 7.35 km/h (5.0 mi/hr) for the Illinois River (S. Knight, Hydraulics Laboratory, U.S. Army

Corps of Engineers, personal communication). For these cases, tow speed over the ground is speed relative to the water plus or minus current speed, respectively, depending on whether the towboat is downbound or upbound.

Wake fraction is defined as $1 - V_p / V_s$, where V_p and V_s are the speeds of the water approaching the propeller and of the vessel relative to the water, respectively. The wake fractions were determined by the draft of the barges (S. Maynord, Hydraulics Laboratory, U.S. Army Corps of Engineers, personal communication), as follows:

Draft m (ft)	Wake fraction
<0.91 (3)	0.3
0.91-2.44 (3-8)	0.5
>2.44 (8)	0.8

Drafts of loaded barges are 2.74 m (9 ft), and drafts of empty barges are taken to be 0.61 m (2 ft). For mixed tows, which contain both loaded and empty barges, we approximated the draft D (m) as the weighted average

$$D \approx \frac{2n_f D_f + n_e D_e}{2n_f + n_e}, \tag{15}$$

where n_f and n_e are the numbers of full and empty barges, respectively, in the tow, and D_f and D_e are their corresponding drafts (m) (S. Maynord, Hydraulics Laboratory, U.S. Army Corps of Engineers Waterways Experiment Station, personal communication).

We approximated the thrust coefficient K_t as

$$K_t \approx \frac{1000T_p}{\rho n_p^2 \Phi_p^4}, \tag{16}$$

where T_p is the thrust (kN) per propeller, $\rho = 1000$ kg/m^3 is the density of water, $n_p = 3$ revolutions/sec is the tabled value of rotational speed of the propellers, and Φ_p is the propeller diameter (m) (S. Maynord, Hydraulics Laboratory, U.S. Army Corps of Engineers Waterways Experiment Station, personal communication). Our runs of DIFFLAR2 compute K_t and n_p from input values of T_p, but the model required placeholder input of both K_t and n_p.

We approximated propeller diameter Φ_p, in inches, as

$$\Phi_p \approx 5.25 H_{\max}^{0.35}, \tag{17}$$

for towboats equipped with Kort nozzles and

$$\Phi_p \approx 6.30 H_{\max}^{0.33}, \tag{18}$$

for open-wheel propellers, where $H_{\max}$ is the installed horsepower rating of the towboat (S. Maynord, Hydraulics Laboratory, U.S. Army Corps of Engineers Waterways Experiment Station, personal communication). Values of $H_{\max}$, the numbers of propellers, and identifications of propeller type (Kort nozzle or open) were obtained from *The Waterways Journal* (1998) for each towboat identified in the entrainment sampling.

We approximated the vertical distance (m) from the water surface to the center of the propeller shafts as $0.5\Phi_p$ because towboat propellers are installed in partial tunnels and extend nearly to the surface of the water (S. Maynord, Hydraulics Laboratory, U.S. Army Corps of Engineers Waterways Experiment Station, personal communication). We approximated the distance between the propellers (m) as $2.2\Phi_p$ (S. Maynord, Hydraulics Laboratory, U.S. Army Corps of Engineers Waterways Experiment Station, personal communication).

Individual barge containers average approximately 10.7-m (35-ft) wide and 59.4-m (195-ft) long. We approximated the total length and width of each tow, here defined as the towboat plus the raft of barges, from tabled values of barge configuration. Because the initial study plan predated the DIFFLAR model and did not foresee its use in estimation of the g_i, we recorded the towboat name and the numbers of full and empty barges in each tow, but not the configuration of each raft (physical arrangement of barges). We used the following barge configurations (numbers of units):

Total barges	Barge lengths	Barge widths
0	0	1
1	1	1
2	1	2
3	2	2
4	2	2
5	3	2
6	3	2
7	4	2
8	4	2
9	3	3
10	4	3
11	4	3
12	4	3
>12	5	3

For tows containing 1-4, 6, 9, 12, or 15 barges, we assumed that the length of the tow would equal the total length of the raft of barges plus the length of the towboat. Otherwise we assumed that the towboat could push the raft with 1-2 barges aligned next to the side of the towboat so that the total length of the tow would equal the total length of the raft of barges. We obtained the lengths of each identified towboat from *The Waterways Journal* (1998).

Depths of the navigation channel for our study sites were obtained from the bathymetric database maintained by the U.S. Geological Survey Upper Midwest Environmental Sciences

Center (J. Rogala, U.S. Geological Survey Upper Midwest Environmental Sciences Center, Onalaska, Wisconsin, personal communication). We used 50% exceedance depths for our computations.

We approximated the thrust per propeller T_p (kN) by using the POWER.BAS program (S. Maynord, Hydraulics Laboratory, U.S. Army Corps of Engineers Waterways Experiment Station, personal communication), which is based on Van de Kaa (1978) and Toutant (1982). POWER.BAS requires, as input, return velocity, drawdown, the dimensions and draft of the tow, river depth, propeller type, and tow speed relative to the water. We approximated return velocity V_r (ft/sec), which is the increment to the velocity of the river adjacent to the tow, as

$$V_r \approx \frac{50}{\kappa W_c} S_t, \tag{19}$$

where W_c is the channel width (m), S_t is the speed of tow relative to the water (ft/sec), and $\kappa = 1$, 2, or 3 for barge drafts >2.44 m, 0.91-2.44 m, and <0.91 m, respectively (S. Maynord, Hydraulics Laboratory, U.S. Army Corps of Engineers Waterways Experiment Station, personal communication). Here, W_c is the bank-to-bank width of the main channel, and values were obtained from navigation charts. We approximated drawdown h (ft), which is the decrease in water surface elevation adjacent to the tow, as

$$h \approx \frac{30 V_r^2}{2G}, \tag{20}$$

where here $G = 32.16$ ft/s^2 is the gravitational constant (S. Maynord, Hydraulics Laboratory, U.S. Army Corps of Engineers Waterways Experiment Station, personal communication). POWER.BAS produces, as output, the total resistance to the tow (lbs force) which we converted to total thrust (kN) for all propellers (1 N = 4.448 lbs force).

We obtained estimates of the concentration distribution of killed fish c_{ikm} behind the ith tow, at the kth distance behind the tow x_{ik}, and in the mth lateral strip following the sailing line (Figure 3). Because the tows traveled faster than the trawler, x_{i1} is the following distance at the beginning of the entrainment sample and x_{i4} is the final following distance. We retained all results from DIFFLAR2 for which the mass balance error did not exceed 5% and for which probabilities of detection were successfully computed for at least three following distances. We assumed the position of the trawler along the y axis (Figure 3) followed a uniform distribution over the central 11 and 15 strips, respectively, for up- and downbound tows. Under the uniform distribution, $\hat{c}_i$ is the simple mean of the c_{ikm} and the conventional variance estimator applies.

We lacked complete data for 8 of 41 towboats followed during entrainment sampling. Either the names of these towboats were not visible to the trawler operator or the names printed on them did not match any vessels listed in the Inland River Record. For these tows, and for those that produced DIFFLAR2 mass balance errors in excess of 5% or for which computations were not successful for at least three following distances, we used $\bar{c}_u$ or $\bar{c}_d$, as appropriate, where $\bar{c}_u$ is the average of the $\hat{c}_i$ from upbound tows and $\bar{c}_d$ is the average from the downbound tows.

Incorporation of entrainment kills observed from ambient samples.

In addition to observing fish that were likely killed by tows in the entrainment samples, it was also possible to observe kills in the ambient samples because of the presence of background traffic. Therefore it is reasonable to use any such observations, to the extent possible, to augment the estimates obtained from the entrainment sampling when tow-related kills of a particular species are observed in ambient samples but not in the entrainment samples. In this case it would be untenable to claim that a particular species is not killed by entrainment because the ambient samples demonstrate the contrary. However, because any kills observed in ambient samples cannot be ascribed to a measured travel distance by a particular tow, we cannot obtain an associated probability of detection to estimate kills per unit distance of tow travel using equation (11), and another method is required. Following, we explain our approach to this problem descriptively using an example, and then formalize the method with a derivation of the estimators.

Our ancillary estimator for entrainment mortality of species for which entrainment kills were observed in ambient samples—but not in entrainment samples—is based on a simple and intuitive idea. Suppose we have a set of entrainment samples from which we observed three fish of species 1 that were likely killed by entrainment. Suppose further that from these data and the methods outlined previously, we obtain an estimate of eight fish killed per kilometer of towboat travel for species 1. Additionally, suppose we have a set of ambient samples from which we observed one additional fish of each of species 1 and 2 that were recently killed by entrainment. Kills of species 2 were observed in the ambient samples, but not in the entrainment samples. We therefore observed four entrainment kills of species 1 and one entrainment kill of species 2 in the *combined* ambient and entrainment samples. Hence, from all of the data, we estimate that one fish of species 2 is killed for every four fish of species 1 that are killed. By simple extension, we estimate that ¼ × 8 = 2 fish of species 2 were killed per kilometer of tow travel for every eight fish of species 1 that were killed per kilometer of tow travel, but that these kills of species 2 went unobserved in the entrainment samples.

To formalize this estimator, consider the distribution of counts of kills of species h, $h = 1,...,$ H, in the *combined* entrainment and ambient samples. Suppose that kills of only species 1 are observed in the entrainment samples, but that kills of all H species are observed in the ambient samples. Let n_h denote the numbers of observed kills of species h in the *combined* set of samples, and let $n = \Sigma_h n_h$ denote the total number of observed kills in that set. We can safely assume that the n observed kills represent a random selection from an unknown but sufficiently large population N so that our sampling without replacement is equivalent to sampling with replacement. In this case, the n_h have a multinomial probability distribution given by

$$f(\boldsymbol{n}_h | n, \boldsymbol{\pi}) = \frac{n!}{n_1! \cdots n_H!} \pi_1^{n_1} \cdots \pi_H^{n_H}, \tag{21}$$

where $\boldsymbol{n}_h$ is the vector $[n_1, \ldots, n_H]$, and $\boldsymbol{\pi}$ is the vector of parameters $[\pi_1, \ldots, \pi_H]$ (Agresti 1990). The π_h can be interpreted as the probabilities that a particular killed fish is of species h. The sample proportions $p_h = n_h/n$ have mean π_h and variance $\pi_h(1 - \pi_h)/n$, and for $h \neq h'$ have covariance $\mathrm{cov}(p_h, p_{h'}) = -\pi_h \pi_{h'}/n$. Further, define $\theta_{h'}$, $\forall h' : h' > 1$, as the odds of kills of species h' to species 1 such that $\theta_{h'} = \pi_{h'}/\pi_1$. Recall the estimate of the number of fish of species 1 killed per unit distance of tow travel, $\hat{\tau}_1$, obtained from the entrainment sampling and equation (11). We claim that

$$\hat{\tau}_{h'}^{*} = \hat{\theta}_{h'}\hat{\tau}_1 \tag{22}$$

is a plausible *ancillary* estimate of the numbers of fish of species h' that are killed per unit distance of tow travel, where $\hat{\theta}_{h'} = p_{h'}/p_1 = n_{h'}/n_1$. From successive application of the delta method (Efron 1982), the variance of $\hat{\tau}_{h'}^{*}$ is

$$\mathrm{Var}(\hat{\tau}_{h'}^{*}) \approx \hat{\theta}_{h'}^{2}\mathrm{Var}(\hat{\tau}_1) + \hat{\tau}_1^{2}\mathrm{Var}(\hat{\theta}_{h'}), \tag{23}$$

where

$$\mathrm{Var}(\hat{\theta}_{h'}) \approx \frac{p_{h'}^{2}}{p_1^{4}}\mathrm{Var}(p_1) - 2\frac{p_{h'}}{p_1^{3}}\mathrm{cov}(p_1, p_{h'}) + \frac{1}{p_{h'}^{2}}\mathrm{Var}(p_{h'}).$$

In words, the ancillary estimate of entrainment kills for species observed in the ambient but not the entrainment samples, say species 2, is the product of the entrainment sampling estimate of kills per distance of tow travel for species 1 and the odds of observing a kill of species 2 relative to observing a kill of species 1 in the *combined* entrainment and ambient samples. The above estimators presume that only one species is represented in the entrainment sampling. If more than one species is observed in the entrainment sampling, the same formulas hold but with species 1 redefined as the combination of all species observed in the entrainment sampling.

The above ancillary estimation method creates a paradox. Given the existence of an ancillary estimate, there are now two estimates of the total number of fish killed per unit distance of tow travel. The first is obtained from the entrainment sampling and equation (12). This estimate is unbiased under the sampling design. The second is the sum of the former and the ancillary estimates obtained from equation (22). This second estimate is ad hoc because it is partly external to the entrainment sampling design. For this reason, we do not propose that the ancillary estimates and the entrainment estimates should be interpreted equally. Rather, the ancillary estimates are plausible measures of the entrainment mortality for species for which the entrainment sampling alone was insufficient.

The original study plan suggested, but did not prescribe, the less defensible approach of estimating entrainment mortality of species not observed in the entrainment samples as the product of entrainment mortality and the ratios of relative abundance of live fish in the ambient samples. This approach would produce non-zero estimates of entrainment mortality for species for which kills were never observed because it assumes that entrainment mortality is a constant proportion of abundance of live fish for all species. We believe this approach is untenable because of this untestable and questionable assumption, and did not pursue it.

Assessment of precision of estimates of entrainment mortality.

The statistical distributions of the entrainment estimator $\tau.$ (equation 12) and the ancillary entrainment estimator $\tau_{h'}^{*}$ (equation 22) are skewed, and therefore construction of normal-theory confidence intervals on the resulting estimates is untenable. Further, although $\tau.$ is design-unbiased, bias of $\tau_{h'}^{*}$ is unknown. Therefore we used the bootstrap (Efron 1982; Efron and Tibshirani 1993) to obtain estimates of variances and bias, and 80% confidence intervals. The bootstrap estimates the unknown distribution function F of a random variable from B independent random resamplings, with replacement, from the empirical distribution observed in the data. Bootstrap estimates do not rely on assumptions about the specific form of F, and are therefore said to be nonparametric. Confidence intervals are correctly interpreted as intervals or bounds about an estimate, that when repeatedly constructed independently from F, will enclose the true value of the estimated parameter some specified percentage of the time. We chose the 80% confidence level for our intervals because we believe that choice is appropriate given our sample size and the spatial and temporal limitations of this project. Generally, $B = 2{,}000$ is considered the minimum of resamplings for estimation of bootstrap confidence intervals (Efron and Tibshirani 1993), and we used $B = 6{,}000$ resamplings for all of our work. Exploratory analyses indicated that confidence intervals for our estimators had become stable at $B \ll 6{,}000$.

We constructed bias-corrected and accelerated percentile method (BC_a; Efron 1987; Efron and Tibshirani 1993) confidence intervals for our estimate of entrainment mortality $\tau.$ obtained from the entrainment samples. For bias-corrected bootstrap confidence intervals, bias refers to *median* bias, and is different from the estimates of bias described below. BC_a intervals are second-order accurate in that errors in estimating the tail probabilities go to zero at the rate $1/n$, where n is the sample size (Efron and Tibshirani 1993). We also constructed ordinary bias-corrected intervals (BC; Efron 1982), which require more restrictive assumptions than do BC_a intervals (Efron 1987), and therefore we prefer the BC_a intervals but provide the BC intervals for contrast. We computed BC and BC_a intervals and bias using Warren Sarle's SAS-based JACKBOOT macros (World Wide Web, http://www.sas.com/service/techsup/ftp_products.html). Bootstrapping the ancillary estimator is more complicated, and bias-corrected intervals are undefined for equation (22). We made 6,000 bootstrap resamplings of the numbers of entrainment kills from the set of ambient samples. We concatenated these, column-wise, with the 6,000 bootstrapped estimates of $\tau.$ obtained previously from the set of entrainment samples, which results in a completely and independently random pairing of the bootstrapped estimates of $\tau.$ obtained from the entrainment samples with the bootstrap resamplings of the entrainment kills from the ambient samples. We then summed the kills for each species in the combined ambient and entrainment samples, and computed $\hat{\tau}_{h'}^{\,*}$ for each resampling. Finally, we computed ordinary percentile-method bootstrap confidence (Efron and Tibshirani 1993) intervals from these 6,000 estimates of $\hat{\tau}_{h'}^{\,*}$. Percentile-method confidence intervals are only first-order accurate in that errors in estimating the tail probabilities go to zero at the rate $1/\sqrt{n}$ (Efron and Tibshirani 1993). Estimation of bias is straight-forward in both cases, and is the difference between the expectation of the estimator over the bootstrapped resamplings and the value of the estimator obtained from the empirical distribution provided by the data (Efron and Tibshirani 1993).

Results

Estimation of densities of larval fishes.

Illinois River—During 1996, larval fish density was lowest during July, averaging 0.96 larvae/m^3, and greatest during June, at 1.65 larvae/m^3 (Table 3). Nine larval taxa were identified in the navigation channel drift during May (Table 4), with common carp and clupeid, primarily *Dorosoma*, being the two dominant taxa. In June, eight larval taxa were present, with clupeid and common carp larvae again dominant (Table 4). Seven taxa were found during July; freshwater drum larvae were more abundant than any other larval taxon by at least 10-fold (Table 4).

Larvae were sampled in main channel, side channel, and backwaters at one site in the Illinois River, during 1997. Once again, mean larval density in the main channel was greatest during June, at 4.13 larvae/m^3, and lowest during July, at 0.10 larvae/m^3 (Table 5). A similar pattern held in the side channel, where larval abundance peaked in June at a mean of 7.43/m^3 and was lowest in July at 0.03 larvae/m^3 (Table 5). Backwater larval fish densities were greatest during May (6.99 larvae/m^3) and lowest during June (1.70 larvae/m^3; Table 5).

Four to eight taxa were represented in the main channel during the sampling period (Table 6). Clupeid larvae were dominant during May, followed by freshwater drum in June and catostomids during July (Table 6). Three to seven larval taxa were present in the side channel, with freshwater drum dominant during May and June, and clupeid larvae dominant in July (Table 6). Taxonomic diversity was consistent at four or five taxa in the Illinois River backwater throughout the May-July sampling period (Table 6). Clupeid larvae predominated in the backwater during May but centrarchids were the dominant larvae during June and July (Table 6).

Mississippi River—In 1996, larval fish density was greatest during May, averaging 0.84 larvae/m^3 and least in June, averaging 0.54 larvae/m^3 (Table 7). Ten taxa were present in May, with common carp larvae the dominant taxon; clupeid, primarily *Dorosoma*, and catostomid larvae also were relatively abundant (Table 8). During June, eleven taxa occurred. Abundance of common carp larvae declined whereas clupeid and freshwater drum larvae increased, generating a larval assemblage with several important taxa represented (Table 8). Six larval taxa were represented during July; freshwater drum was the dominant taxon present (Table 8).

Sampling during 1997 included four paired main channel and side channel sites as well as one backwater. Main channel larval fish density was greatest during June, at 0.54 larvae/m^3 and least in April, at < 0.01 larvae/m^3 (Table 5). Side channel larvae exhibited a similar pattern of density, peaking in June at 1.25 larvae/m^3 but present at <0.01 larvae/m^3 in April (Table 5). Larvae were much more abundant in the backwater, generating 27.47 larvae/m^3 in June and 3.60 larvae/m^3 in May, the only two months in which larvae were collected in the backwater (Table 5). Larvae were not present in the backwater during April and we could not sample the backwater in July because the water level had receded sufficiently to prevent our nets from fishing.

From seven to nine larval taxa were present in the main channel during April-July (Table 9). No taxon was dominant in April, all larvae being present at low levels. Percid, hiodontid, and catostomid larvae were prevalent during May, whereas freshwater drum, clupeid and catostomid larvae were most dense in June. Cyprinid larvae were most abundant in July (Table 9). In side channels, taxonomic diversity was highest during May and June, when nine and ten larval taxa occurred, respectively; only percid larvae were present in April (Table 10). Hiodontids and catostomids were most prevalent in May. Clupeid and freshwater drum larvae dominated the June samples, and cyprinid larvae comprised most of the larvae collected in July (Table 10). Seven and six larval taxa were present in the backwater during May and June, respectively (Table 11). Clupeid and centrarchid larvae were the two dominant taxa throughout the sampling period.

Larval fish present in the navigation channel of both rivers during both years exhibited a predictable pattern of appearance. Common carp larvae and some catostomids, primarily ictiobid larvae, were the first dominant larval group appearing during May. At the end of May and into June, clupeid larvae were the dominant representative in the larval drift. Finally, freshwater drum larvae dominated in late June and July. Percid larvae, primarily *Stizostedion* spp., occurred primarily during May but never approached dominant levels. Centrarchid and *Morone* larvae also appeared in relatively small numbers during late May through June.

Detailed summaries of volumes of river water strained during ichthyoplankton sampling are included in Appendix B. Density estimates (number/l) from each sample are included in Appendix C.

Trawling performance.

Trawl speed relative to the ground averaged 1.1 m/sec (4.0 km/hr) with standard deviation 0.2 m/sec (0.7 km/hr) over 43 measured hauls. Wingspread of the rockhopper trawl averaged 3.9 m with standard deviation 0.7 m over 258 measurements made during 18 trawl hauls monitored by using the hydroacoustic net measurement system. Headrope height of the rockhopper trawl averaged 1.2 m with standard deviation 0.7 m over 265 measurements made during 18 hauls.

Catch and abundance of small fish captured with the beam trawl.

In the Illinois River, catch per unit effort (CPUE; fish/hr trawling) averaged 120 fish per hour during September 1997 (Table 12). Seven species were captured by beam trawling in the Illinois River. Freshwater drum were most abundant, with estimated densities averaging 88.9 fish/ha, followed by gizzard shad and channel catfish (Table 13). Total estimated densities averaged 125 fish/ha and total biomass averaged 5.3 kg/ha. Detailed CPUE data, by month and river mile, are included in Appendix D.

In Pool 26 of the Mississippi River, total CPUE of small fish averaged 105.4 per hour in July but only 11.5 per hour in September 1997 (Table 12). A total of nine species were captured by beam trawling in Pool 26. Channel catfish were, by far, the most abundant species with estimated densities averaging 39.4 fish/ha, followed by freshwater drum and mooneye (Table 14). Total estimated densities of small fish in Pool 26 averaged 57.6 fish per ha in 1997, with an average estimated biomass of 1 kg/ha (Table 14).

The beam trawl captured primarily small fishes (Table 15) including juvenile channel catfish and freshwater drum, which averaged 43 mm and 26 mm in length, respectively, in the Mississippi River, and 70 mm and 93 mm, respectively, in the Illinois River. Occasionally large adult fish were captured in the beam trawl, as reflected in the sometimes large standard deviations for length and the large mean weights, which are particularly sensitive to the presence of only a few large fish.*Catch and abundance of 'adult' fishes captured by the rockhopper bottom trawl.*

During the course of this study, monthly mean estimated densities of all species combined varied by approximately 100-fold in the navigation channels of both the lower Illinois River and in Pool 26 of the Mississippi River (Figure 4). Total fish densities in the lower Illinois River averaged 157.3 (Table 16) and 177.7 fish/ha (Table 17) in 1996 and 1997, respectively. Corresponding mean estimated biomasses were 26.5 and 32.2 kg/ha. Total fish densities in Pool 26 of the Mississippi River averaged 109.0 (Table 18) and 55.5 fish/ha (Table 19) in 1996 and 1997, respectively. Corresponding mean estimated biomasses were 22.7 and 19.2 kg/ha. In our effort-adjusted catch model given by equations (2) and (4), total catch differed significantly between rivers (Table 20; P=0.01) and, in Pool 26, was 100exp(p_1) = 52% of that in the lower Illinois River. All parameters for the cubic polynomial in month were statistically significant (Table 20) indicating that the seasonal rise and fall of total estimated densities apparent in Figure 4 is real. Our conclusions are unchanged by the relaxed assumption of autoregressive serial correlation in catches, and are therefore unlikely to be an artifact of a particular model choice. The extra-Poisson scale parameter indicated that the variance of our total catch data was approximately nine-fold greater than expected from the Poisson distribution, indicating the importance of accommodating this overdispersion.

Blue catfish densities peaked during late summer and fall, and were greater in the lower portion of Pool 26 than in the upper portion or in the Illinois River (Figure 5). Densities of blue catfish averaged 0.8 and 0.6 fish/ha during 1996 (Table 16) and 1997 (Table 17), respectively, in the navigation channel of the Illinois River, and averaged 2.0 (Table 18) and 1.3 fish/ha (Table 19) during those years in Pool 26. Effort-adjusted catches of blue catfish differed significantly between upper and lower Pool 26 ($P<0.01$), but did not differ significantly between years or rivers (Table 21). Catches tended to be $\exp(l_{1(1)}) = 9.8$ times greater in lower Pool 26 than in the upper segment. Catch did not change linearly with month, but the quadratic and cubic effects of month (Table 21) indicate that the seasonal peak in density during late summer and fall is real. Again, our results were invariant under the assumptions of serially independent and serially autoregressive catches.

Estimated densities of channel catfish appeared greater in the navigation channel of the Illinois River than in Pool 26 (Figure 6). Densities of channel catfish averaged 18.9 and 10.3 fish/ha during 1996 (Table 16) and 1997 (Table 17), respectively, in the navigation channel of the Illinois River, and averaged 8.8 (Table 18) and 7.1 fish/ha (Table 19) during those years in Pool 26. Average estimated biomasses ranged from 0.8 to 1.8 kg/ha (Tables 16-19) in these navigation channels. Effort-adjusted catch differed significantly ($P \leq 0.05$) between rivers, and in Pool 26 was $100\exp(p_1)$ = 24% of that from the lower Illinois River (Table 22). Catch also differed significantly between upper and lower Pool 26 ($P<0.01$), and was 3.5 times greater in the lower portion of that pool. Catches of channel catfish did not show any significant seasonal response (Table 22).

Monthly mean estimated densities of common carp tended to peak during fall (Figure 7). Mean estimated densities for each combination of river and year ranged from 0.4 to 4.2 fish/ha, and corresponding estimated biomasses ranged from 0.5 to 5.0 kg/ha (Tables 16-19). Effort-adjusted catches of common carp could not be adequately fitted to our Poisson models because of uncertain convergence of the iterative algorithms, and therefore our analysis is based on the Gaussian errors model [equation (7)]. Log(CPUE) did not differ significantly between rivers, years or between locations in Pool 26 (Table 23). However, the parameter estimates for the cubic polynomial in month indicate the seasonal fall peak was real (all $P \leq 0.02$).

Monthly mean estimated densities of freshwater drum seemed to differ among river segments and showed a strong seasonal response with maxima during late fall (Figure 8). This species typically dominated density and biomass in our rockhopper bottom trawl samples (Tables 16-19), with mean annual density exceeding 122 fish/ha in the lower Illinois River during 1996. Effort-adjusted catches of freshwater drum differed significantly between rivers ($P<0.01$), and location within Pool 26 ($P \leq 0.01$), but not between years (Table 24). The quadratic seasonal response was marginally significant ($P<0.09$), and the cubic effect was clearly important ($P \leq 0.04$), indicating that the seasonal fall peak is real. Our results were again insensitive to model choice, and the variance of catch was 6.2 times greater than expected from the Poisson distribution.

Estimated densities of gizzard shad varied by approximately 100-fold during this study (Figure 9). Because this species is largely pelagic, our bottom trawl samples likely underestimate their true areal abundance. The Gaussian errors model indicated that log(CPUE) differed significantly between rivers, locations within Pool 26 and over seasons (Table 25).

Estimated densities of goldeye showed no consistent pattern over this study (Figure 10). The Gaussian errors model showed marginally significant differences between rivers (P=0.10) and between locations within Pool 26 (P=0.08), but showed no seasonal effect (Table 26). The closely related mooneye showed a somewhat similar pattern in estimated density, although their apparent abundance was greater during 1996 (Figure 11). The Gaussian errors model for mooneye indicated that log(CPUE) differed significantly between years (P<0.01) and between locations in Pool 26 (P<0.01; Table 27). Like goldeye, mooneye showed no significant seasonal response (Table 27).

Estimated densities of shovelnose sturgeon differed greatly among river sections, and in upper Pool 26 averaged over 18 fish/ha in June 1997 (Figure 12). Log(CPUE) differed significantly between years and locations within Pool 26 (Table 28). This pattern reflects a strong preference for upper Pool 26, which tends to be more riverine than the other study areas. Seasonal effects were only marginally significant ($0.06 \le P \le 0.07$).

Estimated densities of smallmouth buffalo showed a strong seasonal pattern with peak abundance typically occurring during early fall (Figure 13). Effort-adjusted catches of smallmouth buffalo differed significantly between upper and lower Pool 26 ($P \leq 0.03$) but not between years or rivers (Table 29). The parameter estimates for the cubic polynomial in month indicated a significant seasonal effect (Table 29), and we conclude that the peaks in Figure 13 are real. Again, our results were insensitive to model choice.

The distribution of blue suckers (and other species) in our samples was sufficiently restricted that we did not attempt formal analyses of abundance. However, the blue sucker is an important species because of common perceptions about its status. We encountered blue suckers only in the upper portion of Pool 26, where catch rates frequently exceeded 1 fish/h of trawling effort (Figure 14). This is consistent with the fact that the blue sucker is a habitat specialist preferring areas of relatively swift current. Our results suggest that the blue sucker may not be uncommon in deep riverine channels of the Upper Mississippi River. Detailed summaries of CPUE of all species captured by the rockhopper bottom trawl are included as Appendix Tables E1-E8.

A detailed analysis of species richness is well beyond the scope of this study, and would be difficult because species richness is an unusually challenging quantity to estimate (Bunge and Fitzpatrick 1993). Instead, we note informally the seasonal tendency for the mean numbers of species per trawl haul to peak during fall (Figure 15). These data and our underlying catches suggest that some species use the main channel only seasonally.

The rockhopper bottom trawl captured primarily large-bodied fish (Table 30). Black buffalo, common carp, flathead catfish, lake sturgeon, shortnose gar and shovelnose sturgeon captured by this gear averaged nearly 0.5 m or more in length.

Incidence of injured and dead fish in ambient and entrainment sampling.

While using the rockhopper trawl for entrainment sampling behind towboats, we collected three gizzard shad during 1996 that were most likely killed as a result of impact with the propellers of the preceding tows, but no killed or wounded fish were collected during entrainment sampling in 1997 (Table 31). The sizes of these gizzard shad strongly suggest they were spawned in 1996. While conducting ambient sampling using the rockhopper bottom trawl, we collected 27 fish that were either dead, wounded, or alive with wound scars in Pool 26 and the lower Illinois River during 1996 and 1997 (Table 32). Of these 27 fish, one was a smallmouth buffalo, five were shovelnose sturgeon, and the remainder were gizzard shad. The smallmouth buffalo, one shovelnose sturgeon, and one gizzard shad were freshly wounded fish with serious injuries consistent with propeller impact. Most of the other gizzard shad had been dead for some time and were collected during November-March, suggesting that these fish had died during this period because of natural causes during the winter (Bodensteiner and Lewis 1994). No injured or dead fish were collected during the ambient beam trawling.

Entrainment mortality of 'adult' fishes.

We completed 41 successful entrainment samples (Table 33). Of these, 23 were completed behind upbound tows. Most tows consisted of 15 barges, and downbound tows tended to be comprised of full barges more often than upbound tows. The installed horsepower ratings of the towboats we sampled ranged from 650 to 7,200. Kort nozzles were installed on 19 of the 33 identified tows. Most tows were identified from names recorded during sampling, but six were identified from lock passage records. The name "Evey-T" was assigned to a tow whose name was recorded as "Eve" at the time of sampling because the former name was the only boat registered in the Inland River Record (The Waterways Journal 1998) that contained "Eve." The names of two towboats recorded on the water could not be located in the Inland River Record and these tows could not be unambiguously identified from lock records.

We measured the speeds of 12 of the 41 tows; the remaining speeds were averages for the Mississippi River and Illinois River, as appropriate (Table 34). The return velocities estimated for these tows ranged from 0.03 to 0.34 m/sec. Estimated drawdown ranged from less than 0.01 m to 0.32 m.

Our distances trawled behind the tows ranged from 450 to 1,820 m, and trawl durations ranged from seven to 23 minutes (Table 35). These departures from the 20-min sampling goals were usually due to early termination because the trawl became partially fouled in such a way that the catch was not likely lost or because of the development of unsafe conditions. Current speed during entrainment sampling ranged from 0.1 to 1.3 m/sec. Channel widths at entrainment sampling sites ranged from 244 to 1,402 m. The narrow channel where the towboat "Evey-T" was sampled (Table 35) resulted in a large value of drawdown (Table 34). The tabled speed of 2.26 m/sec may therefore have been an overestimate of the actual speed of this tow through that segment of channel.

We obtained estimates of average mass concentrations $\hat{c}_i$ of propeller water per 1-m^2 of transverse section across the area trawled behind 19 upbound tows and 9 downbound tows (Table 36). The $\hat{c}_i$ for the remaining 4 upbound and 9 downbound tows were obtained as the averages of the 'completed' estimates obtained from up- and downbound tows, respectively. Concentrations were greatest over the sailing line of the tow and nearest to the propellers. Figure 16 shows, for example, an estimated concentration field for a typical upbound tow equipped with open propellers. The Gaussian distribution of concentration across the transverse section is apparent, as is increased diffusion downstream from the propellers. A concentration field for an otherwise comparable downbound tow (Figure 17) shows more dramatic spatial differences in concentrations because of the greater range of following distances. The concentration field for a roughly comparable downbound tow equipped with Kort nozzles (Figure 18) shows somewhat increased concentration near the sailing line than for another equipped with open propellers (Figure 17). The average mass concentration of propeller water per 1-m^2 of area of transverse sections in the sampling zone was 0.0029 for upbound tows and 0.0014 m^{-2} for downbound tows. Complete input into the DIFFLAR2 model is given in Appendix F.

The projection of the surface area of the mouth $\hat{A}_m$ of the rockhopper trawl onto the plane of transverse sections across the river averaged 3.66 m^2 over 258 measurements made during 18 entrainment and ambient trawl hauls that were monitored by using the hydroacoustic net measurement system. The standard deviation over all measurements was 1.71 m^2, and 50% of the measurements ranged within 2.32-4.59 m^2.

The resulting estimates of detection probabilities $\hat{g}_i = \hat{c}_i \hat{A}_{mi}$ ranged from 0.0030 to 0.0151 (Table 36). Among the 41 entrainment samples, kills of gizzard shad that could be attributed to entrainment were observed on two occasions; two kills were recovered in one sample collected on 2 October 1996 and one was observed on 6 November 1996 (Table 31). The resulting expansions for kills per unit distance of travel for each of the 41 tows therefore ranged from 0 to 236 gizzard shad per km (Table 36).

Our estimate of the number of ‘adult’ gizzard shad and the total fish killed by entrainment per unit distance of tow travel, averaged over all 41 entrainment samples, is 9.5 fish/km (15.3 fish/mi; Table 37). The entrainment mortality rate estimator (equation 12) is unbiased under random sampling with replacement (Thompson and Seber 1994) and consonantly our bootstrap estimate of bias is trivially small. The analytical variance estimator performed well against our bootstrapping. Our bias-corrected percentile-method bootstrap 80% confidence interval on this entrainment mortality rate is 3.8-22.8 fish/km (6.1-36.7 fish/mi). The sampling distribution of the entrainment estimator $\hat{\tau}$ is highly non-Gaussian (Figure 19) and has a lower bound of zero.

Our ancillary estimates of kills of 'adult' shovelnose sturgeon and smallmouth buffalo $\hat{\tau}^*$ were 2.4 fish/km of tow travel (Table 37).Our analytical variance approximation (equations 23-24) performed well against our bootstrapping. Our bootstrapping results suggest that our ancillary entrainment mortality rate estimator (equation 22) is essentially unbiased, underestimating mortality by only 0.12 fish/km. Our bootstrap percentile-method 80% confidence interval is 0-6.0 fish/km indicating that values only trivially larger than zero are plausible. In fact, the probability that entrainment mortality of each of these species is essentially zero is approximately 0.44 (Figure 20). The median (50^{th} percentile) ancillary mortality rate from our bootstrapping was 1.9 fish/km.

Our estimate of the augmented total entrainment mortality rate, which is the sum of the estimates for all three species, is 14.3 fish/km (22.9 fish/mi; Table 37).Our analytical approximations to the standard error underestimated the bootstrap estimate of the standard error. Our augmented estimator of the total number of fish of all species that are killed per km has a estimated bias of −0.22 fish/km; that is, it tends to underestimate the augmented total by a very small amount and is essentially unbiased. Our bootstrapped 80% confidence interval on the augmented total is 0-26.7 fish/km. The lower bound of this confidence interval is zero, rather than the 3.8 fish/km obtained from estimate of the total from entrainment sampling because the ancillary estimation imposes a variance penalty for the uncertainty in the ratios of the probabilities of occurrence of shovelnose sturgeon and smallmouth buffalo to the probability of occurrence of gizzard shad in the combined ambient and entrainment samples. Given the lower confidence limit of the total from the entrainment sampling, this lower limit on the augmented total is not reasonable.

Discussion

Larval Fish Sampling.

Larval fish had a distinct temporal component to their arrival in the main channel drift during both years. Ictiobid and common carp larvae dominated the larval assemblage through late May, to be replaced by shad larvae as the dominant taxon. Freshwater drum larvae were the last major taxon present in larval samples during both years. Peak larval diversity appears at about the end of May to early June. These results are consistent with other larval fish studies in the Upper Mississippi and Illinois Rivers, which also indicate that clupeid and freshwater drum larvae form a major component of main channel larval fish assemblages throughout the length of the Upper Mississippi River System (Holland and Sylvester 1983; Holland-Bartels et al. 1995).

Variability between years was evident, both in terms of larval density and composition of the larval assemblage. Larval densities were greater during 1996, possibly because of the more extensive flood that allowed more fishes to take advantage of the flood pulse (Junk et al. 1989). Cyprinid larvae were present in 1997, but not in 1996. Common carp larvae were much more numerous during 1996 than 1997, perhaps because of a larger flood more closely timed to the peak of carp spawning.

During 1997, larval density and composition varied across larval habitats. Larval densities were greatest in backwaters, intermediate in side channels, and lowest in the main channel. Centrarchids were dominant only in backwaters, although they appeared in small numbers at main channel and side channel sites. Conversely, freshwater drum larvae were dominant at main channel and side channel sites, rarely occurring in backwaters. Shad larvae were common across all aquatic areas, suggesting that adults of this taxon spawn successfully in all areas. In the Illinois River backwater, larval fish composition was less diverse than main channel and side channel habitats, supporting only four or five taxa, whereas up to eight taxa were collected in flowing water habitat. The Mississippi River backwater contained a more diverse larval fish assemblage than the Illinois River backwater, with six or seven taxa present, reflecting the greater diversity of large fishes collected by trawling in the Mississippi River, as compared to the lower Illinois River.

Main channel and side channel areas generally produced similar assemblages of larvae, whereas backwater areas supported a very different larval assemblage than channels. Backwaters were dominated by clupeid, primarily *Dorosoma* spp., and centrarchid larvae. Other taxa frequently present included brook silverside and *Gambusia* spp. larvae. Of these common backwater larval taxa, only clupeid larvae also were common in channels. Conversely, larval percids, *Morone*, freshwater drum, and common carp were rarely or never found in backwaters. Thus, we speculate that effects of commercial navigation on early life stages may be most severe on species whose larvae reside primarily in the flowing water habitats, especially the navigation channel.

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Most of the fishes commonly collected by rockhopper trawling were also encountered as larvae. However, larvae thought to be primarily benthic in nature were not sampled particularly effectively with our pelagic sampling regime. In particular, larvae of catfish and sturgeon were rare or absent from our larval samples, despite the abundance of adults in our trawl catches from the Mississippi River. The beam trawl used to collect small fishes does appear to be an effective gear to sample fishes with benthic early life stages, especially catfishes and freshwater drum. Early life stages of shovelnose sturgeon or paddlefish were not collected by either of these gears, suggesting that 1) their abundance is low within the system, 2) they use other riverine habitats for spawning and early life stages, or 3) the gears we used were not effective for sampling larvae of these species. For species that we sampled poorly as larvae but well at older life stages, conclusions should not be drawn regarding the impact of commercial navigation on the larval stages until future research can generate quantitative estimates of their larval density and spatial distribution.

Sampling of larval fishes in the navigation channel during two years reveals that dynamic shifts in both the abundance and composition of larvae occur among years. Peak density did not differ greatly between these years, but the timing of peak densities did. Peak larval density occurred in May 1996 in Pool 26 but in July in the Illinois River, whereas larval density peaked in both rivers during June 1997. Larval density during 1996 was relatively constant during May-July; larval density peaked in June of 1997 in both rivers, at least 10-fold greater than larval density in any other month.

Some major shifts in the composition of larvae also occurred between years. Cyprinid larvae were present only during 1997; these larvae were an important component of the late-season larval assemblage. Hiodontid and percid larvae also were a greater component of the larval assemblage during 1997 than in 1996. Conversely, common carp and freshwater drum larval abundance dropped substantially in 1997, compared to 1996, despite still being a major component of the larval assemblage. Given these major swings in larval composition and seasonal abundance, additional larval fish sampling would be required to determine the extent of year-to-year variability in abundance and composition of the larval fish assemblage in the Upper Mississippi and Illinois Rivers.

Abundance of small fishes in the navigation channels.

Results of our beam trawling are limited in scope due to the time constraints placed on the project associated with delays in initially making funding available and further complications following a mid-project temporary funding suspension. However results show that the beam trawl, when fished on the bottom in the navigation channel, will be useful primarily during late June through September, when age-0 fishes in the main channel are small enough to be captured efficiently by the gear. As fish grow larger they increasingly avoid the gear, rendering it ineffective.

Age-0 channel catfish, freshwater drum, and mooneye were common near the bottom of the navigation channel of the Mississippi River, suggesting that this habitat is an important area for these young fish. Age-0 freshwater drum and gizzard shad were common near the bottom of the lower Illinois River main channel, whereas channel catfish, freshwater drum, and mooneye were most abundant in Pool 26. Because we did not sample higher in the water column, we do not know whether more pelagic species (e.g., skipjack herring, gizzard shad, and white bass) are efficiently sampled by this gear. However, from larval sampling and sampling with the rockhopper trawl, these fish are regularly collected in the main channel, so we would expect that they are present in the main channel at sizes between 25 and 100 mm.

Additional investigation of potential indirect effects of commercial navigation on small fishes residing in the main channel seems desirable. Due to the short duration of this study and restricted spatial extent, we do not believe that a complete picture of either 1) potential vulnerability of small fishes to entrainment mortality or 2) the abundance and distribution of small fishes has been developed. Given that small fish, primarily age-0 fishes growing after the spring and early summer spawning season, are abundant in the main channel, it also seems appropriate to determine to what extent these fishes may be behaviorally and energetically impacted.

Abundance of adult fishes in the navigation channels and implications for estimation of entrainment mortality.

Our results from rockhopper trawling indicate that the navigation channels of Pool 26 of the Mississippi River and the lower Illinois River provide important habitat for large riverine fishes. The fish species composition in our main-channel sites was quite different from that apparent from other aquatic areas in Pool 26 or the La Grange Pool of the Illinois River (Burkhardt et al. 1997). The navigation channel seems particularly important to riverine species such as the sturgeons, buffaloes, blue catfish and blue sucker, for example, which are less commonly encountered in aquatic areas sampled by the Long Term Resource Monitoring Program (Burkhardt et al. 1997).

Although the catch rates, expressed as number of fish per hour of sampling effort, are comparable with those from other sampling gear in other habitat types associated with the Upper Mississippi River (Gutreuter 1997), our trawling swept larger sampling areas and therefore CPUE does not provide an adequate basis for comparison of abundance with other data. Our estimated biomass estimates are less than 10% of the biomass of the littoral fish community as measured by toxicant (primarily rotenone) sampling in other areas of the Upper Mississippi River (Pitlo 1987). However, we do not believe that this necessarily reflects a lesser importance of riverine channels as fish habitat. First, our biomass and density estimates are minimal because they do not include fishes that escaped our gear. Escapement is perhaps less likely in toxicant sampling because treated areas are enclosed with a barrier net. Bias in estimation of abundance is particularly important for pelagic fishes that were suspended above the top of the headrope of our trawl. Our biomass estimates for pelagic species such as gizzard shad and white bass, for example, are likely underestimates. Second, channels comprise a large fraction of the aquatic area of the Upper Mississippi River System and seem to support greater abundances of some characteristically riverine fishes such as shovelnose sturgeon, blue sucker and blue catfish, than other aquatic areas. For these reasons the ecological importance of large deep channels may far exceed that reflected by simple comparisons of fish biomass with other aquatic areas.

Fishes, both in terms of biomass and species richness, were most abundant in the navigation channel during fall (September-November), coinciding with the time of year when large floodplain river hydrographs are low (Sparks 1995) and water temperatures are moderate. Nevertheless, several common fishes were present in the main channel throughout the year (e.g., shovelnose sturgeon, channel catfish, and gizzard shad), revealing that a considerable number of species and individuals do thrive in the presence of traffic, current, and other environmental factors that characterize the navigation channel.

Catch rates were generally lower during 1997 than in 1996. This may be due to what appears to be a relatively poor year in 1997 (compared to 1996) for recruitment of pelagic fishes including gizzard shad, mooneye, and freshwater drum, as well as for blue catfish and channel catfish. Young-of-year of these species were very abundant in our trawls during fall 1996, but occurred only occasionally during 1997. Without multiple years of sampling, we cannot fully describe the extent to which fish populations in the navigation channel may fluctuate on a yearly basis. In addition to shifts in reproductive success, flow rate and temperature shifts probably influence the magnitude and timing of any seasonal migration into the main channel. This annual variation is particularly important because the magnitude of entrainment mortality is likely an increasing function of population density and therefore is unlikely to remain constant through time. Additional sampling during at least 3-5 years would be needed to more completely determine the magnitude of temporal variation in the abundance of fishes in the navigation channel.

Our results also suggest that the navigation infrastructure affects the distribution of fishes. The locks and dams create both tailwater areas having relatively high current velocities and lower-gradient impounded areas of navigation channels. Fishes adapted to survive in swifter current (e.g., shovelnose sturgeon and blue sucker) were distributed almost exclusively above the control point in Pool 26, whereas channel-dwelling fishes preferring lower current velocities (e.g., blue and channel catfish) were most abundant in the lower portion of Pool 26 and in the lower Illinois River. Thus the locks and dams may have created, or at least may be maintaining, important physical heterogeneity at the spatial scale of pools. This effect is potentially important in the assessment of effects of navigation because it suggests that, with more samples, stratified estimation of entrainment mortality may improve precision for spatially restricted species such as shovelnose sturgeon. However, we did not attempt that given our distribution of our relatively few samples, and therefore our estimates are averages over all study areas.

Abundance of several species differed between Pool 26 of the Mississippi River and our study section on the lower Illinois River. This difference suggests that variation among other navigation pools of the Upper Mississippi River System may also be important, and is consistent with results obtained from the Long Term Resource Monitoring Program of the Upper Mississippi River System (LTRMP). Fish assemblage composition differed significantly among the six LTRMP study reaches during 1990 (Gutreuter 1992). For many species, including gizzard shad and smallmouth buffalo, linear trends in relative abundance from 1990-1994 also differed significantly among reaches (Gutreuter 1997). Because entrainment mortality is likely an increasing function of abundance, these results suggest that entrainment mortality may also differ among navigation pools. However, our entrainment sampling was insufficient to resolve any such effect.

Estimation of entrainment mortality of adult fishes.

We succeeded in developing a method for estimation of tow-induced entrainment mortality of 'adult' fishes in commercially navigated waterways. This estimation had never before been accomplished. We believe this approach is applicable to other waterways, and view it as a major result of this study.

However, the results of our efforts to estimate entrainment mortality of 'adult' fishes are somewhat indeterminate because of high variance. If our estimates are approximately correct, they portend potentially large total entrainment losses throughout the Upper Mississippi River System. For example, during 1992 approximately 4.8×10^6 km of towboat travel was logged in the Upper Mississippi and Illinois Waterways, and preliminary forecasts for the year 2050 are approximately 6.3×10^6 km/yr and 8.3×10^6 km/yr, respectively, without and with expansion of navigation capacity under the National Economic Development Plan (D. Sweeney, U.S. Army Corps of Engineers, St. Louis, Missouri, personal communication). The projected increment in traffic between the National Economic Development Plan and no action is therefore approximately 2.0×10^6 km/yr in 2050. Thus, our residual uncertainty is extremely important because this expansion factor for the incremental change in total tow traffic is large. Unfortunately we cannot determine, from our results alone, whether towboat entrainment is an important source of mortality for gizzard shad, shovelnose sturgeon, smallmouth buffalo, and perhaps other species because the duration of the present study was obviously insufficient, as demonstrated by the large variances of our estimates. A prudent interim conclusion is that entrainment mortality of certain larger fishes, including gizzard shad, shovelnose sturgeon and smallmouth buffalo, may be an important factor influencing their abundance and dynamics in the Upper Mississippi River System. This much still represents an advancement over previous knowledge from which entrainment of larger fish was known only anecdotally.

Our data suggest that entrainment mortality may vary seasonally. All observed fish having recent injuries that could be attributed to towboat entrainment were recovered from October 1996 through March 1997. Our ambient abundance sampling using the rockhopper trawl demonstrated that abundance in the main channels increased through the fall of 1996. Increased abundance puts more fish at risk of entrainment, and this may partly explain the seasonal distribution of observed entrainment losses. Swimming performance is reduced at low temperatures (Beamish 1978), and therefore some riverine fishes require reduced current velocities during winter (Sheehan et al. 1990). Bodensteiner and Lewis (1992) studied causes of increased impingement of freshwater drum in the cooling water intakes of a power generating facility along the Mississippi River and concluded that the ambient drift of disoriented and incapacitated fish in the main channel increased in response to low temperatures and low dissolved oxygen in thermal refuges. Through similar mechanisms, the risks of entrainment through towboat propellers may also increase at low water temperatures. However, we stress that the present data are inadequate to resolve this issue because we lack replication of fall and winter sampling. This study was officially ended on 30

September 1997, and as a result we conducted only one entrainment sample after 1 October 1997. This is particularly unfortunate because the existence of any seasonal component would suggest potentially important management options. For example, if entrainment does increase during the cold months, then the present mortality estimates fail to account for potentially lower rates during the warm months and higher rates during the cold months. In that case, total entrainment losses could be reduced by maximizing traffic during the warm months and minimizing it during the cold months.

Our estimates of entrainment mortality rates presume that our in situ forensic diagnoses of the cause of death were correct. In fact, we cannot know, with complete certainty, that an impact injury was caused by the preceding towboat, or that the fish was alive and healthy before it was entrained. We used diagnostic criteria that provide reasonable attribution of the cause of death that is consistent with the principles that guided all elements of the navigation assessment studies.

Lacerations and impact injuries might have been caused by something other than towboat propellers, but that seems improbable. The only other remotely possible cause is injury by recreational (leisure) boats. Even the largest leisure boats usually have propellers that are smaller than 0.5 m in diameter and develop thrusts of only a few kN (our 415-hp trawler develops a maximum thrust of less than 9 kN), whereas towboats have propellers exceeding 2.5 m in diameter and develop thrusts of several hundred kN. Further, all of the killed fish kill used to estimate entrainment mortality were observed from October through December of 1996. This is well past the period of peak leisure-boat traffic, as indicated by the monthly numbers of boats that locked through Lock and Dam 26 (Figure 21). All other factors being equal, if leisure boats were the cause of the types of wounds we observed, then we would have expected to observe peak wounding rates from July through September, and we should have observed virtually no woundings during December. Given these factors, we believe it is far more likely that the wounds we observed were caused by towboats than by leisure boats.

Although towboats may be the more likely cause of wounds on adult fish, that still does not mean that those wounds were the causes of death. It might be that the wounded fish we collected died of other causes or were unhealthy just prior to entrainment through the propellers. Such fish might be more likely to be entrained through towboat propellers. Although it was not possible to determine the status of fish health immediately prior to entrainment, there is evidence in our data to refute the hypothesis that the woundings we observed were made by propeller impact on fish that were already dead from other causes. Dead unwounded fish were only rarely encountered in our sampling. We encountered substantial numbers of dead fish in the ambient drift only on December 10, 1996, and on March 24-26, 1997 (Table 32). These fish were almost entirely gizzard shad that had no wounds and that had been dead for at least several hours. With the exception of the live but mortally wounded smallmouth buffalo we captured in an ambient sample on December 10, 1996, all other fish that had fresh wounds were collected on days during which no other dead fish were observed. Although some moribund fish are likely entrained and struck by propellers, our data suggest that possibility was unlikely on those dates during which we attributed wounds to recent entrainment.

For logistic reasons, we could not sample passing tows completely at random and with replacement for reasons described in the Methods section. We opportunistically sampled passing tows without regard for tow configuration. Because downbound tows were slightly more difficult to sample, we may have avoided a few of them when learning to deploy the gear early in the study and again when testing newly repaired gear, and this might have imparted a small degree of bias. Of the 41 tows we sampled for estimation of entrainment mortality, 23 (56%) were upbound. Assuming that upbound and downbound trips are equally common, then under the binomial distribution, the probability of selecting 23 or more upbound tows is 0.27. This probability is not inconsistent with random selection of tows, and suggests that any bias we incurred toward selection of upbound tows was not large. Because we happened to have detected entrainment kills only following downbound tows, the likely effect of this unknown selection bias is underestimation of entrainment mortality rate.

Despite the limitations created by the inadequate duration of this study, we are confident in the methods we developed, and we gained insights that could be used to refine those methods. The principal difficulty is that it is presently impossible, or at least impractical, to strain large fractions of the propeller wash and still equate the volume strained to distance of towboat travel. The rockhopper trawl proved to be an extremely effective fish capture device for use in these large river channels, but it strains only a small fraction of the propeller wash. Therefore we were left with the problem of detecting extremely rare events. Any future efforts should therefore address ways to increase the probabilities of detection. This can be accomplished by increasing the area of the trawl mouth and optimizing the position of the trawler in the propeller wash.

The rockhopper trawl is adjustable to provide some capability to adjust net dimensions. However, because the start of this study was delayed and the hydraulic system required major and time-consuming tuning prior to sampling, we lacked time to experiment with the trawl. We therefore used factory settings for all of our sampling. We suspect that it may be possible to increase the surface area of the mouth by increasing the number of headrope floats and increasing the length of the headrope. Because trawls rely on a complicated balance of gravitational and drag forces to operate properly (Dickson 1970; Freedman 1970; O'Neill and O'Donoghue 1997), this would require careful experimentation and monitoring of net performance. An alternative approach is to use a larger trawl. However, the trawling boat used in this study could not safely accommodate a significantly larger net.

The DIFFLAR2 model results clearly indicate that probability of detection is maximized near the towboat propellers. Therefore, greater fractions of the propeller jets can be strained with a net of a given size by simply trawling directly on the sailing line and nearer to the towboat. Our starting proximity to the tows was limited by mixing. We needed to assume complete vertical mixing and in 5-8 m deep channels this requires 100-150 m. In pursuit of upbound tows, we were also limited by our trawling speed. Although we usually had sufficient power to increase trawl speed, doing so is at least partly offset by declining net performance. Although wing- and door-spread of bottom trawls is largely independent of speed, headrope height decreases linearly with increasing speed (Morse et al. 1992). Therefore, increasing speed to follow the tow more closely might be a helpful strategy only if trawl adjustments can be made to retain headrope height. Downbound tows present a more difficult problem. Because we always trawled upriver, our sampling distances behind downbound tows became so large that concentrations of propeller water became very small. Therefore large numbers of samples are required to estimate entrainment mortality rates as low as 15 fish/km. The only way to substantially increase the probability of detection is to trawl downriver or conduct many short upriver trawls beginning approximately 150-200 m from the propellers. We do not advocate trawling downriver without substantially more hull buoyancy than is provided by our trawling boat, and without the escort of a second boat.

Estimation of entrainment mortality depends on estimation of probabilities of detection of fish killed by entrainment. Our approach relied on a model of diffusion processes rather than in situ estimation of efficiency. Our approach depends on the assumption that the mass distribution of killed fish is isomorphic with the mass distribution of water entrained through the propellers of the tow. For particles that have specific gravity exactly equal to the water, this assumption is uncontroversial. However killed fish, and particularly fragments that do not contain the intact gas bladder, may have different specific gravities. Negatively buoyant particles such as fish having ruptured gas bladders or even some benthic fishes with intact gas bladders will tend to settle to the bottom, and this constitutes a violation of our assumption. Measurement of this effect was well beyond the scope of this study, and instead we relied on the guiding principle that such residual uncertainties would be accommodated in a way that is reasonably sure not to underestimate the impact. Our bottom trawling is consistent with this principle. Near the propellers, where any settling has not yet occurred, we may safely assume complete vertical mixing of both the water and suspended particles and that our bottom trawling provides unbiased samples of entrained fish. However, at greater distances where settling may have occurred, bottom trawling will have the effect of straining water that may contain disproportionately more entrained fish than the mass concentration of entrained water. To that extent, our estimates may be biased upward by the unknown degree of settling that occurs with increasing distance behind the tows. Because of the distances involved, this effect would be larger for downbound tows than for upbound tows. Although it is important to recognize this effect, it is equally important to also recognize another that tends to offset it. The trawl mouth will strain all particles larger than the mesh size that enter the mouth. Particles that are suspended off the bottom are easily strained by the net. However, the rockhopper foot gear will also tend to ride over the top of some particles that lay on the bottom, and in this way underestimate the density of settled particles. All bottom trawls will have this effect (Walsh 1992). We do not know the relative effects of these two counteracting sources of bias, and this remains part of the residual uncertainty in this study.

We can hardly overstate the difficulties of trawling in these navigation channels. Gear loss and damage were routine due to the forces inherent in trawling and the hazards of the main channel. Therefore equipment repair and the resulting sampling delays were common. Any future work should better accommodate the occurrence of these hazards through a longer timetable and a larger reserve of contingency gear.

We recognize the capabilities of some fish to avoid approaching vessels (Lowery et al. 1987; Todd et al. 1989; Soria et al. 1996). However, we know very little about the acoustic emissions of riverine tows and the behavioral responses of channel-dwelling fishes. More detailed study could produce estimates of the fractions of resident fish that successfully avoid tows, and these would assist interpretation of estimates of entrainment mortality. Further, investigation of sound emissions and behavioral responses might possibly lead to development of emitting hydrophones to maximize the avoidance response and thereby minimize the risks of entrainment. However, avoidance reactions incur bioenergetic costs because movement requires energy. This cost can presently be quantified by using electromyelographic transmitters, which monitor the activity of fish muscle in situ. Another approach to indirect estimation of longer-term avoidance effects is comparison of abundance of fish in paired areas of navigation channel and large riverine side channels which are approximately similar to the navigation channel except for the occurrence of tow traffic.

Summary.

This study quantified the abundance and composition of larval fishes in the navigation channel, as well as side channel and backwater areas, for the purpose of providing these data for input into models of losses of adult-fish equivalents, production foregone, and recruitment foregone. We also have developed methods to estimate abundance and entrainment mortality of juvenile and adult fishes in navigation channels of large rivers. Our current estimates of the abundance of all life stages of fish suggest that substantial year-to-year variability in timing of appearance in the navigation channel and in density of fishes does occur, but the duration of the current study was not sufficient to determine to what extent this variability might affect entrainment mortality rates. Gizzard shad was the only species observed freshly killed in our specialized entrainment sampling behind towboats. We estimate that 9.5 adult gizzard shad are killed or seriously injured, on average, per km of travel by each towboat, with an 80% confidence interval of 3.8-22.8 fish/km. We also observed additional freshly killed adult gizzard shad, shovelnose sturgeon, and smallmouth buffalo in our ambient abundance samples. We developed a statistical method to estimate entrainment mortality rates of adult shovelnose sturgeon and smallmouth buffalo from the combined entrainment and ambient samples. These ancillary entrainment mortality estimates for shovelnose sturgeon and smallmouth buffalo are each 2.4 adult fish/km of tow travel, with 80% confidence intervals of 0-6.0 fish/km of tow travel. Because the confidence intervals for shovelnose sturgeon and smallmouth buffalo include zero, we believe that it is reasonable to conclude only that entrainment mortality cannot be disregarded as an important component of their dynamics in the navigation channels of the Upper Mississippi River System. The ancillary estimates create a paradox because there are now two estimates of the total entrainment mortality rate for all species combined. The first is the estimate of 9.5 fish/km from the entrainment sampling, which is unbiased within that sampling design. The second is the sum of the entrainment-sampling estimate plus the ancillary estimates for shovelnose sturgeon and smallmouth buffalo. This second augmented mortality estimate is 14.3 adult fish/km of tow travel with an 80% confidence interval of 0-26.7 fish/km of tow travel. The freshly wounded fish from which all these estimates were obtained were all observed during fall and early winter, suggesting a substantial seasonal effect that cannot be confirmed because the study included only one fall-winter sampling period. This work has provided a much clearer picture of the fish assemblage that uses the navigation channel and has successfully generated the first estimates of entrainment mortality inflicted by towboats. However, substantial uncertainty remains, suggesting the need for additional refinement as river managers seek to determine the potential impacts of commercial navigation on fishes within the navigation channel.

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Table 1. Accuracy and precision of Netmind™ acoustic trawl monitoring sensors. Ten measurements were made at each fixed distance. The coefficient of mean variation is the standard error (SE)/mean, and mean bias the difference between measurement means and actual distances. Measurements were made in a test tank by Northstar Technical, Vancouver, British Columbia, Canada (J. Hall, personal communication). All measurements were made in feet (1 ft = 0.3048 m).

Actual distance (ft)	Measurement means (SE)	Coefficient of mean variation (%)	Mean bias (ft)
Headrope height			
3	3.06 (0.11)	3.6	0.06
6	5.91 (0.05)	0.8	−0.09
9	9.02 (0.08)	0.9	0.02
Wingspread			
9	8.93 (0.15)	1.7	−0.07
12	12.10 (0.12)	1.0	0.10
15	14.86 (0.15)	1.0	−0.14
18	17.95 (0.18)	1.0	−0.05
21	21.05 (0.16)	0.8	0.05
24	24.04 (0.19)	0.8	0.04
27	26.87 (0.20)	0.8	−0.13

Table 2. Parameter estimates for conversion of fish lengths *L* (mm) to weights *L* (g). Estimates were obtained from ordinary least-squares regressions of $\log_{10}$(weight) on $\log_{10}$(length) obtained by the Long Term Resource Monitoring Program of the Upper Mississippi River. Weight is given by $W = 10^a L^b$.

Common name	*a*	*b*
Bigmouth buffalo	-5.0259	3.09248
Black buffalo	-4.5351	2.86949
Black crappie	-5.1740	3.15754
Blue catfish	-4.7467	2.86173
Blue sucker	-5.2630	3.06332
Channel catfish	-4.8697	2.90154
Common carp	-4.7180	2.93829
Flathead catfish	-4.8603	2.95780
Freshwater drum	-5.0166	3.03092
Gizzard shad	-4.9405	2.97189
Goldeye	-4.9496	2.97128
Highfin carpsucker	-4.7740	2.95227
Lake sturgeon	-4.6474	2.78062
Mooneye	-5.3446	3.13296
Quillback	-4.7555	2.93778
River carpsucker	-4.9245	3.01383
Sauger	-5.6274	3.21970
Shorthead redhorse	-4.8011	2.92351
Shortnose gar	-5.5697	3.03535
Shovelnose sturgeon	-5.2691	2.86491
Silver chub	-4.9915	2.96721
Skipjack herring	-4.8758	2.90371
Smallmouth bass	-4.8701	2.99699
Smallmouth buffalo	-4.9549	3.04769
Speckled chub	-4.3945	2.54206
White bass	-5.0174	3.04664

Table 3. Mean larval fish density expressed as number/m³ (1 SE) for all taxa collected from the navigation channel of the lower Illinois River during May through July 1996. Sampling was conducted during only one day in July, and therefore standard errors were not estimated.

	Mean larval fish density (1 SE) number per m³		
River mile	May	June	July
4.5	3.09 (2.15)	2.34 (0.83)	0.14
9.3	0.90 (0.43)	1.39 (0.98)	1.02
13.5	1.09 (0.18)	1.68 (1.01)	0.71
18.7	1.45 (0.88)	1.17 (0.30)	2.00

Table 4. Mean larval fish density expressed as number/m³ (1 SE) for each taxon collected from the navigation channel of the Illinois River during May-July 1996. Sampling was conducted during only one day in July, and therefore standard errors were not estimated.

Fish taxon	River mile	Mean larval fish density (1 SE) number per m³		
		May	June	July
Channel catfish	13.5	0	0	<0.01
Common carp	4.5	2.94 (0.002)	0.62 (0.48)	0.01
	9.3	0.80 (0.52)	0.54 (0.46)	0
	13.5	0.87 (0.37)	0.45 (0.42)	<0.01
	18.7	1.23 (1.02)	0.41 (0.33)	0.01
Freshwater drum	4.5	0.04 (0.04)	0.08 (0.03)	0.08
	9.3	0.02 (0.02)	0.08 (0.04)	0.90
	13.5	0.02 (0.02)	0.06 (0.05)	0.58
	18.7	0.01 (0.01)	0.05 (0.01)	1.88
Lepisosteidae	13.5	<0.01 (<0.01)	0	0
	18.7	<0.01 (<0.01)	<0.01 (<0.01)	0
Mosquitofish	4.5	<0.01 (<0.01)	0	0
Clupeidae	4.5	0.05 (0.05)	1.61 (1.25)	0.04
	9.3	0.05 (0.05)	0.07 (0.05)	0.06
	13.5	0.14 (0.14)	1.15 (0.55)	0.08
	18.7	0.13 (0.13)	0.69 (0.03)	0.07
Catostomidae	4.5	0.04 (0.04)	0.01(0.01)	0.01
	9.3	0.01 (0.003)	0.01 (0.01)	0.06
	13.5	0.03 (0.003)	0.01(0.01)	0.01
	18.7	0.05 (0.02)	0.01 (0.01)	0.02

Table 4 continued...

Fish taxon	River mile	Mean larval fish density (1 SE) number per m^3		
		May	June	July
Centrarchidae	4.5	0.01 (0.01)	0.02 (0.02)	0
	9.3	0.01 (0.01)	0.01 (0.01)	0
	13.5	0.03 (0.03)	<0.01(<0.01)	0
	18.7	0.02 (0.02)	<0.01 (<0.01)	<0.01
Morone	4.5	<0.01(<0.01)	0.01 (0.01)	0.01
	9.3	<0.01 (<0.01)	0.01 (0.01)	<0.01
	13.5	0.01 (0.01)	0.01 (0.004)	<0.01
	18.7	0.01 (0.01)	<0.01(<0.01)	0
Percidae	18.7	<0.01<(0.01)	0	0
Unidentified	4.5	0.01(0.01)	<0.01 (<0.01)	<0.01
	9.3	<0.01 (<0.01)	0.08 (0.08)	<0.01
	13.5	<0.01 (<0.01)	0.01 (0.01)	0.01
	18.7	0.01 (0.01)	<0.01 (<0.01)	0.02

Table 5. Mean larval fish density expressed as number/m³ (1 SE) for all larval taxa collected from main channel, side channel, and backwater habitats in Pool 26 of the Mississippi River and the lower Illinois River during April-July 1997. DNS= did not sample.

River mile	Habitat type	Mean larval fish density (1 SE) number per m³			
		April	May	June	July
		Illinois River			
13.5	Main channel	DNS	0.68 (0.35)	4.13 (0.87)	0.10 (0.050)
13.5	Side channel	DNS	0.55 (0.29)	7.43 (5.43)	0.03 (0.01)
9.3	Backwater	DNS	6.99 (4.76)	1.70 (0.83)	5.30 (2.18)
		Mississippi River			
208.5	Main channel	0.001 (0.001)	0.07	0.89 (0.52)	0.05 (0.02)
	Side channel	0	0.12	2.10 (0.75)	0.14
215.7	Main channel	0.004 (0.003)	0.01	0.46 (0.04)	0.05 (0.03)
	Side channel	0	0.10	2.47	0.15 (0.12)
223.0	Main channel	0.001 (0.001)	0.06 (0.01)	0.24 (0.23)	0.09 (0.01)
	Side channel	0.001 (0.001)	0.07 (0.05)	0.28 (0.25)	0.13 (0.06)
	Backwater	0	3.60 (2.99)	27.47 (1.19)	DNS
233.5	Main channel	<0.01 (<0.02)	0.06 (0.01)	0.58 (0.57)	0.10 (0.01)
	Side channel	0	0.04 (0.02)	0.18 (0.17)	0.22 (0.10)

Table 6. Mean larval fish densities expressed as number/m³ (1 SE) for each taxon collected from main channel (MC; river mile 13.5), side channel (SC; river mile 13.5), and backwater (BW; river mile 9.3) habitat types in the Illinois River during May-July 1997.

		Mean larval fish density (1 SE) number/m³		
Fish taxon	Habitat type	May	June	July
Brook silverside	BW	<0.01(<0.01)	0.22(0.21)	0.59(0.08)
Common carp	MC	<0.01(<0.01)	0.19(0.13)	0
	SC	<0.01(<0.01)	0.08(0.02)	0
	BW	0	<0.01(<0.01)	0
Freshwater drum	MC	0.12(0.12)	3.37(0.49)	0
	SC	0.51(0.41)	7.02(5.13)	<0.01(<0.01)
	BW	0	0	0
Mosquitofish	MC	0	<0.01(<0.01)	0
	SC	0	0	0
	BW	0.01(0.001)	0	0.02(0.02)
Cyprinidae	MC	0	<0.01(<0.01)	0.01(0.01)
	SC	<0.01(<0.01)	0.01(0.01)	<0.01(<0.01)
	BW	0	0	0
Clupeidae	MC	0.47(0.40)	0.06(0.02)	0.04(0.01)
	SC	0.30(0.28)	0.03(0.02)	0.02(0.01)
	BW	6.93(4.77)	0.44(0.28)	<0.01(<0.01)
Catostomidae	MC	0	0.49(0.48)	0.05(0.05)
	SC	<0.01(<0.01)	0.24(0.24)	0
	BW	0.01(0.001)	0	0
Centrarchidae	MC	0	<0.01(<0.01)	<0.01(<0.01)

Table 6 continued...

Fish taxon	Habitat type	Mean larval fish density (1 SE) number/m³		
		May	June	July
Centrarchidae	SC	0	<0.01(<0.01)	0
	BW	0.03(0.03)	1.03(0.89)	4.63(2.12)
Morone	MC	0.08(0.05)	<0.01(<0.01)	0
	SC	0.01(0.01)	<0.01(<0.01)	0
	BW	0	0	0
Unidentified	MC	0.01(0.01)	0.01(0.01)	0
	SC	0.01(0.003)	0.04(0.001)	0
	BW	0.02(0.01)	0.01(0.01)	0

Table 7. Mean larval fish density expressed as number/m³ (1 SE) for all taxa combined collected from the navigation channel of Pool 26 of the Mississippi River during May-July, 1996. DNS= did not sample.

	Mean larval fish density (1 SE) number/m^3		
River mile	May	June	July
203.2	0.98 (0.71)	0.63 (0.56)	0.59
207.1	2.38	0.30 (0.18)	0.51
208.5	1.11 (0.27)	0.39	1.02
211.2	0.46 (0.18)	0.23	0.55
213.5	1.02	0.75	0.82
215.7	0.56	1.40 (0.70)	0.86
223.0	0.22 (0.06)	0.30	0.20
225.8	0.26	0.20 (0.17)	0.39
230.5	DNS	0.75 (0.72)	DNS
233.5	0.54	0.48 (0.45)	0.46
240.2	DNS	DNS	0.70

Table 8. Mean larval fish density expressed as number/m³ (1 SE) for each taxon collected from the navigation channel in Pool 26 of the Mississippi River during May-July 1996.

Fish taxon	River mile	Mean larval fish density (1 SE) number per m³		
		May	June	July
Bowfin	203.2	0	<0.01 (<0.01)	0
Ictiobidae	203.2	0	0.02 (0.02)	0
	207.1	0	0.01 (0.01)	0
	208.5	0.10(0.10)	0.01	0
	211.2	0.01 (0.01)	0.01	0
	213.5	0	0.02	0
	215.7	0	<0.01 (<0.01)	0
	230.5	DNS	0.01 (0.003)	DNS
Common carp	203.2	0.91 (0.76)	0.29 (0.27)	<0.01
	207.1	2.28	0.14 (0.09)	<0.01
	208.5	0.67 (0.64)	0.18	<0.01
	211.2	0.32 (0.12)	0	0
	213.5	0.97	0.13	0.01
	215.7	0.50	0.28 (0.13)	<0.01
	223.0	0.19 (0.05)	0.01	0
	225.8	0.22	0.02 (0.01)	0
	230.5	DNS	0.02 (0.001)	DNS
	233.5	0.44	0.02 (0.01)	<0.01
	240.2	DNS	DNS	<0.01

Table 8 continued...

Fish taxon	River mile	Mean larval fish density (1 SE) number per m³		
		May	June	July
Freshwater drum	203.2	0.00	0.01 (0.01)	0.57
	207.1	0	0.01 (0.01)	0.45
	208.5	<0.01 (<0.01)	0.01	0.97
	211.2	<0.01	0	0.54
	213.5	0	0.01	0.71
	215.7	0	0.14 (0.14)	0.84
	223.0	0	0.28	0.20
	225.8	0	0.18 (0.18)	0.39
	230.5	DNS	0.71 (0.71)	DNS
	233.5	0	0.45 (0.45)	0.46
	240.2	DNS	DNS	0.70
Lepisosteidae	203.2	<0.01 (<0.01)	0	0
	207.1	0	<0.02 (<0.02)	0
	213.5	0	<0.01	0
	225.8	0	<0.01	0
	230.5	DNS	<0.01 (<0.01)	DNS
	233.5	0	<0.01 (<0.01)	0
Hiodontidae	203.2	<0.01 (<0.01)	0	0
	207.1	0	<0.01 (<0.01)	0
	208.5	0	<0.01	0
	211.2	0	<0.01	0

Table 8 continued...

Fish taxon	River mile	Mean larval fish density (1 SE) number per m³		
		May	June	July
Hiodontidae	215.7	<0.01	0	0
	223.0	0	<0.01	0
	230.5	DNS	<0.01 (<0.01)	DNS
	233.5	0	<0.01 (<0.01)	0
Percidae	203.2	<0.01 (<0.01)	<0.01 (<0.01)	0
	207.1	0.01	0	0
	208.5	<0.01 (<0.01)	0	0
	213.5	<0.01	0	0
	215.7	0.01	<0.01 (<0.01)	0
	223.0	0.01 (0.01)	0	0
	225.8	0.01	0	0
	233.5	0.01	0	0
Clupeidae	203.2	0.03 (0.03)	0.28 (0.24)	0.02
	207.1	0.08	0.12 (0.07)	0.05
	208.5	0.29 (0.29)	0.18	0.03
	211.2	0.02 (0.02)	0.11	<0.01
	213.5	0	0.57	0.10
	215.7	0	0.89 (0.35)	0.01
	223.0	0	0.01	0
	225.8	0.01 (<0.01)	0	0
	230.5	DNS	<0.01 (<0.01)	DNS

Table 8 continued...

Fish taxon	River mile	Mean larval fish density (1 SE) number per m³		
		May	June	July
	233.5	0	<0.01 (<0.01)	0
Catostomidae	203.2	0.03 (0.02)	0	<0.01
	207.1	0	0.01 (0.01)	0.01
	208.5	0.04 (0.04)	0	0.02
	211.2	0	0	0.01
	213.5	0.05	0	<0.01
	215.7	0.04	0.07 (0.07)	<0.01
	223.0	0.03 (0.003)	<0.01	0
	225.8	0.03	<0.01 (<0.01)	0
	233.5	0.08	0.01 (0.003)	0
Centrarchidae	203.2	<0.01 (<0.01)	<0.01 (<0.01)	0
	207.1	0	0.01 (0.01)	0
	208.5	0	0.01	<0.01
	211.2	0	0.01	0
	213.5	0	0.01	0
	230.5	DNS	<0.01 (<0.01)	DNS
	233.5	<0.01	0	0
Morone	203.2	0	0.01 (0.01)	0
	207.1	0	<0.01 (<0.01)	0
	208.5	0.01 (0.01)	<0.01	<0.01
	213.5	0	<0.01	0

Table 8 continued...

Fish taxon	River mile	Mean larval fish density (1 SE) number per m³		
		May	June	July
Morone	215.7	0	<0.01 (<0.01)	0
	233.5	0	<0.01	0
Unidentified	203.2	0.01 (0.01)	<0.01 (<0.01)	<0.01
	207.1	0	<0.01 (<0.01)	0
	208.5	0	<0.01	<0.01
	211.2	0	0	<0.01
	213.5	0	<0.01	<0.01
	215.7	0	0.01 (0.01)	0
	223.0	<0.01	<0.01	0
	225.8	0	0.01 (0.01)	0
	230.5	DNS	<0.01 (<0.01)	DNS
	233.5	0	<0.01 (<0.01)	0.01
	240.2	DNS	DNS	<0.01

Table 9. Mean larval fish density expressed as number/m^3 (1 SE) for each taxon collected in main channel habitat of Pool 26 of the Mississippi River during April-July 1997.

Fish taxon	River mile	Mean larval fish density (1 SE) number/m^3			
		April	May	June	July
Common carp	208.5	0	<0.01	<0.01 (<0.01)	<0.01 (<0.01)
	215.7	<0.01(<0.01)	0	<0.01 (<0.01)	0
	223.0	0	<0.01 (<0.01)	<0.01 (<0.01)	0
	233.5	0	0	<0.01 (<0.01)	0
Freshwater drum	208.5	0	0	0.62 (0.53)	0
	215.7	<0.01 (<0.01)	0	0.33 (0.06)	<0.01 (<0.01)
	223.0	0	0	0.16 (0.16)	<0.01 (<0.01)
	233.5	<0.01 (<0.01)	0	0.50 (0.50)	0.01 (0.004)
Lepisosteidae	223.0	0	0	0	<0.01 (<0.01)
Hiodontidae	208.5	0	0	<0.01 (<0.01)	0
	215.7	<0.01 (<0.01)	<0.01	<0.01 (<0.01)	0
	223.0	0	0.01 (0.01)	0	0
	233.5	0	0.02 (0.02)	0	<0.01 (<0.01)
Mosquitofish	208.5	0	0	0	0
	215.7	<0.01 (<0.01)	0	0	<0.01 (<0.01)
	223.0	0	0	0	0
	233.5	0	<0.01 (<0.01)	0	<0.01 (<0.01)
Cyprinidae	208.5	0	0	0	0.04 (0.01)
	215.7	0	0	0	0.04 (0.02)
	223.0	0	0	0.01 (0.01)	0.07 (0.02)
	233.5	0	<0.01 (<0.01)	0.01 (0.01)	0.08 (0.02)

Table 9 continued...

Fish taxon	River mile	Mean larval fish density (1 SE) number/m³ April	May	June	July
Clupeidae	208.5	0	0	0.14 (0.07)	<0.01 (<0.01)
	215.7	0	<0.01	0.06 (0.05)	<0.01 (<0.01)
	223.0	0	0	0.02 (0.02)	0.01 (0.01)
	233.5	0	0	0.01 (0.01)	<0.01 (<0.01)
Catostomidae	208.5	0	0.05	0.12 (0.09)	0.01 (0.002)
	215.7	<0.01 (<0.01)	0	0.07 (0.06)	0.01 (0.01)
	223.0	0	0.03 (0.01)	0.05 (0.04)	0.01 (0.001)
	233.5	0	0.02 (0.01)	0.05 (0.04)	0.01 (0.002)
Centrarchidae	208.5	0	0	0	<0.01 (<0.01)
	215.7	0	0	0	0
	223.0	0	<0.01 (<0.01)	0	0
	233.5	0	0	0	<0.01 (<0.01)
Percidae	208.5	<0.01 (<0.01)	0.02	0	0
	215.7	0	0	0	0
	223.0	<0.01	0.09 (0.01)	0	0
	233.5	0	0.01 (0.002)	<0.01 (<0.01)	0
Morone	208.5	0	0	0	0
	215.7	0	0	0	0
	223.0	0	<0.01 (<0.01)	0	0
	233.5	0	0	<0.01 (<0.01)	0

Table 9 continued...

Fish taxon	River mile	Mean larval fish density (1 SE) number/m^3			
		April	May	June	July
Unidentified	208.5	0	<0.01	0	0
	215.7	0	0	0	0
	223.0	0	0	<0.01 (<0.01)	0
	233.5	0	0	0	0

Table 10. Mean larval fish density expressed as number/m³ (1 SE) of each taxon collected in side channel habitat in Pool 26 of the Mississippi River during April-July 1997.

Common name	River mile	Mean larval fish density (1 SE) number/m³			
		April	May	June	July
Common carp	208.5	0	<0.01	0.03 (0.02)	0
	215.7	0	0.01	0.01	0
	223.0	0	<0.01 (<0.01)	<0.01 (<0.01)	0
	233.5	0	<0.01 (<0.01)	0.01 (0.004)	0
Freshwater drum	208.5	0	0	1.91 (0.83)	0.01
	215.7	0	0	0.08	<0.01 (<0.01)
	223.0	0	<0.01 (<0.01)	0.14 (0.14)	0.01 (0.001)
	233.5	0	0	0.13 (0.13)	0.01 (0.004)
Lepisosteidae	223.0	0	<0.01 (<0.01)	0	0
Hiodontidae	208.5	0	0	<0.01 (<0.01)	<0.01
	215.7	0	0.02	0	0
	223.0	0	0.02 (0.02)	<0.01 (<0.01)	<0.01 (<0.01)
	233.5	0	0.01 (0.01)	0	0
Cyprinidae	208.5	0	0	0	0.05
	215.7	0	0	0.05	0.16 (0.10)
	223.0	0	0	<0.01 (<0.01)	0.09 (0.05)
	233.5	0	<0.01 (<0.01)	<0.01 (<0.01)	0.20 (0.10)
Clupeidae	208.5	0	0	0.11 (0.08)	0.05
	215.7	0	0.02	2.21	<0.01 (<0.01)
	223.0	0	<0.01 (<0.01)	0.02 (0.02)	0.01 (0.01)

Table 10 continued...

Common name	River mile	Mean larval fish density (1 SE) number/m³ April	May	June	July
	233.5	0	<0.01 (<0.01)	0.02 (0.02)	<0.01 (<0.01)
Catostomidae	208.5	0	0.07	0.03 (0.02)	0.03
	215.7	0	0.04	0.10	0
	223.0	0	0.03 (0.02)	0.10 (0.09)	0.02 (0.01)
	233.5	0	0.02 (0.02)	0.02 (0.02)	0.01 (0.004)
Centrarchidae	208.5	0	0	<0.01 (<0.01)	0
	215.7	0	0.01	0.01	0
	223.0	0	0.01 (0.01)	0	<0.01 (<0.01)
	233.5	0	<0.01 (<0.01)	<0.01 (<0.01)	0
Percidae	208.5	0	0.04	<0.01 (<0.01)	0
	215.7	0	0.01	0	0
	223.0	<0.01 (<0.01)	<0.01 (<0.01)	0	0
	233.5	0	0.01 (0.01)	0	0
Morone	208.5	0	0	0.01 (0.001)	0
	215.7	0	<0.01	0	0
	223.0	0	<0.01 (<0.01)	<0.01 (<0.01)	0
	233.5	0	0	<0.01 (<0.01)	0
Unidentified	208.5	0	<0.01	0	0
	215.7	0	0	0.01	<0.01 (<0.01)
	223.0	0	<0.01 (<0.01)	0.02 (0.01)	<0.01 (<0.01)
	233.5	0	<0.01 (<0.01)	<0.01 (<0.01)	<0.01 (<0.01)

Table 11. Mean larval fish density expressed as number/m^3 (1 SE) of each taxon collected from backwater habitat (river mile 222.2) in the Mississippi River during April-June 1997.

	Mean larval fish density (1 SE) number/m^3		
Fish taxon	April	May	June
Bighead carp	0	0	<0.01 (<0.01)
Brook silverside	0	0	<0.01(<0.01)
Common carp	0	0.03 (0.03)	0
Freshwater drum	0	<0.01 (<0.01)	0
Mosquitofish	0	0	0.73 (0.73)
Cyprinidae	0	0.01 (0.01)	0.07 (0.03)
Percidae	0	0.01 (0.01)	0
Clupeidae	0	3.01 (2.50)	14.62 (13.63)
Centrarchidae	0	0.49 (0.44)	12.04 (11.67)
Morone	0	0.010 (0.004)	0
Unidentified	0	0.020(0.02)	0

Table 12. Mean monthly catch per unit effort, CPUE, (1 SE) expressed as number of fish per hour of trawling for all small fish collected by bottom frame trawl in the lower Illinois River and in Pool 26 of the Mississippi River during July and September 1997. DNT = did not trawl.

	Mean CPUE (1 SE) number/h	
River	July	September
Illinois	DNT	120.0 (25.0)
Mississippi	105.4 (18.0)	11.5 (4.6)

Table 13. Density and biomass estimates of fishes captured by the beam trawl in the lower Illinois River during 1997. Sample size is three hauls and S.E. is the standard error of the mean.

Species	Density (no./ha)			Biomass (kg/ha)		
	Median	Mean	S.E.	Median	Mean	S.E.
Blue catfish	0	1.4	1.4	0	0	0
Channel catfish	8.3	9.7	1.4	0	0	0
Common carp	0	2.8	2.8	0	0	0
Freshwater drum	95.8	88.9	11.4	1.1	1.3	0.7
Gizzard shad	4.2	16.7	14.6	0	0.1	0.1
Goldeye	0	0	0	0	0	0
Mooneye	0	0	0	0	0	0
River carpsucker	0	1.4	1.4	0	1.5	1.5
Shovelnose sturgeon	0	0	0	0	0	0
Skipjack herring	0	0	0	0	0	0
Smallmouth buffalo	4.2	4.2	0	2.2	2.3	0.3
Unidentified Lepomis	0	0	0	0	0	0
White bass	0	0	0	0	0	0
Total fish	112.5	125	26	3.1	5.3	2.2

Table 14. Density and biomass estimates of fishes captured by the beam trawl in Pool 26 of the Mississippi River during 1997. Sample size is 15 hauls and S.E. is the standard error of the mean.

Species	Density (no./ha)			Biomass (kg/ha)		
	Median	Mean	S.E.	Median	Mean	S.E.
Blue catfish	0	0	0	0	0	0
Channel catfish	9.4	39.4	12.8	0	0.8	0.7
Common carp	0	0	0	0	0	0
Freshwater drum	0	8.7	5.5	0	0	0
Gizzard shad	0	0.3	0.3	0	0	0
Goldeye	0	1.5	0.7	0	0.1	0.1
Mooneye	0	6.5	2.5	0	0	0
River carpsucker	0	0	0	0	0	0
Shovelnose sturgeon	0	0.4	0.4	0	0	0
Skipjack herring	0	0.2	0.2	0	0	0
Smallmouth buffalo	0	0	0	0	0	0
Unidentified Lepomis	0	0.3	0.3	0	0	0
White bass	0	0.4	0.4	0	0.1	0.1
Total fish	31.2	57.6	15.7	0.1	1	0.7

Table 15. Mean, standard deviation (S.D.) and sample size (N) of lengths and weights of fishes captured by beam trawling.

	Pool 26, Mississippi River						Illinois River		
	Length (mm)			Weight (g)			Length (mm)		
Species	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N
Blue catfish							101		1
Channel catfish	43	63	87	133	466	14	70	25	7
Common carp							14	1	2
Freshwater drum	36	52	18	74	97	2	93	71	37
Gizzard shad	92		1	8		1	79	23	12
Goldeye	168	126	4	196	66	2			
Mooneye	71	50	16	23	2	4			
River carpsucker							438		1
Shovelnose sturgeon	93		1						
Skipjack herring	107		1	9		1			
Smallmouth buffalo							333	24	3
Unidentified Lepomis	13		1						
White bass	233		1	155		1			

Table 16. Minimal density and biomass estimates of fishes captured by the rockhopper trawl in the lower Illinois River during 1996. Sample size is 21 hauls and S.E. is the standard error of the mean.

Species	Density (no./ha)			Biomass (kg/ha)		
	Median	Mean	S.E.	Median	Mean	S.E.
Bighead carp	0	0	0	0	0	0
Bigmouth buffalo	0	0.5	0.3	0	0.4	0.2
Black buffalo	0	0	0	0	0	0
Black crappie	0	0	0	0	0	0
Blue catfish	0	0.8	0.4	0	0	0
Blue sucker	0	0	0	0	0	0
Channel catfish	8.2	18.9	6.1	0.7	1.8	0.7
Common carp	2.7	3.1	0.8	2.2	4	1.2
Flathead catfish	0	0.4	0.3	0	0.1	0.1
Freshwater drum	32.3	122.3	34.9	6.8	15.9	4.4
Gizzard shad	1.9	3.6	1.4	0	0.2	0.1
Goldeye	0	0	0	0	0	0
Highfin carpsucker	0	0.2	0.2	0	0.1	0.1
Lake sturgeon	0	0	0	0	0	0
Mooneye	0	0	0	0	0	0
Quillback	0	0	0	0	0	0
River carpsucker	0	0	0	0	0	0
Sauger	0	0.5	0.3	0	0.2	0.1
Shorthead redhorse	0	0.2	0.1	0	0.1	0.1
Shortnose gar	0	0.1	0.1	0	0.1	0.1
Shovelnose sturgeon	0	0	0	0	0	0
Silver chub	0	0	0	0	0	0
Skipjack herring	0	0	0	0	0	0
Smallmouth buffalo	1.6	5.4	2.2	1.1	3.7	1.7
Speckled chub	0	0	0	0	0	0
White bass	0	1.3	0.6	0	0	0
Total fish	83.5	157.3	41.1	15.7	26.5	6.3

Table 17. Minimal density and biomass estimates of fishes captured by the rockhopper trawl in the lower Illinois River during 1997. Sample size is 16 hauls and S.E. is the standard error of the mean.

Species	Density (no./ha)			Biomass (kg/ha)		
	Median	Mean	S.E.	Median	Mean	S.E.
Bighead carp	0	0	0	0	0	0
Bigmouth buffalo	0	0	0	0	0	0
Black buffalo	0	0	0	0	0	0
Black crappie	0	0	0	0	0	0
Blue catfish	0	0.6	0.4	0	0.1	0
Blue sucker	0	0	0	0	0	0
Channel catfish	5.1	10.3	3.6	0.4	0.8	0.2
Common carp	0.9	3.9	1.7	1.5	5	1.9
Flathead catfish	0	0.6	0.3	0	1	0.5
Freshwater drum	60.6	89.7	21.9	12.9	15.7	4.5
Gizzard shad	0.8	59.4	55.6	0	1	0.8
Goldeye	0	0	0	0	0	0
Highfin carpsucker	0	0	0	0	0	0
Lake sturgeon	0	0	0	0	0	0
Mooneye	0	0.2	0.2	0	0	0
Quillback	0	0	0	0	0	0
River carpsucker	0	0.4	0.2	0	0.3	0.2
Sauger	0	0	0	0	0	0
Shorthead redhorse	0	0	0	0	0	0
Shortnose gar	0	0	0	0	0	0
Shovelnose sturgeon	0	0	0	0	0	0
Silver chub	0	0	0	0	0	0
Skipjack herring	0	0	0	0	0	0
Smallmouth buffalo	7.1	12.4	4.2	3.7	8.3	2.9
Speckled chub	0	0	0	0	0	0
White bass	0	0.2	0.2	0	0	0
Total fish	119	177.7	53.6	28.1	32.2	6.8

Table 18. Minimal density and biomass estimates of fishes captured by the rockhopper trawl in Pool 26 of the Mississippi River during 1996. Sample size is 65 hauls and S.E. is the standard error of the mean.

Species	Density (no./ha)			Biomass (kg/ha)		
	Median	Mean	S.E.	Median	Mean	S.E.
Bighead carp	0	0	0	0	0	0
Bigmouth buffalo	0	2	0.9	0	1.4	0.6
Black buffalo	0	0.1	0.1	0	0.2	0.2
Black crappie	0	0	0	0	0	0
Blue catfish	0	2	0.7	0	0.1	0
Blue sucker	0	0.1	0.1	0	0	0
Channel catfish	3.8	8.8	2	0.1	1.2	0.3
Common carp	0	4.2	1.5	0	3.1	1.1
Flathead catfish	0	0.3	0.1	0	0.6	0.2
Freshwater drum	4	27.9	5.9	0.3	4	0.7
Gizzard shad	0	42.1	19	0	0.5	0.1
Goldeye	0	0.2	0.1	0	0	0
Highfin carpsucker	0	0.1	0.1	0	0	0
Lake sturgeon	0	0.3	0.1	0	0.7	0.3
Mooneye	0	5	2.9	0	0.1	0.1
Quillback	0	0.5	0.1	0	0.3	0.1
River carpsucker	0	0.2	0.1	0	0.2	0.1
Sauger	0	0.6	0.2	0	0.3	0.1
Shorthead redhorse	0	0.5	0.2	0	0.3	0.1
Shortnose gar	0	0	0	0	0	0
Shovelnose sturgeon	0	4.2	1	0	2	0.4
Silver chub	0	0.1	0	0	0	0
Skipjack herring	0	0	0	0	0	0
Smallmouth buffalo	2	9.4	2	2.2	7.6	1.4
Speckled chub	0	0	0	0	0	0
White bass	0	0.5	0.2	0	0	0
Total fish	39.1	109	23.4	13.8	22.7	3.1

Table 19. Minimal density and biomass estimates of fishes captured by the rockhopper trawl in Pool 26 of the Mississippi River during 1997. Sample size is 49 hauls and S.E. is the standard error of the mean.

Species	Density (no./ha)			Biomass (kg/ha)		
	Median	Mean	S.E.	Median	Mean	S.E.
Bighead carp	0	0.1	0.1	0	0	0
Bigmouth buffalo	0	0.5	0.2	0	0.6	0.3
Black buffalo	0	0.1	0.1	0	0.1	0.1
Black crappie	0	0	0	0	0	0
Blue catfish	0	1.3	0.5	0	0.5	0.2
Blue sucker	0	0.1	0.1	0	0.1	0.1
Channel catfish	1.5	7.1	2	0	1.4	0.4
Common carp	0	0.4	0.2	0	0.5	0.3
Flathead catfish	0	0.3	0.1	0	0.7	0.4
Freshwater drum	1.9	23.3	7.2	0.2	2	0.6
Gizzard shad	0	3.6	1.4	0	0.2	0
Goldeye	0	0.3	0.1	0	0.1	0
Highfin carpsucker	0	0.3	0.1	0	0.2	0.1
Lake sturgeon	0	0	0	0	0	0
Mooneye	0	1.1	0.4	0	0	0
Quillback	0	2.1	0.9	0	1.3	0.5
River carpsucker	0	2.4	1.1	0	2.2	1
Sauger	0	0.5	0.2	0	0.2	0.1
Shorthead redhorse	0	0.2	0.1	0	0.1	0.1
Shortnose gar	0	0	0	0	0	0
Shovelnose sturgeon	0	4.1	1.2	0	2	0.6
Silver chub	0	0	0	0	0	0
Skipjack herring	0	0.2	0.1	0	0	0
Smallmouth buffalo	1.9	7.5	2.3	0.9	6.9	1.9
Speckled chub	0	0.2	0.2	0	0	0
White bass	0	0.1	0.1	0	0	0
Total fish	15.2	55.5	13.5	4.6	19.2	4.5

Table 20. Analysis of rockhopper trawl catches for all species combined.

Parameter	Overdispersed Poisson model			Overdispersed Poisson autoregressive model		
	Estimate	S.E.	*P*-value	Estimate	S.E.	*P*-value
Intercept λ_0	7.908	4.744	0.100	9.218	5.983	0.12
Year y_1, 1996	0.343	0.252	0.89	−0.045	0.357	0.90
Year y_2, 1997	0	0		0	0	
Pool p_1, Pool 26	−0.653	0.260	0.01	−0.728	0.376	0.05
Pool p_2, Illinois River	0	0		0	0	
Location in pool $l_{1(1)}$ (lower 26)	0.008	0.266	0.97	−0.020	0.396	0.96
Location in pool $l_{1(2)}$ (upper 26)	0	0		0	0	
Location in pool $l_{2(3)}$ (all Ill. R.)	0	0		0	0	
Month β_1	−4.833	1.996	0.02	−5.44	2.54	0.03
Month (quadratic) β_2	0.800	0.265	<0.01	0.876	0.340	0.01
Month (cubic) β_3	−0.038	0.011	<0.01	−0.040	0.014	<0.01
Scale φ	8.890			8.89		

Table 21. Analysis of rockhopper trawl catches for blue catfish.

Parameter	Overdispersed Poisson model			Overdispersed Poisson autoregressive model		
	Estimate	S.E.	*P*-value	Estimate	S.E.	*P*-value
Intercept λ_0	6.685	16.37	0.68	6.735	16.51	0.68
Year y_1, 1996	0.123	0.340	0.72	0.123	0.344	0.72
Year y_2, 1997	0	0		0	0	
Pool p_1, Pool 26	-0.732	0.671	0.28	-0.728	0.679	0.28
Pool p_2, Illinois River	0	0		0	0	
Location in pool $l_{1(1)}$ (lower 26)	2.278	0.542	<0.01	2.274	0.548	<0.01
Location in pool $l_{1(2)}$ (upper 26)	0	0		0	0	
Location in pool $l_{2(3)}$ (all Ill. R.)	0	0		0	0	
Month β_1	-9.016	6.021	0.13	-9.039	6.075	0.14
Month (quadratic) β_2	1.552	0.737	0.04	1.555	0.744	0.04
Month (cubic) β_3	-0.075	0.030	0.01	-0.0752	0.030	0.01
Scale φ	1.469			1.469		

Table 22. Analysis of rockhopper trawl catches for channel catfish.

Parameter	Overdispersed Poisson model			Overdispersed Poisson Autoregressive model		
	Estimate	S.E.	*P*-value	Estimate	S.E.	*P*-value
Intercept λ_0	0.122	4.279	0.98	0.174	4.363	0.97
Year y_1, 1996	0.385	0.312	0.22	0.382	0.320	0.23
Year y_2, 1997	0	0		0	0	
Pool p_1, Pool 26	-1.425	0.394	<0.01	-1.424	0.404	<0.01
Pool p_2, Illinois River	0	0		0	0	
Location in pool $l_{1(1)}$ (lower 26)	1.246	0.376	<0.01	1.243	0.387	<0.01
Location in pool $l_{1(2)}$ (upper 26)	0	0		0	0	
Location in pool $l_{2(3)}$ (all Ill. R.)	0	0		0	0	
Month β_1	-1.476	1.808	0.41	-1.499	1.845	0.42
Month (quadratic) β_2	0.279	0.241	0.25	0.282	0.246	0.25
Month (cubic) β_3	-0.014	0.010	0.16	-0.014	0.010	0.16
Scale φ	3.211			3.211		

Table 23. Analysis of rockhopper trawl catches for common carp.

Parameter	Gaussian errors model		
	Estimate	S.E.	*P*-value
Intercept λ_0	0.536	0.259	0.04
Year y_1, 1996	-0.043	0.030	0.15
Year y_2, 1997	0	0	
Pool p_1, Pool 26	-0.013	0.030	0.65
Pool p_2, Illinois River	0	0	
Location in pool $l_{1(1)}$ (lower 26)	-0.036	0.026	0.17
Location in pool $l_{1(2)}$ (upper 26)	0	0	
Location in pool $l_{2(3)}$ (all Ill. R.)	0	0	
Month β_1	-0.280	0.119	0.02
Month (quadratic) β_2	0.044	0.017	0.01
Month (cubic) β_3	-0.002	0.001	<0.01

Table 24. Analysis of rockhopper trawl catches for freshwater drum.

Parameter	Overdispersed Poisson model			Overdispersed Poisson Autoregressive model		
	Estimate	S.E.	*P*-value	Estimate	S.E.	*P*-value
Intercept λ_0	2.720	7.202	0.70	3.591	7.726	0.64
Year y_1, 1996	0.175	0.263	0.50	0.199	0.299	0.50
Year y_2, 1997	0	0		0	0	
Pool p_1, Pool 26	-2.061	0.371	<0.01	-2.067	0.426	<0.01
Pool p_2, Illinois River	0	0		0	0	
Location in pool $l_{1(1)}$ (lower 26)	1.091	0.387	<0.01	1.072	0.446	0.01
Location in pool $l_{1(2)}$ (upper 26)	0	0		0	0	
Location in pool $l_{2(3)}$ (all Ill. R.)	0	0		0	0	
Month β_1	-2.841	2.680	0.29	-3.218	2.900	0.27
Month (quadratic) β_2	0.550	0.328	0.09	0.601	0.358	0.09
Month (cubic) β_3	-0.028	0.013	0.03	-0.030	0.014	0.04
Scale φ	6.23			6.23		

Table 25. Analysis of rockhopper trawl catches for gizzard shad.

Parameter	Gaussian errors model		
	Estimate	S.E.	*P*-value
Intercept λ_0	2.119	0.979	0.03
Year y_1, 1996	-0.013	0.114	0.91
Year y_2, 1997	0	0	
Pool p_1, Pool 26	0.128	0.112	0.03
Pool p_2, Illinois River	0	0	
Location in pool $l_{1(1)}$ (lower 26)	-0.191	0.098	0.05
Location in pool $l_{1(2)}$ (upper 26)	0	0	
Location in pool $l_{2(3)}$ (all Ill. R.)	0	0	
Month β_1	-1.117	0.451	0.01
Month (quadratic) β_2	0.169	0.063	0.01
Month (cubic) β_3	-0.007	0.003	0.01
Scale φ			

Table 26. Analysis of rockhopper trawl catches for goldeye.

Parameter	Gaussian errors model		
	Estimate	S.E.	*P*-value
Intercept λ_0	-0.003	0.032	0.92
Year y_1, 1996	-0.006	0.004	0.10
Year y_2, 1997	0	0	
Pool p_1, Pool 26	0.004	0.004	0.26
Pool p_2, Illinois River	0	0	
Location in pool $l_{1(1)}$ (lower 26)	0.006	0.003	0.08
Location in pool $l_{1(2)}$ (upper 26)	0	0	
Location in pool $l_{2(3)}$ (all Ill. R.)	0	0	
Month β_1	-0.001	0.015	0.93
Month (quadratic) β_2	~0	0.0001	0.85
Month (cubic) β_3	~0	<0.001	0.85

Table 27. Analysis of rockhopper trawl catches for mooneye.

Parameter	Gaussian errors model		
	Estimate	S.E.	*P*-value
Intercept λ_0	0.206	0.306	0.50
Year y_1, 1996	0.009	0.036	0.80
Year y_2, 1997	0	0	
Pool p_1, Pool 26	0.087	0.035	0.01
Pool p_2, Illinois River	0	0	
Location in pool $l_{1(1)}$ (lower 26)	-0.065	0.030	0.03
Location in pool $l_{1(2)}$ (upper 26)	0	0	0
Location in pool $l_{2(3)}$ (all Ill. R.)	0	0	0
Month β_1	-0.149	0.141	0.29
Month (quadratic) β_2	0.024	0.020	0.22
Month (cubic) β_3	-0.001	0.001	0.18

Table 28. Analysis of rockhopper trawl catches for shovelnose sturgeon.

Parameter	Gaussian errors model		
	Estimate	S.E.	*P*-value
Intercept λ_0	-0.415	0.230	0.07
Year y_1, 1996	-0.005	0.027	0.85
Year y_2, 1997	0	0	
Pool p_1, Pool 26	0.166	0.026	<0.01
Pool p_2, Illinois River	0	0	
Location in pool $l_{1(1)}$ (lower 26)	-0.144	0.022	<0.01
Location in pool $l_{1(2)}$ (upper 26)	0	0	
Location in pool $l_{2(3)}$ (all Ill. R.)	0	0	
Month β_1	0.197	0.106	0.06
Month (quadratic) β_2	-.028	0.015	0.06
Month (cubic) β_3	0.001	0.001	0.07

Table 29. Analysis of rockhopper trawl catches for smallmouth buffalo.

Parameter	Overdispersed Poisson model			Overdispersed Poisson autoregressive model		
	Estimate	S.E.	*P*-value	Estimate	S.E.	*P*-value
Intercept λ_0	4.322	6.220	0.49	3.343	7.716	0.66
Year y_1, 1996	-0.139	0.253	0.58	-0.110	0.333	0.74
Year y_2, 1997	0	0		0	0	
Pool p_1, Pool 26	-0.372	0.336	0.27	-0.295	0.456	0.52
Pool p_2, Illinois River	0	0		0	0	
Location in pool $l_{1(1)}$ (lower 26)	0.800	0.284	<0.01	0.809	0.379	0.03
Location in pool $l_{1(2)}$ (upper 26)	0	0		0	0	
Location in pool $l_{2(3)}$ (all Ill. R.)	0	0		0	0	
Month β_1	-5.167	2.597	0.05	-4.794	3.285	0.13
Month (quadratic) β_2	0.936	0.350	0.01	0.884	0.427	0.04
Month (cubic) β_3	-0.047	0.015	0.01	-0.045	0.018	0.04
Scale φ	2.767			2.767		

Table 30. Mean, standard deviation (S.D.) and sample size (N) of lengths and weights of fishes captured by rockhopper trawling.

	Pool 26, Mississippi River						Illinois River					
	Length (mm)			Weight (g)			Length (mm)			Weight (g)		
Species	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N
Bighead carp	77		1									
Bigmouth buffalo	362	64	66	746	561	33	349	35	5	600	45	4
Black buffalo	438	75	7									
Black crappie	248		1									
Blue catfish	198	106	100	233	654	46	167	72	12	53	66	4
Blue sucker	358	144	5	601	613	4						
Channel catfish	217	114	440	172	309	268	202	81	209	94	107	121
Common carp	383	52	124	786	294	61	452	63	60	1480	954	21
Flathead catfish	487	163	17	3128	1908	9	427	135	8	786	1147	4
Freshwater drum	207	81	1001	167	268	536	221	91	947	196	231	318
Gizzard shad	151	55	324	64	88	199	134	57	113	35	80	60
Goldeye	258	23	14	164	47	12						
Highfin carpsucker	339	51	9	609	145	5	312	11	2			
Lake sturgeon	707	112	10	2371	1657	7						
Mooneye	155	20	118	42	18	70	142		1			
Quillback	358	76	60	709	405	15						
River carpsucker	399	58	75	1206	568	15	403	20	3			
Sauger	369	62	29	520	224	16	303	120	5	316	273	3
Shorthead redhorse	380	97	17	867	300	12	334	43	2			
Shortnose gar	594	56	2	948		1	666		1	1250		1
Shovelnose sturgeon	520	101	234	620	330	124						
Silver chub	136	30	2	52		1						
Skipjack herring	98	4	4									

Continued...

Table 30 continued...

	Pool 26, Mississippi River						Illinois River					
	Length (mm)			Weight (g)			Length (mm)			Weight (g)		
Species	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N
Smallmouth buffalo	363	80	467	1010	1146	256	346	46	140	829	754	31
Speckled chub	51	8	4	3	1	3						
White bass	161	42	18	53	49	11	105	14	11	15	5	8

Table 31. Information on dead and wounded fish, for which injuries could be attributed to entrainment through the propellers of the preceding towboat, collected during entrainment sampling behind towboats passing upstream or downstream during 1996. No dead or wounded fish were collected while sampling for entrainment during 1997.

Date	River	River mile	Species	Length (mm)	Wound age[1/]	Likely cause[2/]	Time of death[3/]
Oct 2	Mississippi	203.2	Gizzard shad	119	1	1	1
Oct 2	Mississippi	203.2	Gizzard shad	124	1	1	1
Nov 6	Mississippi	238.2	Gizzard shad	122	1	1	1

[1/] 1 = fresh, no sign of blood clotting; 2 = less than 1 day, blood clotting evident; 3 = one or more days; N = no wound present.

[2/] 0 = uncertain, may or may not have been a towboat propeller; 1 = propeller.

[3/] 0 = alive; 1 = very recent death, gills red and eyes clear; 2 = recent death, gills pink, at least one eye clear; 3 = not recent, gills white, eyes cloudy.

Table 32. Dead and wounded fish collected during ambient sampling with the rockhopper trawl to determine background occurrence of dead and wounded fish during 1996 and 1997 in Pool 26 of the Upper Mississippi River and the lower 20 miles of the Illinois River. ***Bold*** entries are fish with fresh injuries consistent with propeller wounding that were used to construct the ancillary entrainment mortality rate estimates. NM means fish were not measured.

Date	River	River mile	Species	Length (mm)	Wound age[1/]	Likely cause[2/]	Time of death[3/]
		1996					
Oct 22	***Mississippi***	***215.7***	***Shovelnose sturgeon***	***590***	***1***	***1***	***0****
Oct 31	***Illinois***	***9.3***	***Gizzard shad***	***310***	***1***	***1***	***0****
Nov 22	Mississippi	203.2	Gizzard shad	125	3	0	3
Dec 10	Illinois	18.7	Gizzard shad	NM	N	0	3
Dec 10	Illinois	18.7	Gizzard shad	NM	N	0	3
Dec 10	Illinois	18.7	Gizzard shad	NM	N	0	3
Dec 10	Illinois	18.7	Gizzard shad	NM	N	0	3
Dec 10	Illinois	18.7	Gizzard shad	107	N	0	2
Dec 10	Illinois	18.7	Gizzard shad	NM	N	0	3
Dec 10	***Illinois***	***5.5***	***Smallmouth buffalo***	***518***	***1***	***1***	***0****
Dec 10	Illinois	5.5	Gizzard shad	107	2	0	2
		1997					
Mar 24	Mississippi	213.6	Gizzard shad	NM	3	1	3
Mar 24	Mississippi	213.6	Gizzard shad	NM	N	0	3
Mar 24	Mississippi	213.6	Gizzard shad	NM	N	0	3
Mar 24	Mississippi	213.6	Gizzard shad	NM	N	0	3
Mar 25	Mississippi	207.1	Gizzard shad	NM	N	0	3
Mar 25	Mississippi	207.1	Gizzard shad	NM	N	0	3
Mar 25	Mississippi	207.1	Gizzard shad	NM	N	0	3

Continued...

Table 32 continued.

Date	River	River mile	Species	Length (mm)	Wound age[1/]	Likely cause[2/]	Time of death[3/]
			1997				
Mar 26	Mississippi	233.5	Gizzard shad	NM	N	0	3
Mar 26	Mississippi	230.5	Gizzard shad	NM	N	0	3
Mar 26	Mississippi	277.2	Shovelnose sturgeon	615	3	0	0
Mar 26	Mississippi	223.0	Gizzard shad	NM	N	0	3
Mar 26	Mississippi	223.0	Gizzard shad	NM	N	0	3
Mar 26	Mississippi	223.0	Gizzard shad	NM	N	0	3
June 19	Mississippi	238.5	Shovelnose sturgeon	505	3	0	0
June 19	Mississippi	238.5	Shovelnose sturgeon	505	3	0	0
June 19	Mississippi	238.5	Shovelnose sturgeon	295	3	0	0

[1/]1 = fresh, no sign of blood clotting; 2 = less than 1 day, blood clotting evident; 3 = one or more days; N = no wound present.

[2/]0 = uncertain, may or may not have been a towboat propeller; 1 = propeller.

[3/]0 = alive; 1 = very recent death, gills red and eyes clear; 2 = recent death, gills pink, at least one eye clear; 3 = not recent, gills white, eyes cloudy.

[*]Although alive at time of collection, wounding occurred to vital areas of the body, e.g., head, body cavity.

Table 33. Characteristics of towboats followed during entrainment sampling in Pool 26 of the Mississippi River and the lower Illinois River during 1996 and 1997. Sample barcodes are numbers that uniquely identify individual samples. NA indicates not available.

Sample barcode	Towboat name	Travel Direction[†]	Barges		Installed Horsepower	Propellers		Identification source[‡]	Towboat length (m)
			Empty	Full		Number	Type		
17000002	Arlie	u	0	15	6000	2	kort	2	44.2
17000006		u	15	0	NA	NA		NA	45.7
17000009	William C. Norman	u	0	0	1950	2	open	2	33.5
17000011		d	0	15	NA	NA		NA	45.7
17000014	Walter Hagesta	d	0	9	4200	2	open	2	42.7
17000017		d	0	15	NA	NA		NA	45.7
17000018	Robin B Ingram	u	15	0	6120	2	kort	1	42.7
17000021		u	15	0	NA	NA		NA	45.7
17000024	Nebraska	d	0	15	800	2	open	1	16.8
17000026	Cooperative Venture	u	15	0	3700	2	open	1	51.2
17000030	Penny Eckstein	d	0	15	4800	3	open	1	50
17000031	Midwest Legend	u	16	0	6000	2	kort	1	42.1
17000032	Judy S	d	7	8	4300	2	kort	1	42.1
17000033	Julie S	u	0	15	6200	2	kort	1	51.2
17000038	Aunt Mary	u	3	12	3200	2	kort	1	43.9
17000040	B John Yeager	d	0	15	7200	2	kort	1	50.6
17000046	Evey-T *	u	0	16	4300	2	open	1	42.7
17000049	Mary Fern	u	2	0	650	2	open	1	16.5
17000055	Sierra Dawn	d	0	15	5400	2	kort	1	50
17000056	Tom Talbert	d	0	15	5600	2	kort	1	51.2

Continued...

Table 33. Continued...

Sample barcode	Towboat name	Travel Direction†	Barges Empty	Barges Full	Installed Horsepower	Propellers Number Type	Identification source‡	Towboat length (m)
17000057	Tom Talbert	d	0	15	5600	2 kort	1	51.2
17000067	Neil N Diehl	u	1	0	6150	2 kort	1	42.7
17000070	Judy S	u	0	12	4300	2 kort	1	42.1
17000073	Kathy Ellen	u	15	0	3800	2 open	1	46
17000075	Cooperative Mariner	d	0	15	3700	2 open	1	51.2
17000076	Kathy Ellen	u	15	0	3800	2 open	1	46
17000081	Helen Lay	u	9	8	5600	2 open	1	41.8
17000085	Phyllis	d	0	15	4200	2 kort	1	42.7
17000086	Phyllis	d	0	15	4200	2 kort	1	42.7
17000094	Sunflower	u	3	12	5600	2 kort	1	42.7
17000097	Cecelia Carol	d	0	15	4200	3 open	1	48.8
17000105	Baxter	d	2	0	3600	2 open	1	36.6
17000106	Afton	u	16	0	4200	2 open	1	42.7
17000111		u	0	15	NA	NA	NA	45.7
17000123	Dave Carlton	u	0	15	6140	2 kort	1	51.8
17000172	Hugh C. Blaske	d	0	15	5000	2 kort	2	51.8
17000180	"EMC," unidentified	u	0	5	NA	NA	NA	45.7
17000181	E. Gene Fournace	u	0	15	5600	2 kort	2	42.1
17000184	Luke Burton	u	6	0	4200	2 kort	2	43.9
17000186	"Hollywood," unidentified	d	10	0	NA	NA	NA	45.7
17000385		d	15	0	NA	NA	NA	45.7

† Downbound = d, upbound = u.

‡ 1 = towboat identified by name; 2 = identified by match with lock records; NA = unidentified towboat

* The Evey-T was originally recorded as the "Eve;" the Evey-T is the only boat recorded in the Inland River Record that contains "Eve"

Table 34. Derived characteristics of towboats followed during entrainment sampling in Pool 26 of the Mississippi River and the lower Illinois River during 1996 and 1997. Sample barcodes are numbers that uniquely identify individual samples.

Sample barcode	Towboat name	Travel direction	Tow speed (m/sec)			Tow dimensions (m)			Hydrodynamic effects	
			Method	Relative to the ground	Relative to the water	Width	Total length	Draft	Return velocity (m/sec)	Drawdown (m)
17000002	Arlie	u	Tabled	2.1	2.93	32	341.4	2.7	0.15	0.04
17000006		u	Tabled	1.68	2.26	32	342.9	0.6	0.15	0.04
17000009	William C. Norman	u	Tabled	2.41	2.93	10.7	33.5	0.6	0.09	0.01
17000011		d	Tabled	3.23	2.93	32	342.9	2.7	0.24	0.09
17000014	Walter Hagesta	d	Tabled	3.17	2.93	32	221	2.7	0.12	0.02
17000017		d	Tabled	3.66	2.93	32	342.9	2.7	0.34	0.17
17000018	Robin B Ingram	u	Tabled	2.62	2.93	32	339.9	0.6	0.09	0.01
17000021		u	Tabled	2.07	2.26	32	342.9	0.6	0.12	0.02
17000024	Nebraska	d	Tabled	3.44	2.93	32	313.9	2.7	0.24	0.09
17000026	Cooperative Venture	u	Tabled	2.44	2.93	32	348.4	0.6	0.12	0.02
17000030	Penny Eckstein	d	Tabled	3.23	2.93	32	347.2	2.7	0.15	0.04
17000031	Midwest Legend	u	Tabled	2.62	2.93	32	297.2	0.6	0.06	0.01
17000032	Judy S	d	Tabled	2.93	2.93	32	339.2	2.1	0.06	0.01
17000033	Julie S	u	Tabled	2.68	2.93	32	348.4	2.7	0.15	0.04
17000038	Aunt Mary	u	Tabled	2.53	2.93	32	341.1	2.4	0.24	0.09
17000040	B John Yeager	d	Tabled	3.08	2.93	32	347.8	2.7	0.12	0.02
17000046	Evey-T	u	Tabled	2.26	2.26	32	297.2	2.7	0.46	0.32
17000049	Mary Fern	u	Tabled	2.1	2.26	21.3	75.9	0.6	0.09	0.01
17000055	Sierra Dawn	d	Tabled	3.66	2.93	32	347.2	2.7	0.24	0.09
17000056	Tom Talbert	d	Tabled	3.57	2.93	32	348.4	2.7	0.24	0.09
17000057	Tom Talbert	d	Tabled	3.69	2.93	32	348.4	2.7	0.34	0.17

Continued...

Table 34. Continued...

Sample barcode	Towboat name	Travel direction	Tow speed (m/sec)			Tow dimensions (m)			Hydrodynamic effects	
			Method	Relative to the ground	Relative to the water	Width	Total length	Draft	Return velocity (m/sec)	Drawdown (m)
17000067	Neil N Diehl	u	Measured	3.11	3.81	10.7	102.1	0.6	0.12	0.02
17000070	Judy S	u	Measured	2.87	3.2	32	279.8	2.7	0.12	0.02
17000073	Kathy Ellen	u	Measured	3.29	3.54	32	343.2	0.6	0.24	0.09
17000075	Cooperative Mariner	d	Tabled	2.56	2.26	32	348.4	2.7	0.34	0.17
17000076	Kathy Ellen	u	Measured	1.49	1.8	32	343.2	0.6	0.09	0.01
17000081	Helen Lay	u	Measured	1.86	2.47	32	297.2	1.8	0.06	0.01
17000085	Phyllis	d	Tabled	3.57	2.93	32	339.9	2.7	0.24	0.09
17000086	Phyllis	d	Tabled	3.69	2.93	32	339.9	2.7	0.24	0.09
17000094	Sunflower	u	Measured	2.53	3.29	32	339.9	2.4	0.27	0.12
17000097	Cecelia Carol	d	Tabled	4.27	2.93	32	345.9	2.7	0.12	0.02
17000105	Baxter	d	Tabled	3.14	2.26	21.3	96	0.6	0.12	0.02
17000106	Afton	u	Measured	2.13	2.74	32	297.2	0.6	0.09	0.01
17000111		u	Measured	2.9	3.47	32	342.9	2.7	0.18	0.05
17000123	Dave Carlton	u	Measured	2.13	2.5	32	349	2.7	0.09	0.01
17000172	Hugh C. Blaske	d	Tabled	3.54	2.93	32	349	2.7	0.15	0.04
17000180	"EMC"	u	Tabled	2.65	2.93	21.3	178.3	2.7	0.12	0.02
17000181	E. Gene Fournace	u	Measured	1.68	1.89	32	339.2	2.7	0.06	0.01
17000184	Luke Burton	u	Measured	2.44	2.71	21.3	222.2	0.6	0.03	0
17000186	"Hollywood"	d	Tabled	2.56	2.26	32	237.7	0.6	0.12	0.02
17000385		d	Measured	3.51	3.11	32	342.9	0.6	0.03	0

Table 35. Trawling and river characteristics during entrainment sampling in Pool 26 of the Mississippi River and the lower Illinois River during 1996 and 1997. Sample barcodes are numbers that uniquely identify individual samples. NA indicates not available.

Sample barcode	Towboat name	Travel direction	Trawling distances (m)			Location code[†]	Trawl effort (min)	River characteristics	
			Trawled	Behind tow at start	Behind tow at finish			Current speed (m/sec)	Channel width (m)
17000002	Arlie	u	920	NA	NA	M0213.6	20	0.82	1036
17000006		u	920	NA	NA	I0018.7	20	0.58	244
17000009	William C. Norman	u	1370	NA	NA	M0223.0	20	0.52	518
17000011		d	1250	NA	NA	M0227.5	20	0.3	610
17000014	Walter Hagesta	d	1600	NA	NA	M0203.2	20	0.24	1189
17000017		d	1140	NA	NA	M0230.5	20	0.73	427
17000018	Robin B Ingram	u	1250	NA	NA	M0227.5	20	0.3	610
17000021		u	1520	NA	NA	I0013.5	20	0.18	335
17000024	Nebraska	d	1250	NA	NA	M0238.2	20	0.52	579
17000026	Cooperative Venture	u	1020	NA	NA	M0230.5	15	0.49	427
17000030	Penny Eckstein	d	1060	NA	NA	M0213.6	23	0.3	1036
17000031	Midwest Legend	u	1370	NA	NA	M0215.7	20	0.3	914
17000032	Judy S	d	1310	NA	NA	M0207.1	20	0.1	1341
17000033	Julie S	u	1100	NA	NA	M0213.5	23	0.24	1036
17000038	Aunt Mary	u	1680	NA	NA	M0227.2	20	0.4	579
17000040	B John Yeager	d	1680	NA	NA	M0203.2	21	0.15	1189
17000046	Evey-T	u	760	NA	NA	I0018.7	20	0.1	244
17000049	Mary Fern	u	850	NA	NA	I0005.5	14	0.15	396
17000055	Sierra Dawn	d	1100	NA	NA	M0233.5	20	0.73	579
17000056	Tom Talbert	d	1200	NA	NA	M0238.2	20	0.64	579
17000057	Tom Talbert	d	1280	NA	NA	M0230.5	20	0.76	427

Continued...

Table 35. Continued...

Sample barcode	Towboat name	Travel direction	Trawling distances (m)			Location code[†]	Trawl effort (min)	River characteristics	
			Trawled	Behind tow at start	Behind tow at finish			Current speed (m/sec)	Channel width (m)
17000067	Neil N Diehl	u	1300	402	2816	M0223.0	20	0.7	518
17000070	Judy S	u	1320	322	2092	M0207.1	18	0.34	1341
17000073	Kathy Ellen	u	980	402	1207	I0018.7	9	0.24	244
17000075	Cooperative Mariner	d	830	NA	NA	I0009.3	13	0.3	335
17000076	Kathy Ellen	u	1460	161	483	I0013.5	20	0.3	335
17000081	Helen Lay	u	1350	322	1207	M0215.7	20	0.61	914
17000085	Phyllis	d	1150	NA	NA	M0233.5	20	0.64	579
17000086	Phyllis	d	1200	NA	NA	M0238.2	20	0.76	579
17000094	Sunflower	u	1680	241	1609	M0227.2	20	0.76	579
17000097	Cecelia Carol	d	1370	NA	NA	M0207.1	20	1.34	1341
17000105	Baxter	d	450	NA	NA	I0009.3	7	0.88	335
17000106	Afton	u	1820	241	966	M0227.1	20	0.61	579
17000111		u	1370	644	2736	M0215.7	20	0.58	914
17000123	Dave Carlton	u	1600	322	1287	M0203.2	20	0.37	1189
17000172	Hugh C. Blaske	d	920	NA	NA	M0213.6	20	0.61	1036
17000180	"EMC"	u	1310	NA	NA	M0207.1	20	0.27	1341
17000181	E. Gene Fournace	u	1360	161	805	M0211.2	20	0.21	1402
17000184	Luke Burton	u	1310	483	2092	M0207.1	20	0.27	1341
17000186	"Hollywood"	d	1300	NA	NA	I0009.3	20	0.3	335
17000385		d	660	322	1770	M0207.1	10	0.4	1341

[†] The first letter denotes river (Mississippi = M and Illinois = I), and the remaining numeric digits are the River Mile, as recorded on navigation charts.

Table 36. Estimates of total numbers of gizzard shad (and total numbers of fish) killed per unit distance of tow travel in Pool 26 of the Mississippi River and in the lower 65 km of the Illinois River, 1996-1997.

Sample barcode	Pool	Date	Type†	Travel direction	Conc. of propeller water (m^{-2}) $\hat{c}_i$	Trawl mouth area (m^2) $\hat{A}_{mi}$	Detection probability $\hat{g}_i$	No. kills seen k_i	Tow travel (km) l_i	Estimated total numbers of adult fish killed by entrainment $\hat{\tau}_i$	
										Per km of tow travel	Per mile of tow travel
17000002	26	08/06/96	C	u	0.0025	3.66	0.0092	0	0.92	0	0
17000006	IR	08/07/96	I	u	0.0029	3.66	0.0107	0	0.92	0	0
17000009	26	08/08/96	C	u	0.0029	3.66	0.0106	0	1.37	0	0
17000011	26	08/14/96	I	d	0.0014	3.66	0.0053	0	1.25	0	0
17000017	26	08/14/96	I	d	0.0014	3.66	0.0053	0	1.14	0	0
17000018	26	08/14/96	C	u	0.0032	3.66	0.0116	0	1.25	0	0
17000014	26	10/02/96	I	d	0.0014	3.66	0.0053	2	1.6	236	379
17000021	IR	10/08/96	I	u	0.0029	3.66	0.0107	0	1.52	0	0
17000024	26	10/09/96	C	d	0.0008	3.66	0.003	0	1.25	0	0
17000026	26	10/09/96	C	u	0.0039	3.66	0.0142	0	1.02	0	0
17000030	26	10/11/96	C	d	0.001	3.66	0.0035	0	1.06	0	0
17000031	26	10/16/96	C	u	0.0022	3.66	0.008	0	1.37	0	0
17000032	26	10/16/96	I	d	0.0014	3.66	0.0053	0	1.31	0	0
17000033	26	10/16/96	C	u	0.0022	3.66	0.0082	0	1.1	0	0
17000038	26	10/17/96	C	u	0.0027	3.66	0.0098	0	1.68	0	0
17000040	26	10/21/96	I	d	0.0014	3.66	0.0053	0	1.68	0	0
17000046	IR	10/31/96	C	u	0.0033	3.66	0.012	0	0.76	0	0
17000049	IR	10/31/96	C	u	0.0038	3.66	0.0138	0	0.85	0	0
17000055	26	11/06/96	C	d	0.0019	3.66	0.007	0	1.1	0	0
17000056	26	11/06/96	C	d	0.0015	3.66	0.0054	1	1.2	155	249

Continued...

Table 36. Continued...

Sample barcode	Pool	Date	Type†	Travel direction	Conc. of propeller water (m^{-2}) $\hat{c}_i$	Trawl mouth area (m^2) $\hat{A}_{mi}$	Detection probability $\hat{g}_i$	No. kills seen k_i	Tow travel (km) l_i	Estimated total numbers of adult fish killed by entrainment $\hat{\tau}_i$	
										Per km of tow travel	Per mile of tow travel
17000057	26	11/06/96	C	d	0.0018	3.66	0.0066	0	1.28	0	0
17000067	26	11/20/96	C	u	0.0029	3.66	0.0106	0	1.3	0	0
17000070	26	11/22/96	C	u	0.0022	3.66	0.0082	0	1.32	0	0
17000073	IR	12/10/96	C	u	0.0041	3.66	0.0151	0	0.98	0	0
17000075	IR	12/10/96	I	d	0.0014	3.66	0.0053	0	0.83	0	0
17000076	IR	12/10/96	C	u	0.0037	3.66	0.0134	0	1.46	0	0
17000081	26	12/12/96	C	u	0.0022	3.66	0.008	0	1.35	0	0
17000085	26	12/12/96	C	d	0.0015	3.66	0.0056	0	1.15	0	0
17000086	26	12/12/96	C	d	0.0017	3.66	0.0061	0	1.2	0	0
17000094	26	03/26/97	C	u	0.0027	3.66	0.01	0	1.68	0	0
17000097	26	04/08/97	C	d	0.0017	4.22	0.0072	0	1.37	0	0
17000105	IR	06/18/97	I	d	0.0014	2.83	0.0041	0	0.45	0	0
17000106	26	06/19/97	C	u	0.0028	3.66	0.0103	0	1.82	0	0
17000123	26	07/16/97	C	u	0.0026	3.66	0.0096	0	1.6	0	0
17000111	26	07/17/97	I	u	0.0029	3.66	0.0107	0	1.37	0	0
17000172	26	09/09/97	C	d	0.0016	3.66	0.0058	0	0.92	0	0
17000181	26	09/18/97	C	u	0.0031	2.55	0.0079	0	1.36	0	0
17000184	26	09/19/97	C	u	0.0023	3.72	0.0087	0	1.31	0	0
17000186	IR	09/23/97	I	d	0.0014	2.41	0.0035	0	1.3	0	0
17000180	26	09/24/97	I	u	0.0029	3.87	0.0113	0	1.31	0	0
17000385	26	10/21/97	I	d	0.0014	3.66	0.0053	0	0.66	0	0

† "C" denotes complete estimates of c_i were obtained from sample; "I" denotes use of mean values of c fom complete up-or downbound tows.

Table 37. Final estimates of numbers of adult fishes killed per unit distance of tow travel in Pool 26 of the Mississippi River and the lower 32 km of the Illinois River, 1996-1997. Estimates from gizzard shad and the total are from 41 entrainment samples. The ancillary estimates incorporate kills observed from ambient samples, and the augmented total is the sum of estimates for the three species. Bootstrap standard errors, bias and 80% confidence intervals are estimated from 6,000 bootstrap resamplings of the entrainment mortality rate estimates. See the text for explanation of the ancillary estimation and the bootstrapping.

Species	Estimate	Standard Error		Bias	80% confidence interval
		Analytical[1/]	Bootstrap		
		Kills per kilometer			
Gizzard shad	9.5	6.8	6.6	0.02	3.8-22.8[2/]
					1.0-18.0[3/]
Total	9.5	6.8	6.6	0.02	3.8-22.8[2/]
					1.0-18.0[3/]
Shovelnose sturgeon (ancillary)	2.4	2.5	2.7	−0.12	0-6.0[4/]
Smallmouth buffalo (ancillary)	2.4	2.5	2.7	−0.12	0-6.0[4/]
Augmented total	14.3	7.6	9.3	−0.22	0-26.7[4/]
		Kills per mile			
Gizzard shad	15.3	10.9	10.6	0.03	6.1-36.7[2/]
					1.6-29.0[3/]
Total	15.3	10.9	10.6	0.03	6.1-36.7[2/]
					1.6-29.0[3/]
Shovelnose sturgeon (ancillary)	3.8	4.0	4.3	−0.19	0-9.7[4/]
Smallmouth buffalo (ancillary)	3.8	4.0	4.3	−0.19	0-9.7[4/]
Augmented total	22.9	12.3	15.0	−0.35	0-43.0[4/]

[1/]Equation 13 for gizzard shad and equations 23-24 for shovelnose sturgeon and smallmouth buffalo.
[2/]Bias-corrected and accelerated interval (Efron 1987; Efron and Tibshirani 1993).
[3/]Bias-corrected interval (Efron 1982).
[4/]Percentile-method interval (Efron and Tibshirani 1993).

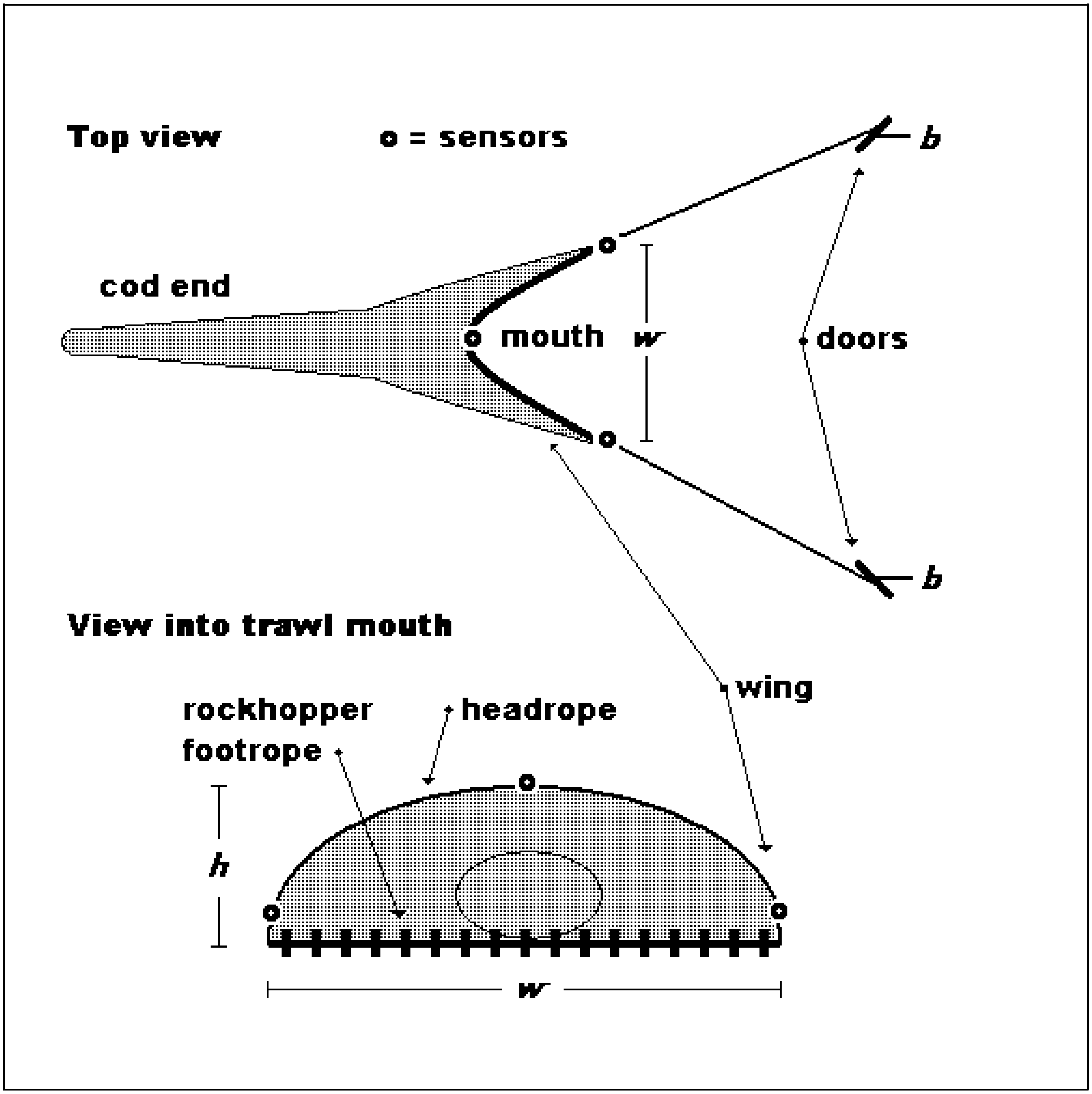

Figure 1. *Upper diagram:* Schematic representation of the 10.2-m rockhopper bottom trawl as viewed from above. Drawing is not to scale. Towing cables from the trawler are attached to the doors at points *b*. Under tow, the doors spread the wings and footrope. *Lower diagram:* View into the trawl mouth from between the doors. Headrope height is *h* and linear distance between the wings is *w*. Positions of the acoustic sensors are as indicated. See text for details.

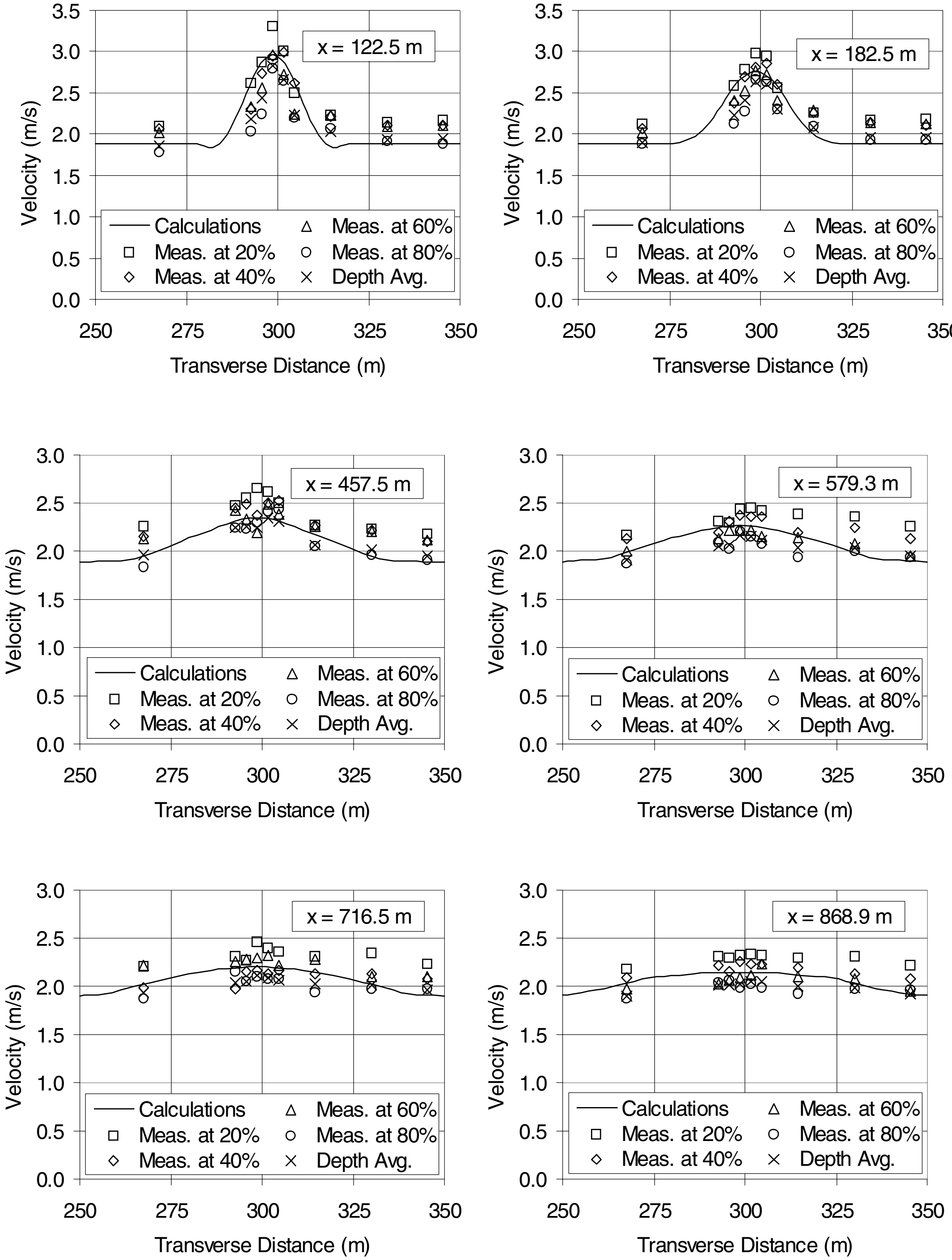

Figure 2. Current velocities calculated by the DIFFLAR numerical model and those measured in a test tank. All measurements are at full scale. Reprinted by permission of E. R. Holley. See text for explanation.

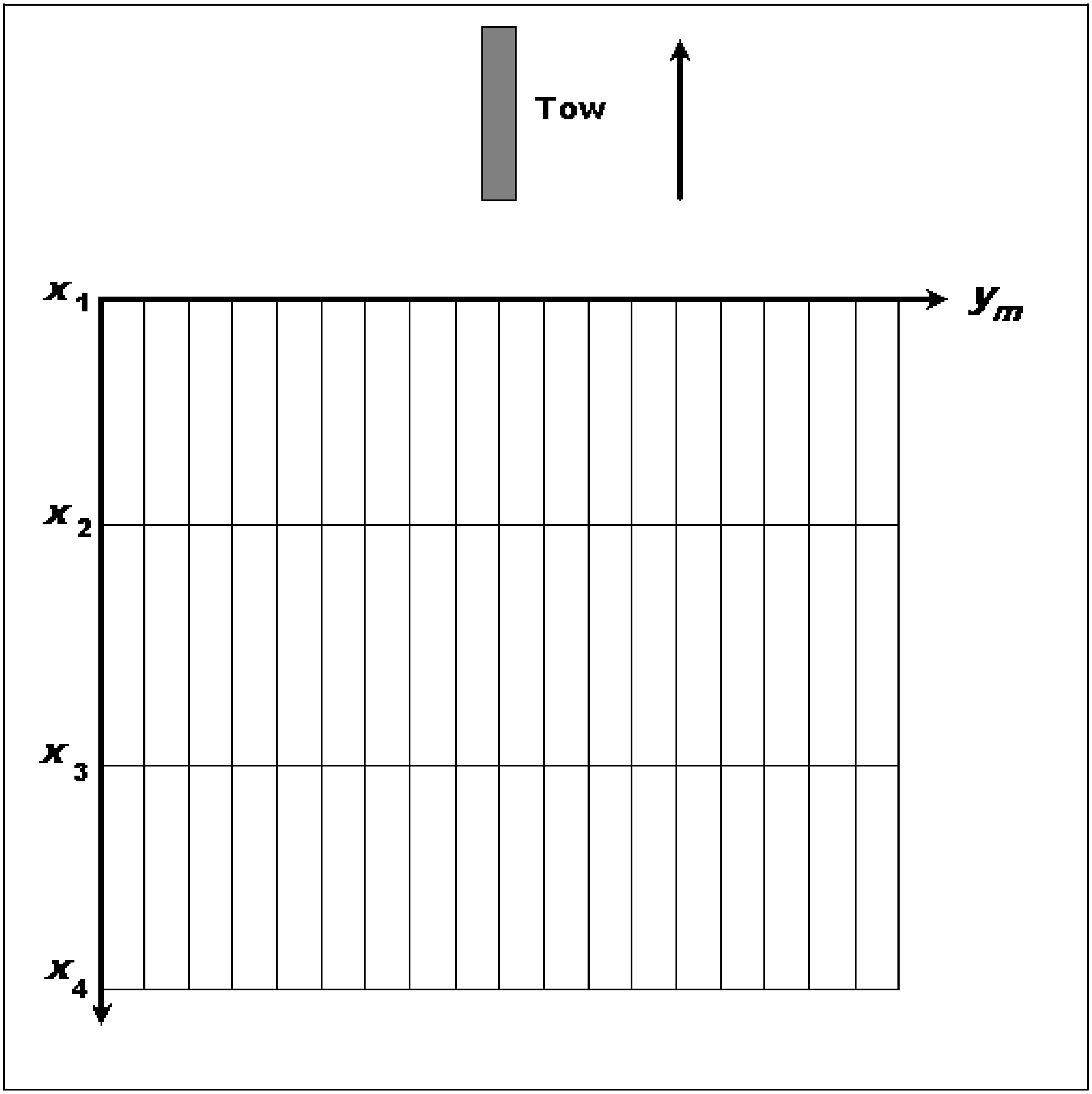

Figure 3. Schematic diagram showing locations of example points for computation of probabilities of detection of killed fish g_{ikm} at distance behind the tow x_k in 5-m wide lateral strip across the channel *m*. Vertical lines represent the centers of the 5-m wide strips. Values of g_{ikm} were computed for each of four values of x_k within 40 lateral strips representing a 200-m wide channel indicated by the intersection points on this grid.

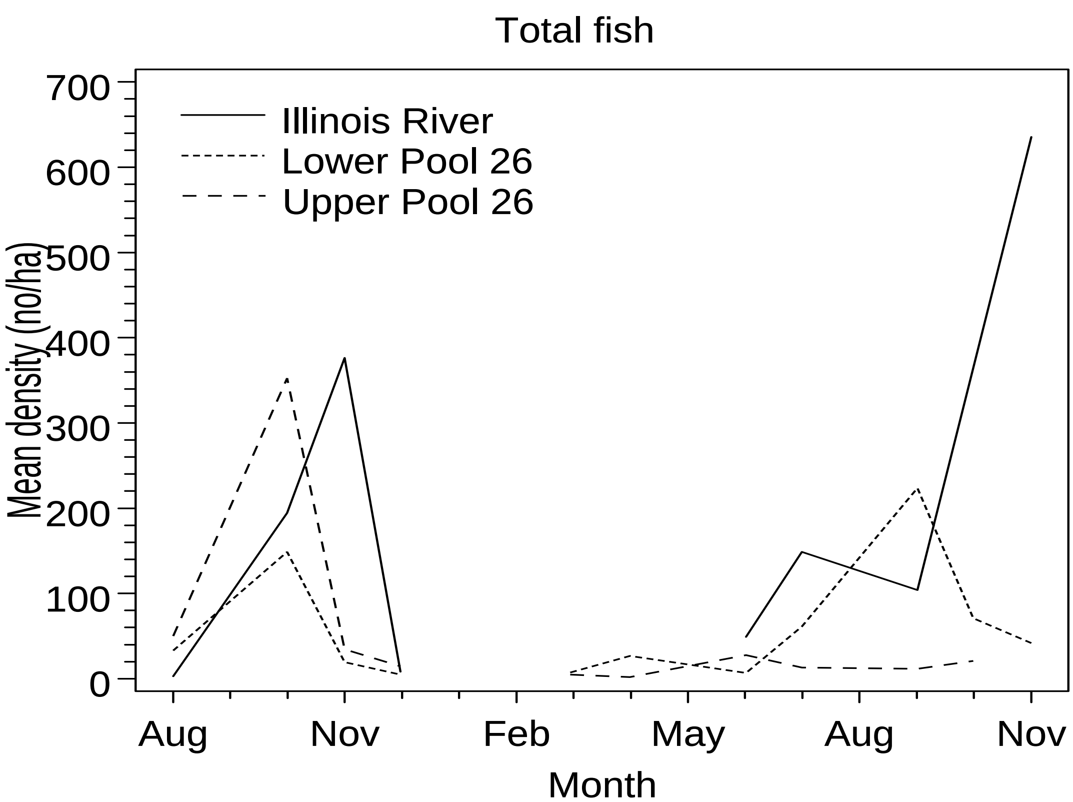

Figure 4. Estimated mean densities of fish of all species combined estimated from rockhopper bottom trawling in the navigation channels of the lower Illinois River and Pool 26 of the Upper Mississippi River. Upper Pool 26 is that segment between River Mile 218 and Lock and Dam 25, and the lower pool is from River Mile 218 to Lock and Dam 26.

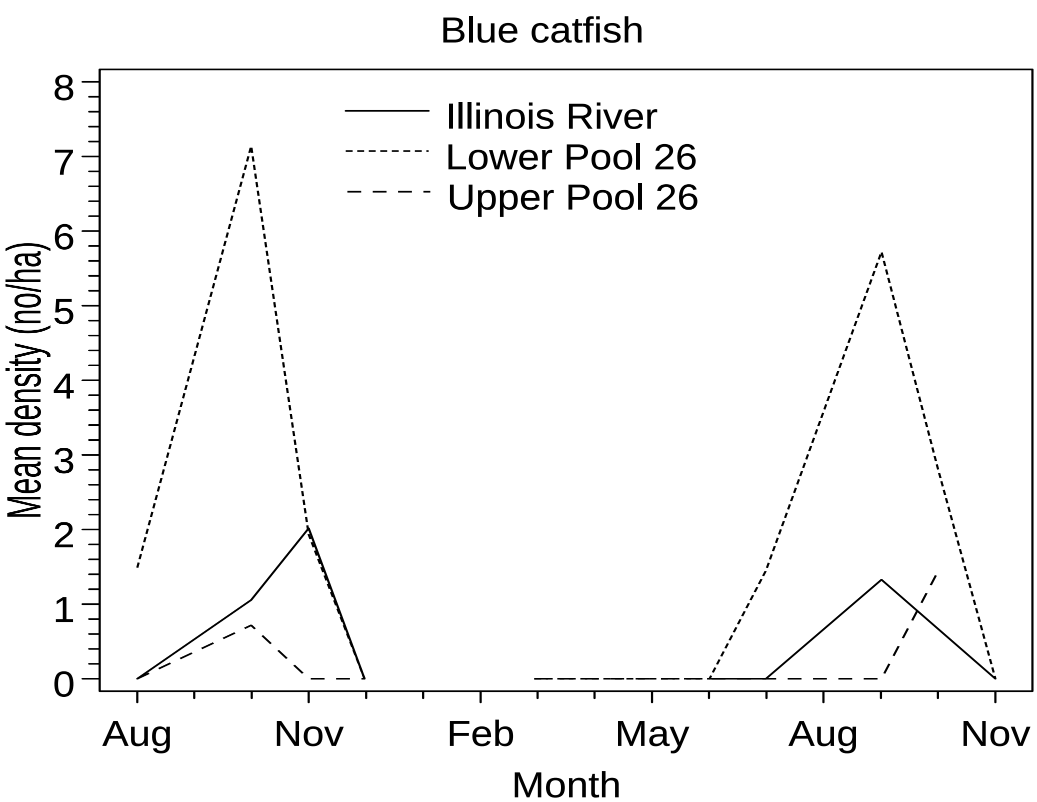

Figure 5. Estimated mean densities of blue catfish estimated from rockhopper bottom trawling in the navigation channels of the lower Illinois River and Pool 26 of the Upper Mississippi River. Upper Pool 26 is that segment between River Mile 218 and Lock and Dam 25, and the lower pool is from River Mile 218 to Lock and Dam 26.

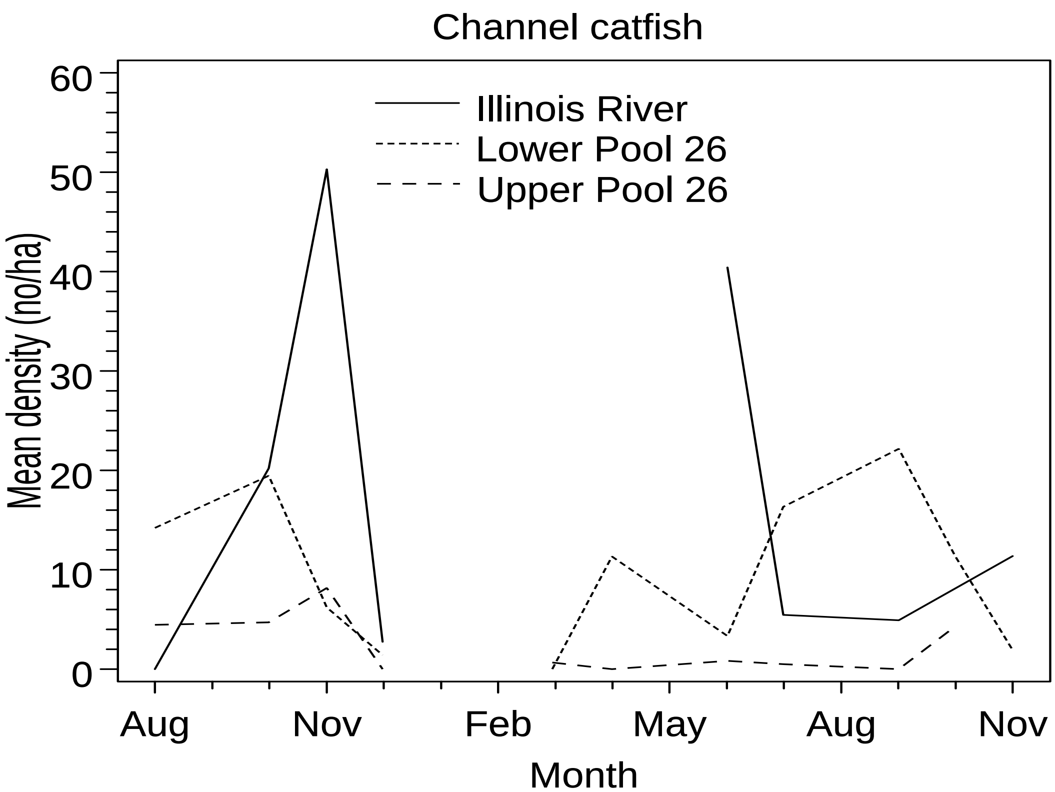

Figure 6. Estimated mean densities of channel catfish estimated from rockhopper bottom trawling in the navigation channels of the lower Illinois River and Pool 26 of the Upper Mississippi River. Upper Pool 26 is that segment between River Mile 218 and Lock and Dam 25, and the lower pool is from River Mile 218 to Lock and Dam 26.

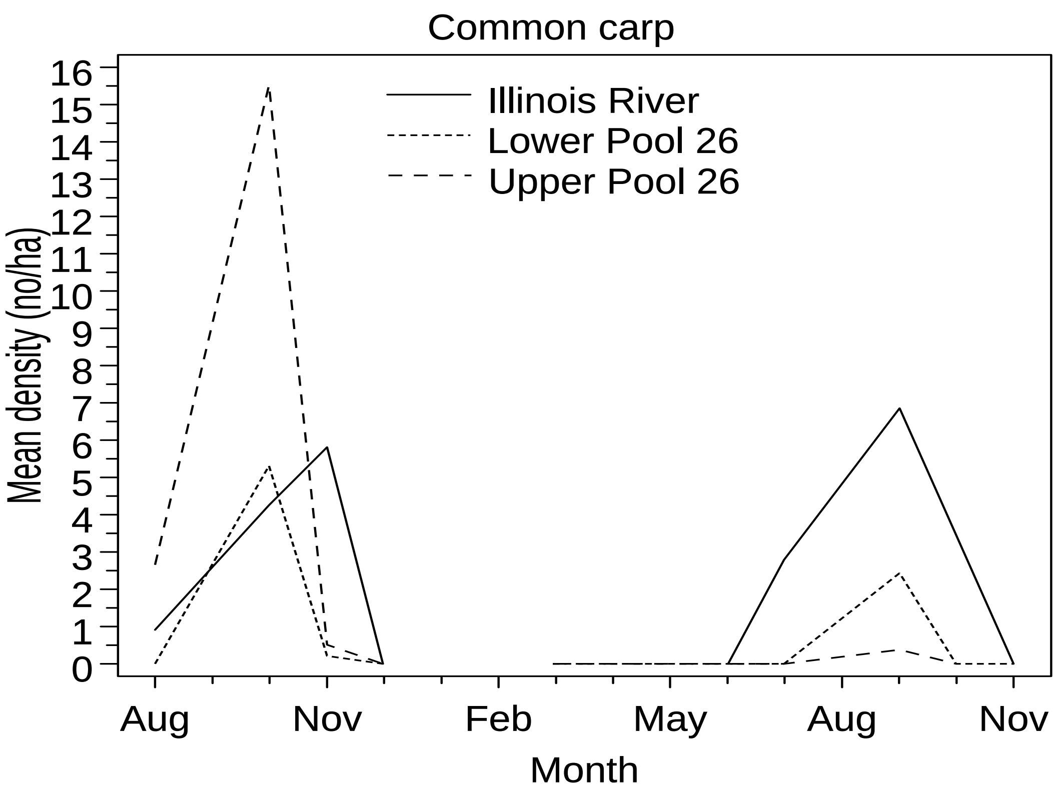

Figure 7. Estimated mean densities of common carp estimated from rockhopper bottom trawling in the navigation channels of the lower Illinois River and Pool 26 of the Upper Mississippi River. Upper Pool 26 is that segment between River Mile 218 and Lock and Dam 25, and the lower pool is from River Mile 218 to Lock and Dam 26.

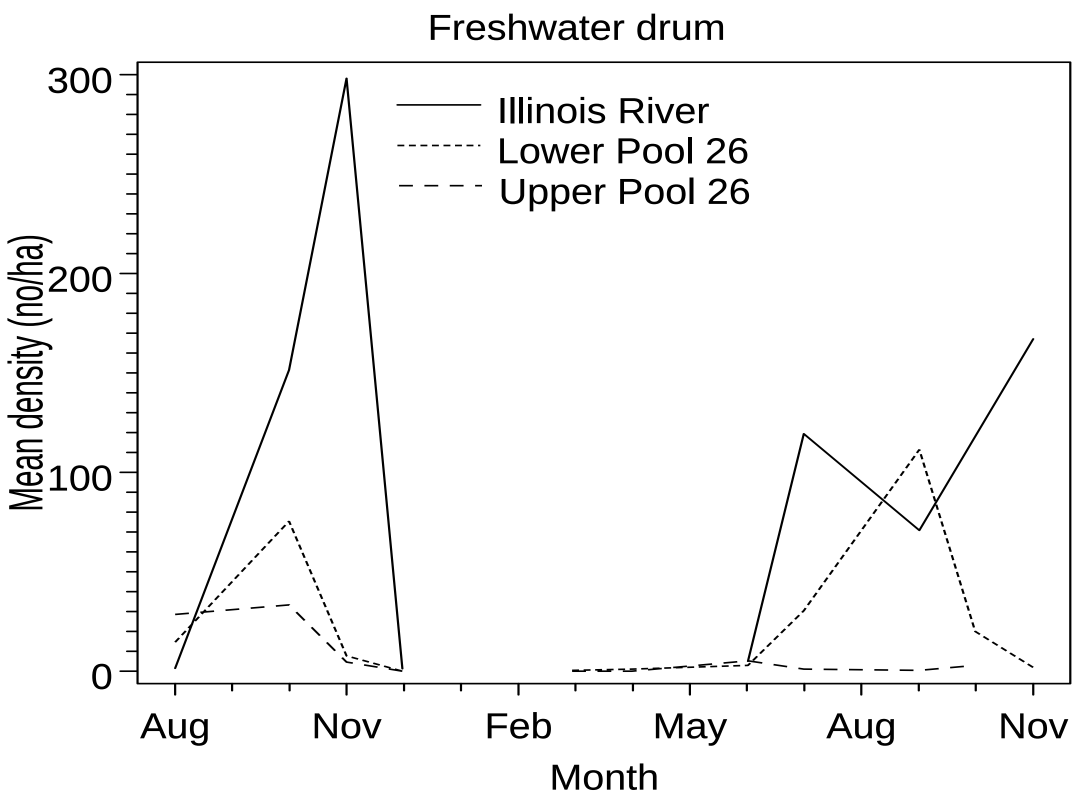

Figure 8. Estimated mean densities of freshwater drum estimated from rockhopper bottom trawling in the navigation channels of the lower Illinois River and Pool 26 of the Upper Mississippi River. Upper Pool 26 is that segment between River Mile 218 and Lock and Dam 25, and the lower pool is from River Mile 218 to Lock and Dam 26.

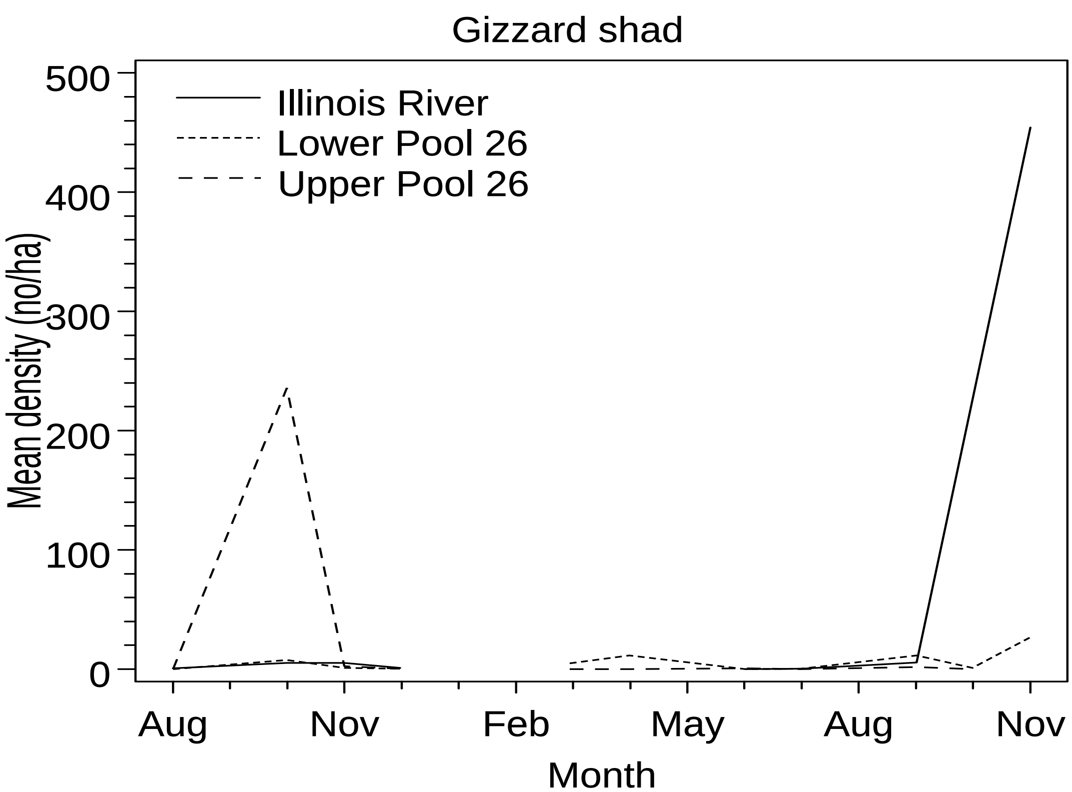

Figure 9. Estimated mean densities of gizzard shad estimated from rockhopper bottom trawling in the navigation channels of the lower Illinois River and Pool 26 of the Upper Mississippi River. Upper Pool 26 is that segment between River Mile 218 and Lock and Dam 25, and the lower pool is from River Mile 218 to Lock and Dam 26.

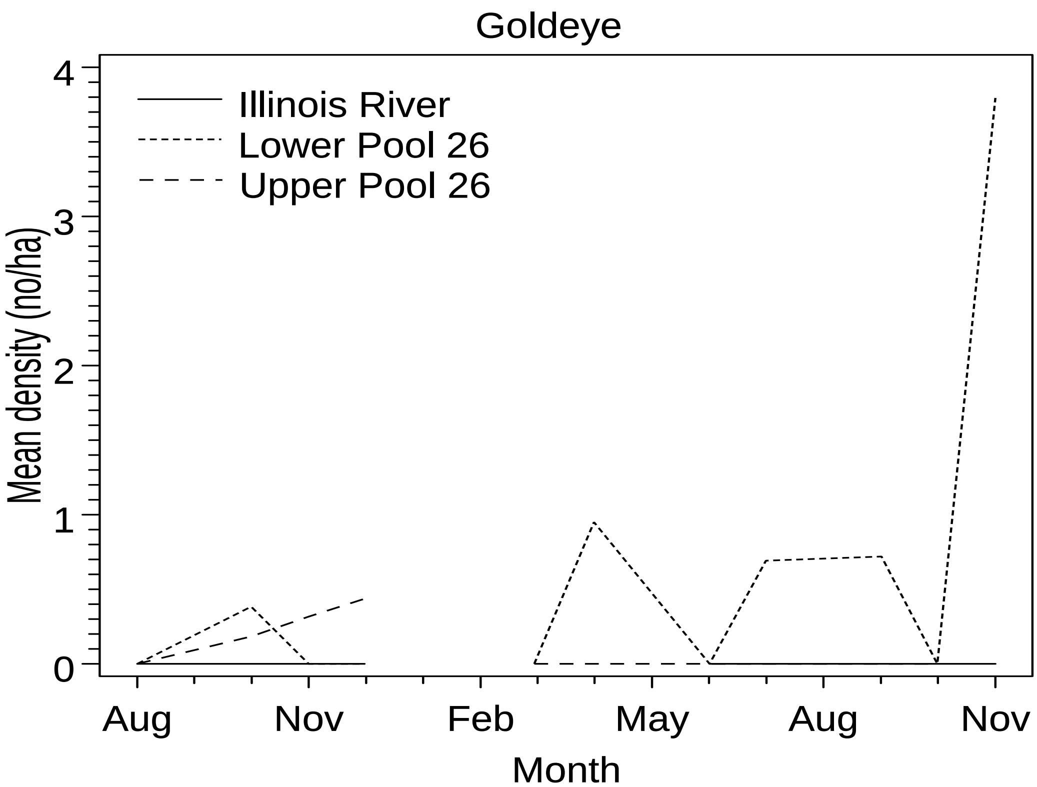

Figure 10. Estimated mean densities of goldeye estimated from rockhopper bottom trawling in the navigation channels of the lower Illinois River and Pool 26 of the Upper Mississippi River. Upper Pool 26 is that segment between River Mile 218 and Lock and Dam 25, and the lower pool is from River Mile 218 to Lock and Dam 26.

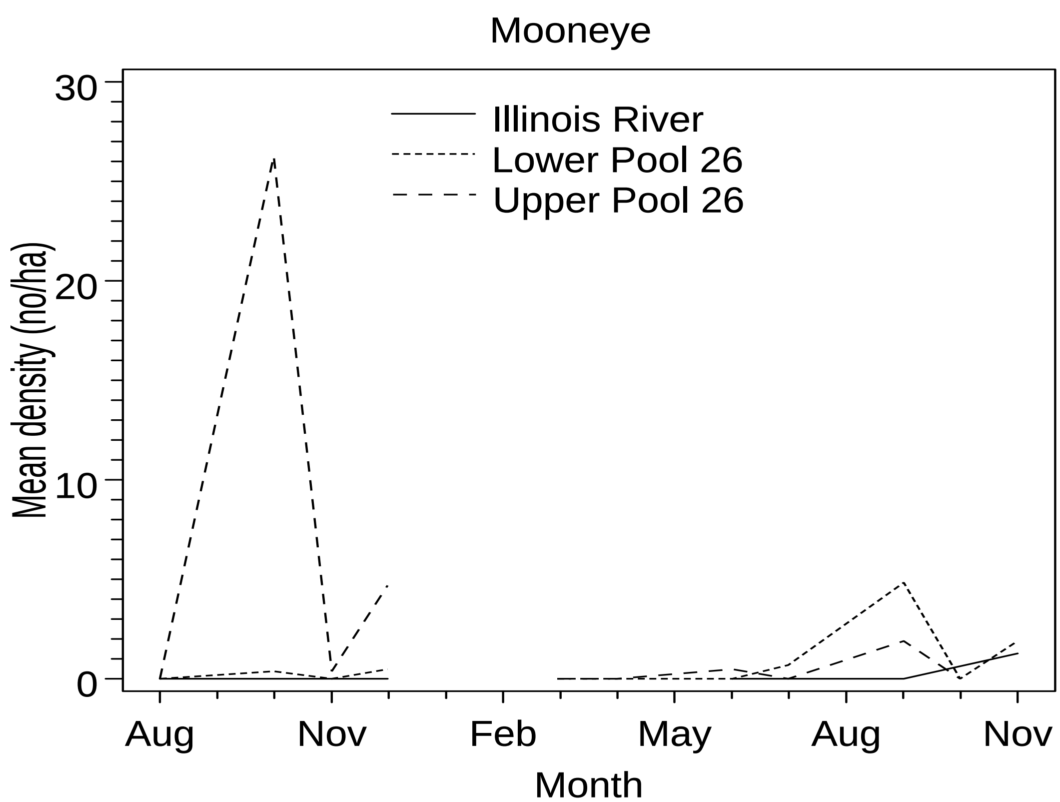

Figure 11. Estimated mean densities of mooneye estimated from rockhopper bottom trawling in the navigation channels of the lower Illinois River and Pool 26 of the Upper Mississippi River. Upper Pool 26 is that segment between River Mile 218 and Lock and Dam 25, and the lower pool is from River Mile 218 to Lock and Dam 26.

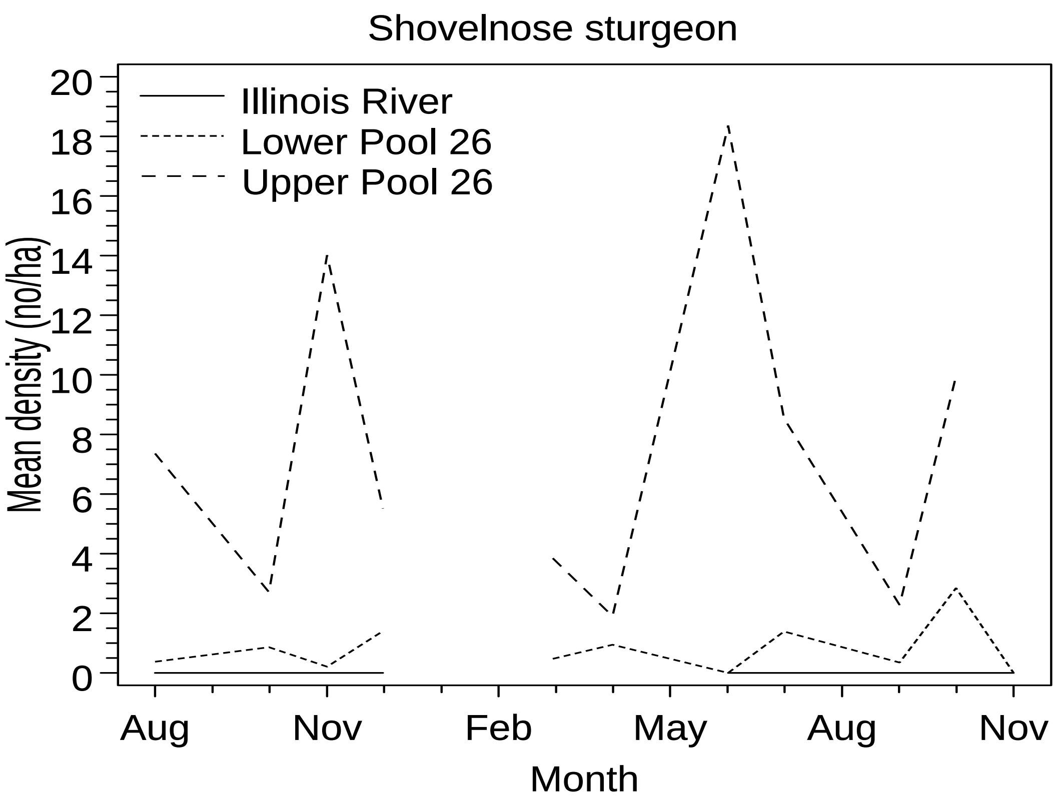

Figure 12. Estimated mean densities of shovelnose sturgeon estimated from rockhopper bottom trawling in the navigation channels of the lower Illinois River and Pool 26 of the Upper Mississippi River. Upper Pool 26 is that segment between River Mile 218 and Lock and Dam 25, and the lower pool is from River Mile 218 to Lock and Dam 26.

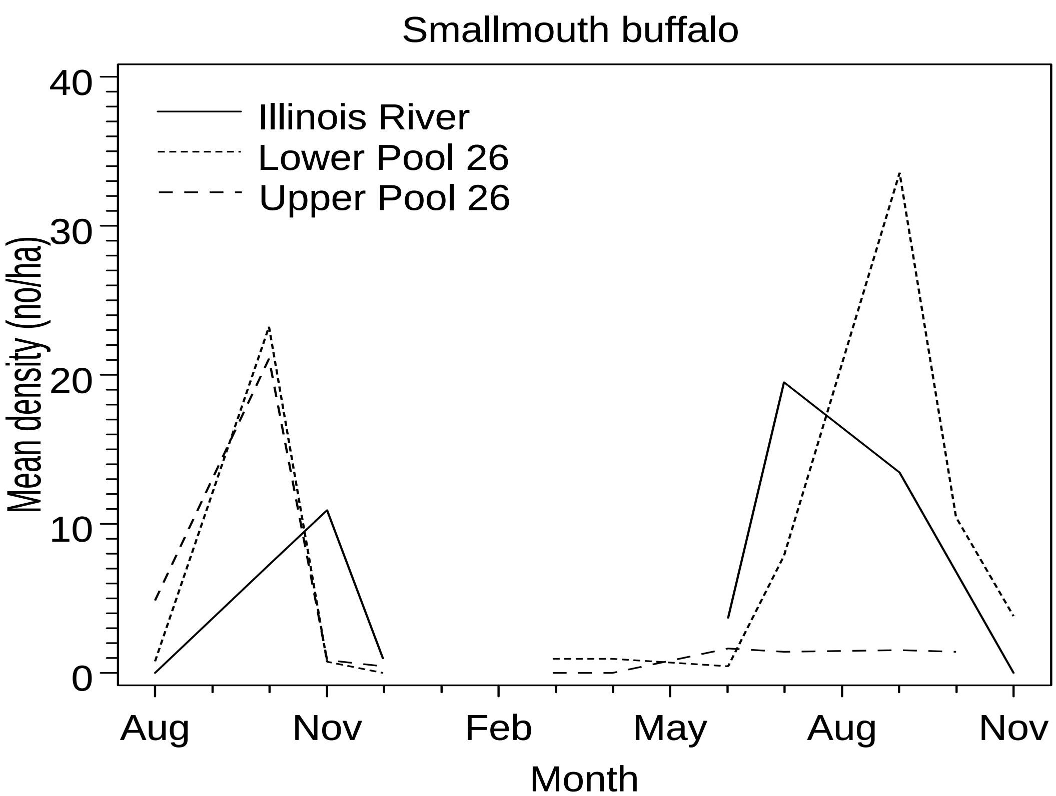

Figure 13. Estimated mean densities of smallmouth buffalo estimated from rockhopper bottom trawling in the navigation channels of the lower Illinois River and Pool 26 of the Upper Mississippi River. Upper Pool 26 is that segment between River Mile 218 and Lock and Dam 25, and the lower pool is from River Mile 218 to Lock and Dam 26.

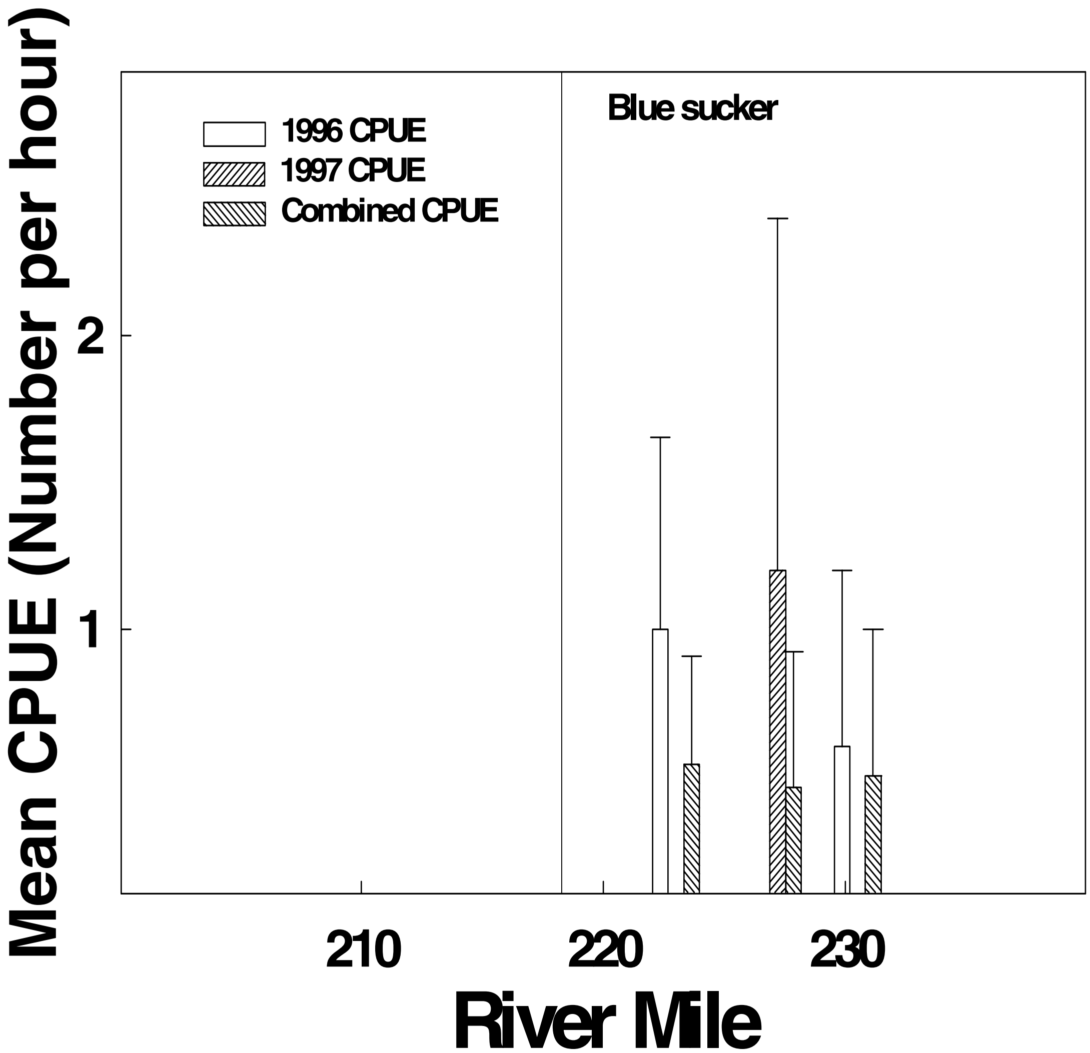

Figure 14. Catch per unit effort (CPUE) of blue sucker captured by rockhopper bottom trawling in the navigation channel of Pool 26 of the Upper Mississippi River.

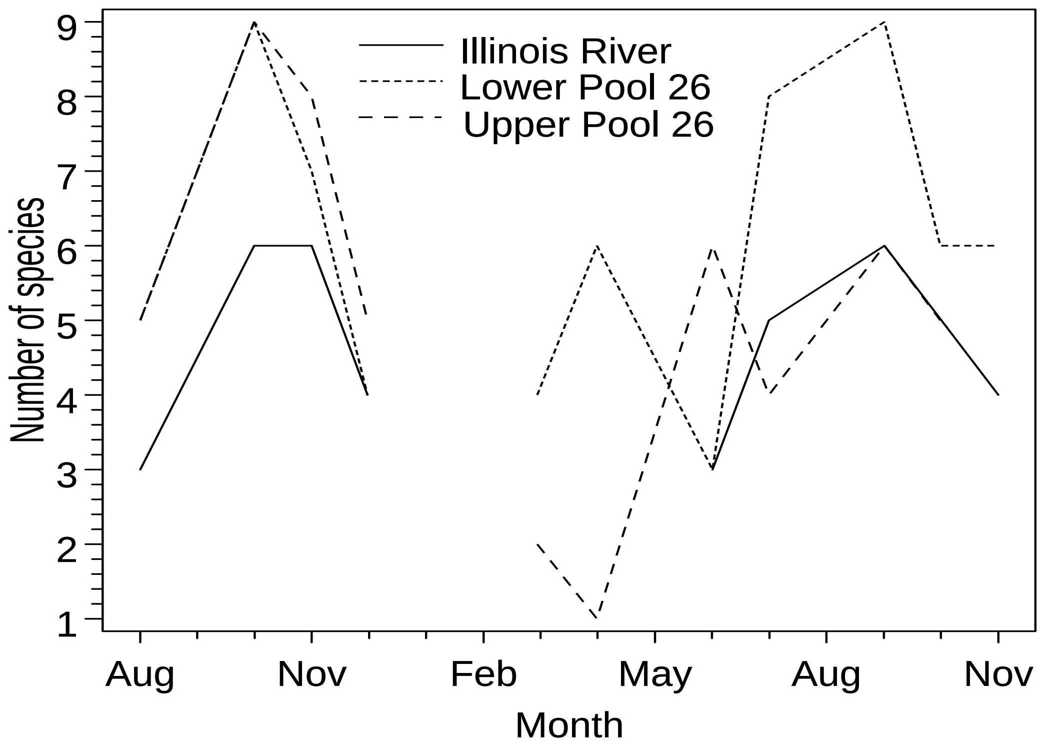

Figure 15. Mean number of species per haul of the rockhopper bottom trawl in the Illinois River and Pool 26 of the Mississippi River, 1996-1997.

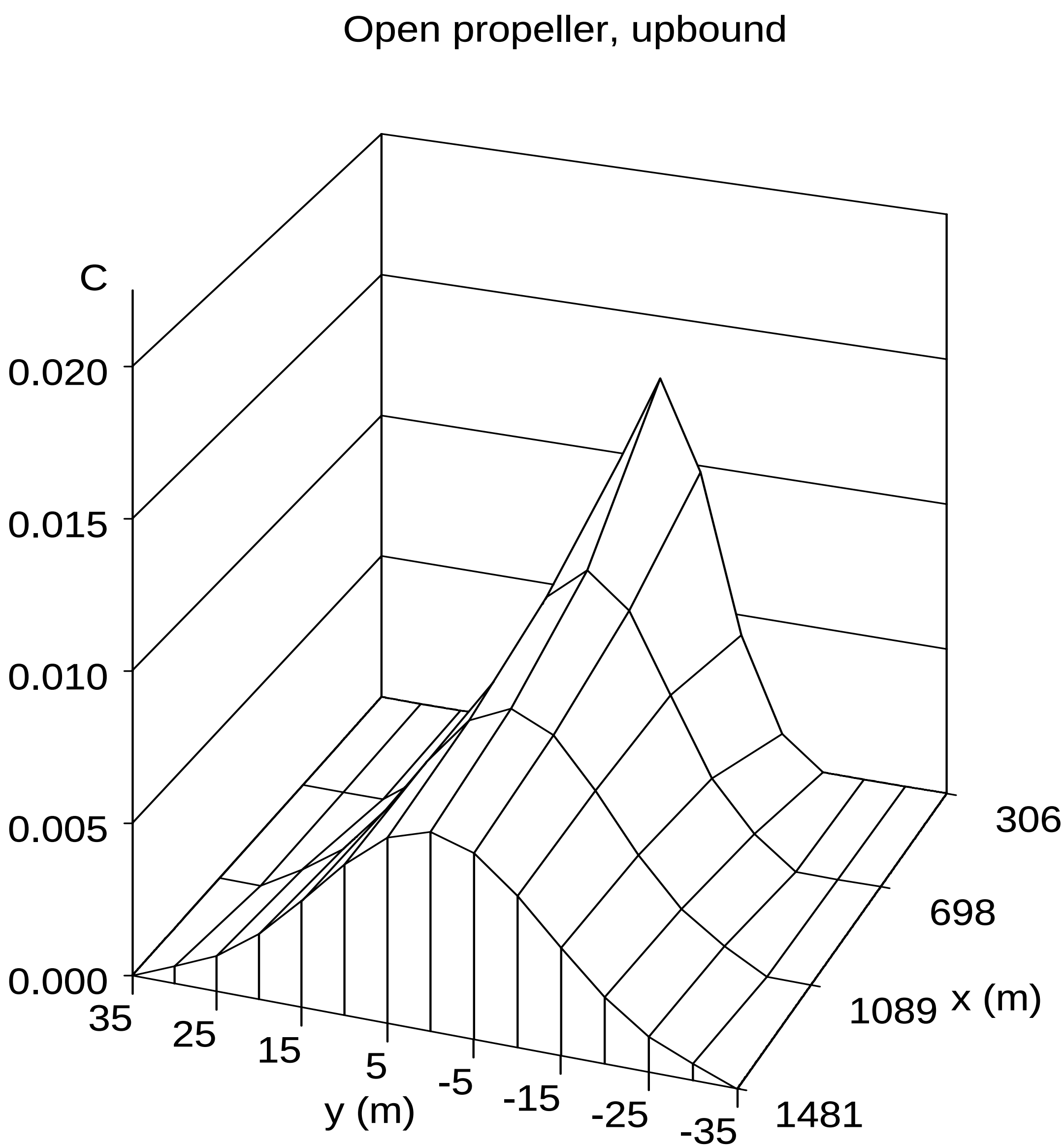

Figure 16. Example mass concentration *c* (m^{-2}) of previously entrained water in the vertical transverse section across the channel at following distance *x* (m) and lateral distance *y* (m) from the keel of an upbound towboat equipped with open propellers, as estimated by the DIFFLAR2 model. The sailing line of the towboat is defined by $y = 0$ m.

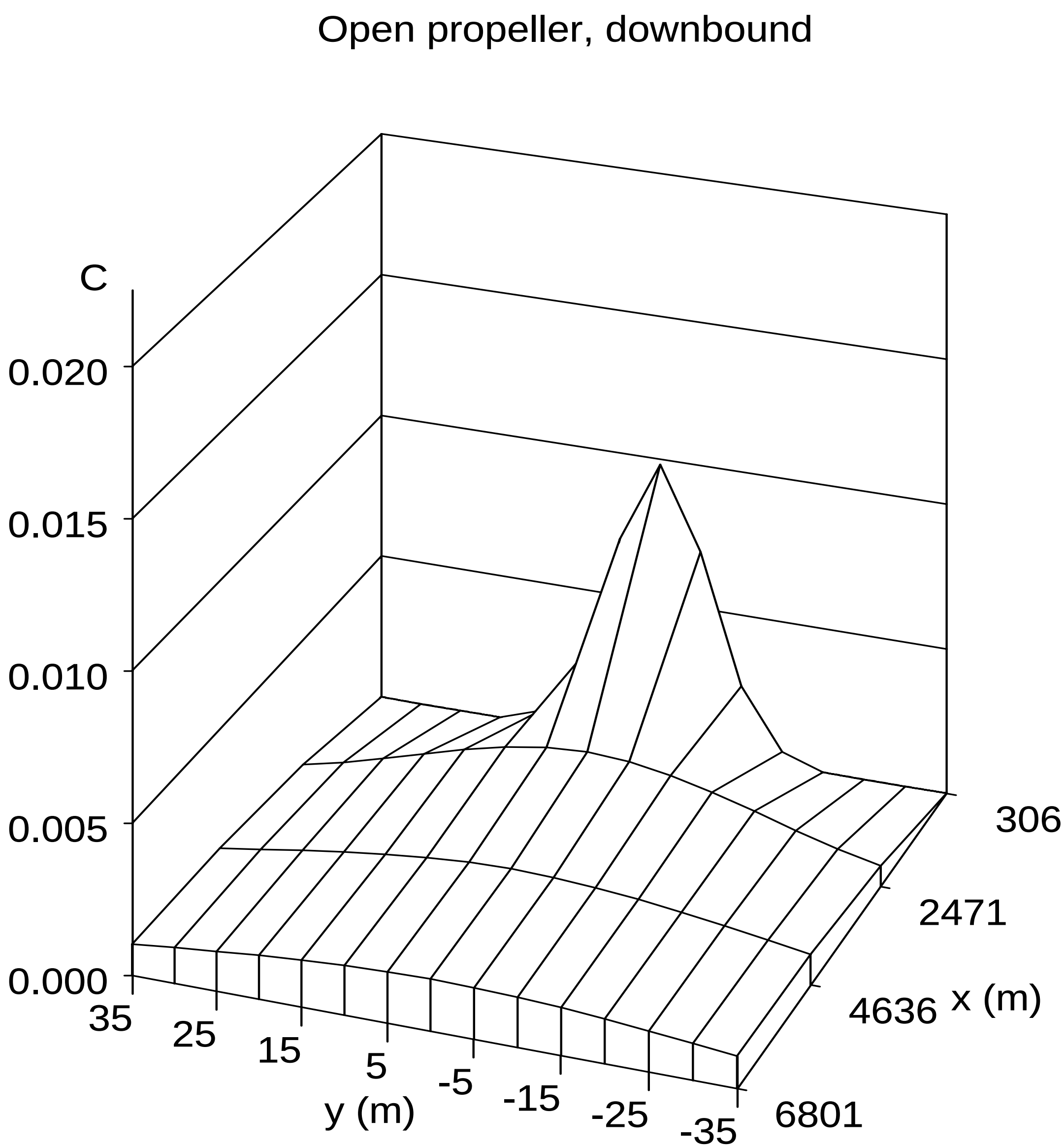

Figure 17. Example mass concentration c (m^{-2}) of previously entrained water in the vertical transverse section across the channel at following distance x (m) and lateral distance y (m) from the keel of a downbound towboat equipped with open propellers, as estimated by the DIFFLAR2 model. The sailing line of the towboat is defined by $y = 0$ m.

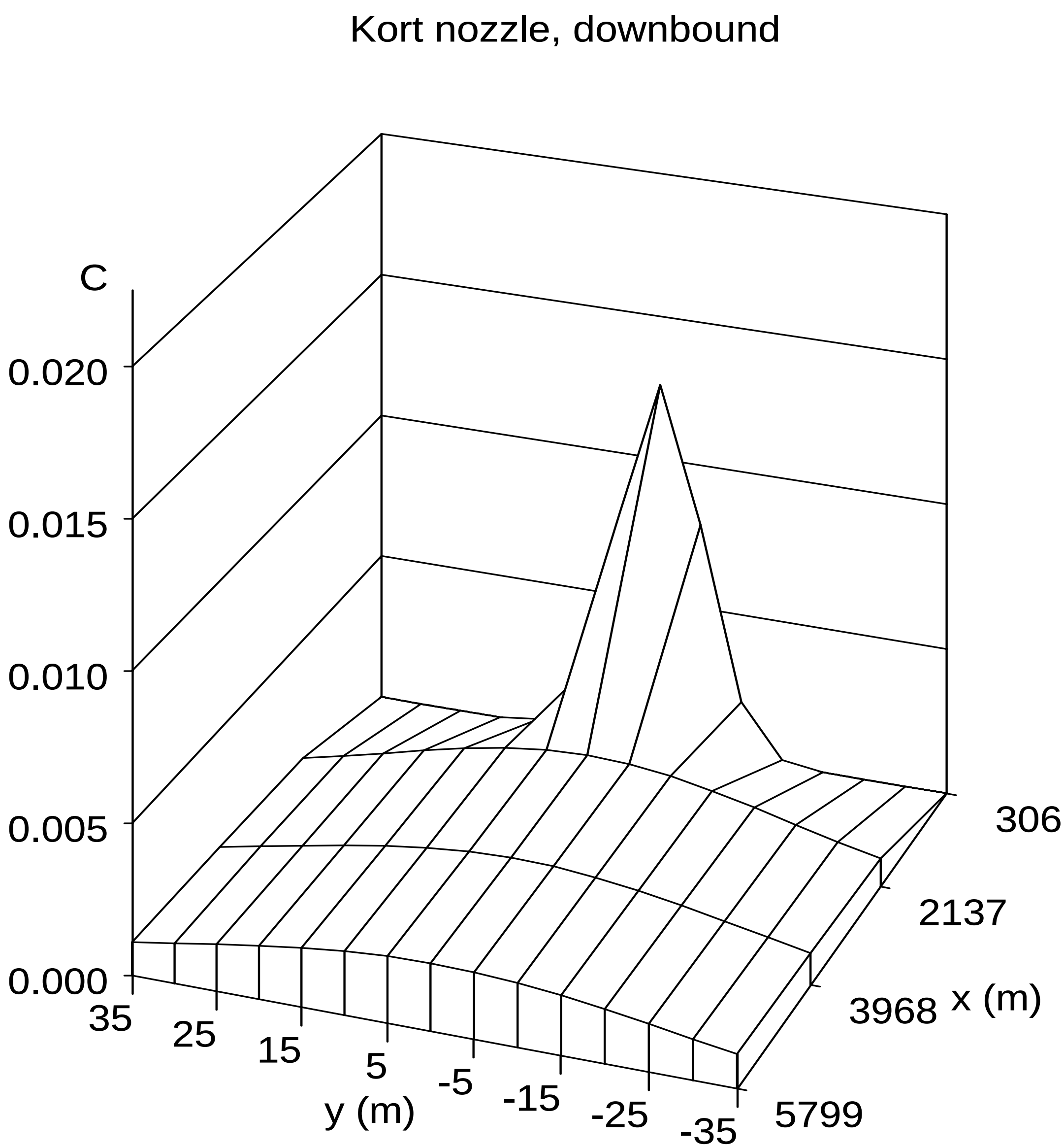

Figure 18. Example mass concentration c (m^{-2}) of previously entrained water in the vertical transverse section across the channel at following distance x (m) and lateral distance y (m) from the keel of a downbound towboat equipped with Kort nozzles, as estimated by the DIFFLAR2 model. The sailing line of the towboat is defined by $y = 0$ m.

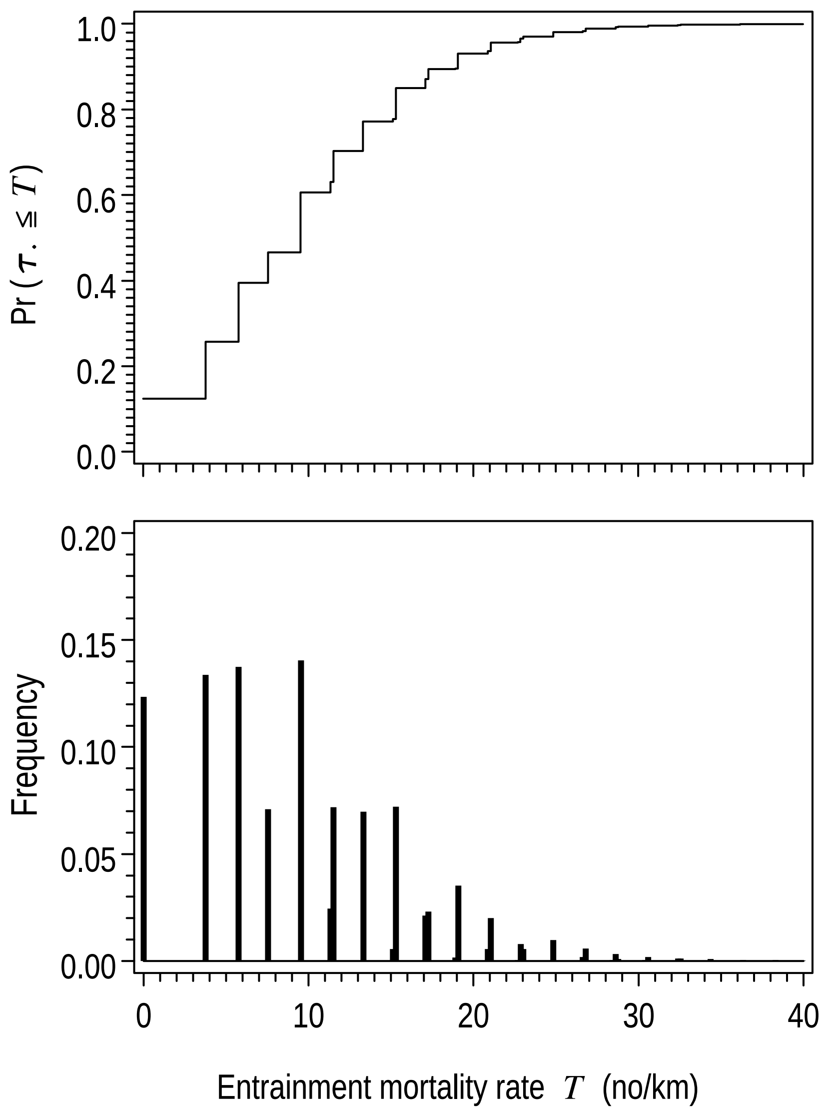

Figure 19. Distributions of entrainment mortality rate τ. (kills per km of towboat travel) of gizzard shad obtained from 6,000 bootstrap resamplings of the 41 entrainment estimates $\hat{\tau}$. *Upper panel*: Estimated cumulative distribution function expressing the probability that τ. does not exceed the nominal value *T*. *Lower panel*: Frequency distribution of the 6,000 bootstrap estimates $\hat{\tau}$.

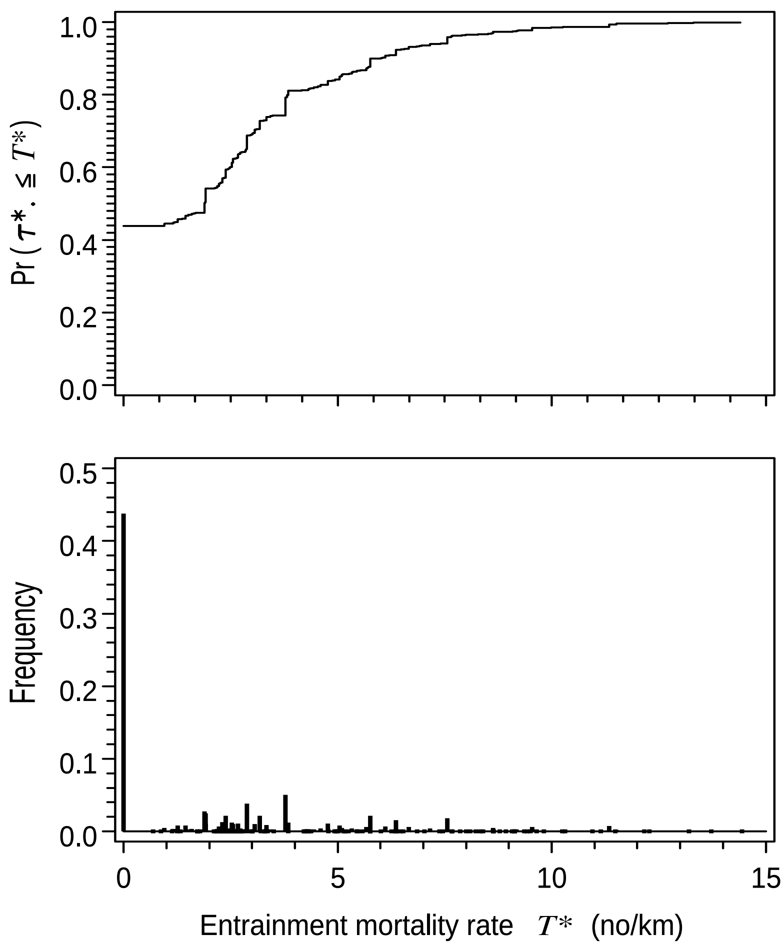

Figure 20. Distributions of ancillary entrainment mortality rates $\tau^*_.$ (kills per km of towboat travel) for either shovelnose sturgeon or smallmouth buffalo obtained from 6,000 bootstrap resamplings of the ancillary estimates $\hat{\tau}^*_.$; see text for explanation. *Upper panel*: Estimated cumulative distribution function expressing the probability that $\tau^*_.$ does not exceed the nominal value *T*. *Lower panel*: Frequency distribution of the 6,000 bootstrap estimates $\hat{\tau}^*_.$

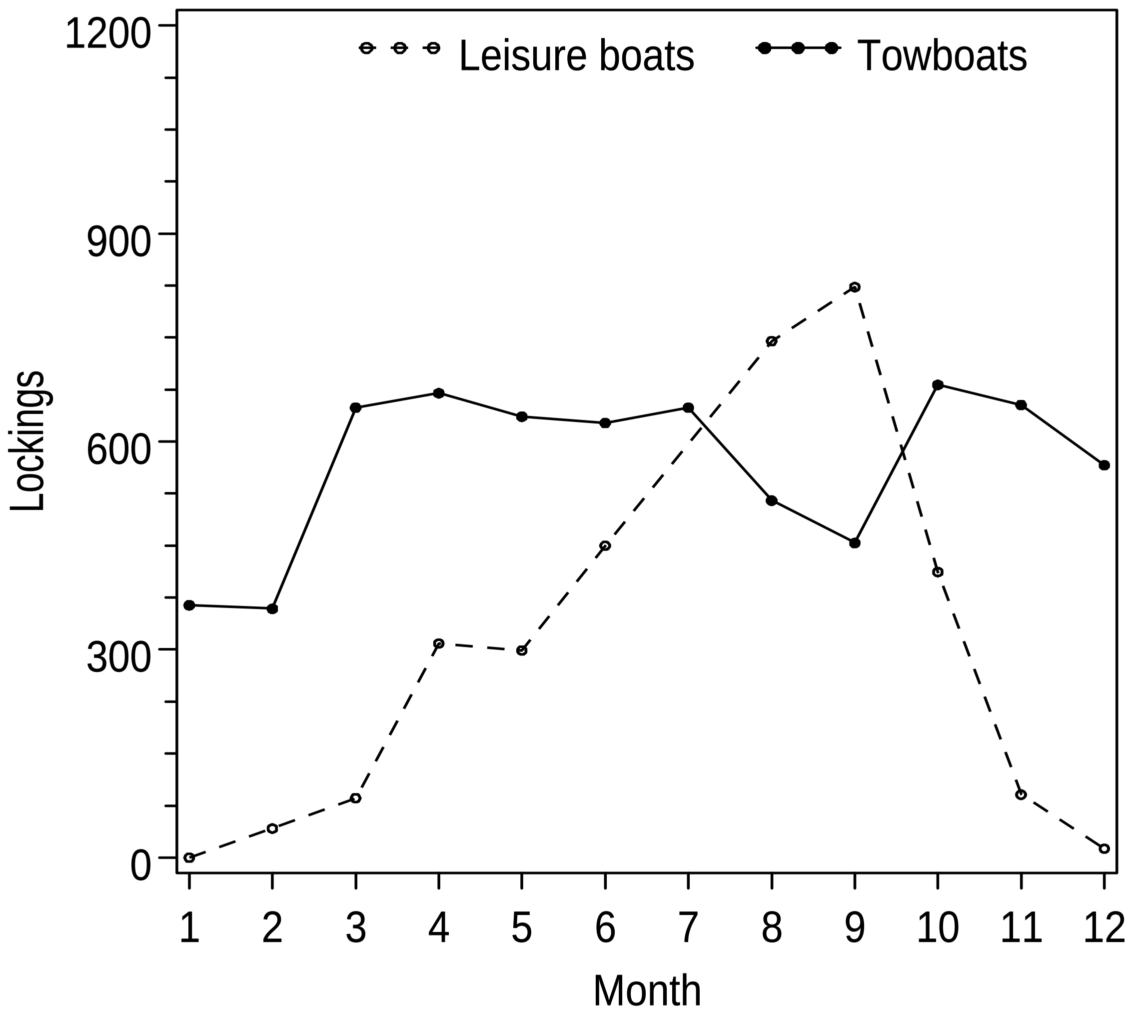

Figure 21. Monthly total counts of leisure boats and towboats that passed through the Melvin Price Locks (Lock and Dam 26) during 1996. Data are from the U.S. Army Corps of Engineers Lock Performance Monitoring System.

Appendix A. List of common and scientific names of fishes, in phylogenetic order from Robins et al. (1991), encountered during studies of potential effects of navigation in Pool 26 of the Mississippi River and in the lower 32 km of the Illinois River.

Appendix A. List of common and scientific names of fishes encountered during studies of potential effects of navigation in Pool 26 of the Mississippi River and in the lower 26 kn of the Illinois River.

Common name	Scientific name
Lake sturgeon	*Acipenser fulvescens*
Shovelnose sturgeon	*Scaphirhynchus platorynchus*
Shortnose gar	*Lepisosteus platostomus*
Goldeye	*Hiodon alosoides*
Mooneye	*Hiodon tergisus*
Skipjack herring	*Alosa chrysochloris*
Gizzard shad	*Dorosoma cepedianum*
Common carp	*Cyprinus carpio*
Bighead carp	*Hypopthalmichthys nobilis*
Speckled chub	*Macrhybopsis aestivalis*
Sicklefin chub	*Macrhybopsis meeki*
Silver chub	*Macrhybopsis storeriana*
River carpsucker	*Carpiodes carpio*
Quillback	*Carpiodes cyprinus*
Highfin carpsucker	*Carpiodes velifer*
Blue sucker	*Cycleptus elongatus*
Smallmouth buffalo	*Ictiobus bubalus*
Bigmouth buffalo	*Ictiobus cyprinellus*
Black buffalo	*Ictiobus niger*
Shorthead redhorse	*Moxostoma macrolepidotum*
Blue catfish	*Ictalurus furcatus*
Channel catfish	*Ictalurus punctatus*
Flathead catfish	*Pylodictis olivaris*
White bass	*Morone chrysops*
Black crappie	*Pomoxis nigromaculatus*
Sauger	*Stizostedion canadense*
Freshwater drum	*Aplodinotus grunniens*

Appendix B. Mean and standard error (SE) of volume (m^3) of water filtered at each sampling site for estimation of larval fish densities. IR= Illinois River and 26= Pool 26 of the Mississippi River. N = number of tows at each site used to calculate the mean volume of water sampled.

Appendix Table B. Mean and standard error (SE) of volume (m^3) of water filtered at each sampling site for estimation of larval fish densities. IR= Illinois River and 26= Pool 26 of the Mississippi River. N = number of tows at each site used to calculate the mean volume of water sampled.

							Volume (m^3)	
Month	Day	Year	Aquatic area	River	River Mile	N	Mean	SE
5	13	96	Main channel	IR	9.3	1	333.94	–
5	13	96	Main channel	IR	13.5	2	310.86	57.80
5	13	96	Main channel	IR	18.7	2	257.96	13.60
5	14	96	Main channel	26	223.0	2	312.08	19.96
5	14	96	Main channel	26	225.8	1	311.94	–
5	14	96	Main channel	IR	4.5	2	376.47	6.56
5	15	96	Main channel	26	203.2	2	347.07	15.98
5	15	96	Main channel	26	207.1	2	243.30	118.74
5	15	96	Main channel	26	211.2	2	334.64	18.25
5	15	96	Main channel	26	215.7	2	350.84	13.71
5	16	96	Main channel	26	208.5	2	353.21	6.32
5	16	96	Main channel	26	213.5	2	347.37	10.01
5	17	96	Main channel	26	223.0	1	443.17	–
5	17	96	Main channel	26	227.5	2	463.01	6.78
5	17	96	Main channel	26	233.5	2	545.58	25.16
5	28	96	Main channel	26	203.2	1	348.16	–
5	29	96	Main channel	26	208.5	1	328.58	–
5	29	96	Main channel	26	211.2	2	358.52	12.49
5	30	96	Main channel	IR	4.5	2	361.54	14.17
5	30	96	Main channel	IR	9.3	2	392.66	2.42
5	30	96	Main channel	IR	13.5	2	426.73	1.51
5	30	96	Main channel	IR	18.7	2	397.92	9.94
6	3	96	Main channel	26	203.2	2	366.63	21.25
6	3	96	Main channel	26	207.1	2	397.92	2.97
6	3	96	Main channel	26	208.5	2	360.51	0.73
6	3	96	Main channel	26	211.2	2	426.37	4.27
6	3	96	Main channel	26	213.5	2	426.26	11.34
6	4	96	Main channel	26	215.7	2	401.61	11.16
6	4	96	Main channel	IR	4.5	2	398.95	2.40

Appendix Table B continued.

Month	Day	Year	Aquatic area	River	River Mile	N	Volume (m^3) Mean	SE
6	4	96	Main channel	IR	9.3	2	380.91	7.96
6	4	96	Main channel	IR	13.5	2	387.06	7.00
6	4	96	Main channel	IR	18.7	2	391.39	2.35
6	5	96	Main channel	26	225.8	2	385.10	5.08
6	5	96	Main channel	26	227.5	2	435.25	10.37
6	5	96	Main channel	26	230.5	2	422.63	6.63
6	5	96	Main channel	26	233.5	2	435.80	0.47
6	17	96	Main channel	26	203.2	2	313.05	25.72
6	17	96	Main channel	26	207.1	2	337.49	3.72
6	20	96	Main channel	26	215.7	1	561.37	–
6	20	96	Main channel	IR	4.5	2	663.63	12.88
6	20	96	Main channel	IR	9.3	2	572.48	12.76
6	20	96	Main channel	IR	13.5	2	522.85	88.60
6	20	96	Main channel	IR	18.7	2	737.39	48.56
6	21	96	Main channel	26	223.0	2	541.94	63.22
6	21	96	Main channel	26	225.8	2	625.59	7.31
6	21	96	Main channel	26	230.5	2	636.03	8.22
6	21	96	Main channel	26	233.5	2	533.82	30.97
7	1	96	Main channel	26	207.1	2	533.68	10.77
7	1	96	Main channel	26	211.2	1	578.52	–
7	1	96	Main channel	26	213.5	2	541.45	16.05
7	2	96	Main channel	26	203.2	2	548.12	10.25
7	2	96	Main channel	26	208.5	1	577.08	–
7	3	96	Main channel	26	223.0	2	492.07	13.80
7	3	96	Main channel	26	225.8	1	504.05	–
7	3	96	Main channel	26	233.5	2	474.87	5.28
7	3	96	Main channel	26	240.2	1	570.46	–
7	5	96	Main channel	26	215.7	2	536.71	2.95
7	5	96	Main channel	IR	4.5	2	327.39	53.23
7	5	96	Main channel	IR	9.3	2	399.22	7.06
7	5	96	Main channel	IR	13.5	2	395.38	39.21
7	5	96	Main channel	IR	18.7	2	371.45	15.72
4	23	97	Main channel	26	208.5	2	460.26	6.12

Appendix Table B continued.

Month	Day	Year	Aquatic area	River	River Mile	N	Volume (m^3) Mean	SE
4	23	97	Main channel	26	215.7	2	485.77	9.67
4	23	97	Main channel	26	233.0	2	481.08	19.09
4	23	97	Side channel	26	208.5	2	428.82	10.09
4	23	97	Side channel	26	215.7	2	427.22	7.28
4	23	97	Side channel	26	222.6	2	391.10	78.89
4	29	97	Main channel	26	208.5	2	384.72	5.67
4	29	97	Main channel	26	215.7	2	1050.64	396.75
4	29	97	Main channel	26	222.6	2	401.57	12.34
4	29	97	Main channel	26	233.5	2	427.39	14.20
4	29	97	Side channel	26	208.5	2	410.96	7.45
4	29	97	Side channel	26	215.7	2	1039.18	419.97
4	29	97	Side channel	26	222.6	2	456.24	9.40
4	29	97	Side channel	26	233.5	2	392.81	4.97
5	1	97	Side channel	IR	13.5	2	312.91	23.56
5	2	97	Backwater	26	222.0	2	81.85	5.52
5	13	97	Main channel	26	208.5	2	350.11	9.97
5	13	97	Main channel	26	223.0	2	331.67	30.45
5	13	97	Main channel	26	233.5	1	338.39	–
5	13	97	Side channel	26	208.5	2	341.80	3.87
5	13	97	Side channel	26	222.6	2	872.68	530.68
5	13	97	Side channel	26	233.2	2	380.45	2.00
5	16	97	Backwater	26	222.0	2	188.20	112.80
5	16	97	Backwater	IR	9.3	2	74.78	4.80
5	19	97	Main channel	IR	13.5	2	229.46	14.36
5	19	97	Side channel	IR	13.5	2	243.79	15.11
5	27	97	Main channel	IR	13.5	1	429.71	–
5	28	97	Backwater	26	222.0	2	85.80	0.23
5	28	97	Backwater	IR	9.3	2	117.25	2.99
5	29	97	Side channel	IR	13.5	2	457.43	46.16
5	30	97	Main channel	26	215.7	1	332.23	
5	30	97	Main channel	26	223.0	2	393.97	40.39
5	30	97	Main channel	26	233.5	1	443.87	–

Appendix Table B continued.

Month	Day	Year	Aquatic area	River	River Mile	N	Volume (m^3) Mean	SE
5	30	97	Side channel	26	215.7	1	395.92	–
5	30	97	Side channel	26	222.6	2	336.23	35.72
5	30	97	Side channel	26	233.5	2	427.76	22.73
6	10	97	Main channel	IR	13.5	2	459.93	23.15
6	10	97	Side channel	IR	13.5	2	478.41	5.20
6	11	97	Backwater	26	222.0	2	75.91	0.73
6	11	97	Backwater	IR	9.3	2	120.36	23.52
6	12	97	Main channel	26	208.5	2	447.58	23.42
6	12	97	Main channel	26	215.7	2	433.14	2.56
6	12	97	Main channel	26	223.0	2	434.65	27.97
6	12	97	Main channel	26	233.5	1	403.09	–
6	12	97	Side channel	26	208.5	2	425.40	14.42
6	12	97	Side channel	26	222.6	2	436.72	17.53
6	12	97	Side channel	26	233.5	2	432.37	33.48
6	24	97	Backwater	26	222.0	2	81.53	1.49
6	24	97	Backwater	IR	9.3	1	54.61	–
6	25	97	Main channel	IR	13.5	2	536.17	11.32
6	25	97	Side channel	IR	13.5	2	411.97	6.24
6	26	97	Main channel	26	208.5	2	423.09	66.58
6	26	97	Main channel	26	215.7	2	408.22	77.06
6	26	97	Main channel	26	223.0	2	345.06	82.44
6	26	97	Main channel	26	233.5	2	318.62	104.23
6	26	97	Side channel	26	208.5	2	468.69	50.81
6	26	97	Side channel	26	215.7	2	417.52	50.29
6	26	97	Side channel	26	222.6	2	390.35	110.83
6	26	97	Side channel	26	233.5	2	270.27	147.71
7	8	97	Main channel	26	208.5	2	441.64	111.25
7	8	97	Main channel	26	215.7	2	473.63	39.38
7	8	97	Main channel	26	223.0	1	547.13	–
7	8	97	Main channel	26	233.5	2	461.98	41.57
7	8	97	Side channel	26	208.5	1	421.91	–
7	8	97	Side channel	26	215.7	2	482.71	73.51

Appendix Table B continued.

Month	Day	Year	Aquatic area	River	River Mile	N	Volume (m^3) Mean	SE
7	8	97	Side channel	26	222.6	2	478.30	50.81
7	8	97	Side channel	26	233.5	2	453.06	47.15
7	9	97	Backwater	IR	9.3	2	73.46	1.00
7	10	97	Main channel	IR	13.5	1	491.67	–
7	10	97	Side channel	IR	13.5	2	548.11	201.37
7	22	97	Main channel	26	208.5	2	511.88	28.08
7	22	97	Main channel	26	215.7	2	510.19	22.76
7	22	97	Main channel	26	223.0	2	493.38	30.59
7	22	97	Main channel	26	233.5	2	485.55	27.47
7	22	97	Side channel	26	215.7	2	287.94	92.62
7	22	97	Side channel	26	222.6	2	490.24	37.94
7	22	97	Side channel	26	233.5	1	476.44	–
7	23	97	Main channel	IR	13.5	2	491.18	24.49
7	23	97	Side channel	IR	13.5	2	374.85	138.59
7	25	97	Backwater	IR	9.3	2	78.61	3.06

Appendix C. Number of larval fish of each taxon collected from all sampled sites during 1996 and 1997. N=number of ichthyoplankton tows collected at each site.

Appendix Table C. Number of larval fish of each taxon collected from all sampled sites during 1996 and 1997. N=number of ichthyoplankton tows collected at each site.

Month	Day	Year	Aquatic area	River	River mile	Taxon	N	Catch Mean	Catch SE
5	13	96	Main channel	IR	9.3	Common carp	1	440.0	
5	13	96	Main channel	IR	9.3	Catostomidae	1	4.0	
5	13	96	Main channel	IR	13.5	Common carp	2	384.5	28.5
5	13	96	Main channel	IR	13.5	Catostomidae	2	8.5	4.5
5	13	96	Main channel	IR	18.7	Common carp	2	580.5	294.5
5	13	96	Main channel	IR	18.7	Catostomidae	2	17.0	8.0
5	13	96	Main channel	IR	18.7	Percidae	2	1.5	1.5
5	13	96	Main channel	IR	18.7	Unidentified	2	2.5	2.5
5	14	96	Main channel	26	223.0	Common carp	2	74.5	9.5
5	14	96	Main channel	26	223.0	Catostomidae	2	9.5	4.5
5	14	96	Main channel	26	223.0	Percidae	2	3.5	1.5
5	14	96	Main channel	26	203.2	Catostomidae	2	11.5	9.5
6	3	96	Main channel	26	223.0	Unidentified	2	1.5	1.5
5	14	96	Main channel	26	225.8	Common carp	1	68.0	
5	14	96	Main channel	26	225.8	Catostomidae	1	10.0	
5	14	96	Main channel	26	225.8	Percidae	1	4.0	
5	14	96	Main channel	IR	4.5	Common carp	2	1945.5	282.5
5	14	96	Main channel	IR	4.5	*Gambusia* sp.	2	0.5	0.5
5	14	96	Main channel	IR	4.5	Catostomidae	2	28.0	6.0
5	15	96	Main channel	26	203.2	Common carp	2	582.0	61.0
5	15	96	Main channel	26	203.2	Catostomidae	2	3.0	3.0
5	15	96	Main channel	26	203.2	Percidae	2	1.0	1.0
5	15	96	Main channel	26	207.1	Common carp	2	555.5	2.5
5	15	96	Main channel	26	207.1	Catostomidae	2	20.0	9.0
5	15	96	Main channel	26	207.1	Percidae	2	3.5	1.5
5	15	96	Main channel	26	211.2	Catostomidae	2	62.0	1.0
5	15	96	Main channel	26	211.2	Percidae	2	4.5	0.5
5	15	96	Main channel	26	211.2	Unidentified	2	1.0	1.0
5	15	96	Main channel	26	215.7	Common carp	2	174.0	57.0
5	15	96	Main channel	26	215.7	Catostomidae	2	14.5	6.5
5	15	96	Main channel	26	215.7	Hiodontidae	2	1.5	1.5
5	15	96	Main channel	26	215.7	Percidae	2	5.0	4.0
5	16	96	Main channel	26	208.5	Common carp	2	459.0	11.0

Appendix Table C continued.

Month	Day	Year	Aquatic area	River	River mile	Taxon	N	Catch Mean	Catch SE
5	16	96	Main channel	26	208.5	Catostomidae	2	27.0	2.0
5	16	96	Main channel	26	208.5	Percidae	2	1.0	0.0
5	16	96	Main channel	26	213.5	Common carp	2	336.5	44.5
5	16	96	Main channel	26	213.5	Catostomidae	2	16.0	4.0
5	16	96	Main channel	26	213.5	Percidae	2	1.5	1.5
5	17	96	Main channel	26	223.0	Common carp	1	60.0	
5	17	96	Main channel	26	223.0	Catostomidae	1	11.0	
5	17	96	Main channel	26	227.5	Common carp	2	177.0	13.0
5	17	96	Main channel	26	227.5	Catostomidae	2	29.0	5.0
5	17	96	Main channel	26	227.5	Percidae	2	2.0	2.0
5	17	96	Main channel	26	227.5	Unidentified	2	1.0	1.0
5	17	96	Main channel	26	233.5	Common carp	2	239.0	64.0
5	17	96	Main channel	26	233.5	Catostomidae	2	44.5	9.5
5	17	96	Main channel	26	233.5	Centrarchidae	2	2.0	1.0
5	17	96	Main channel	26	233.5	Percidae	2	3.5	3.5
5	17	96	Main channel	26	233.5	Unidentified	2	5.0	2.0
5	28	96	Main channel	26	203.2	Common carp	1	52.0	
5	28	96	Main channel	26	203.2	Clupeidae	1	18.0	
5	28	96	Main channel	26	203.2	Catostomidae	1	16.0	
5	28	96	Main channel	26	203.2	Centrarchidae	1	2.0	
5	28	96	Main channel	26	203.2	Lepisosteidae	1	3.0	
5	28	96	Main channel	26	203.2	Percidae	1	2.0	
5	28	96	Main channel	26	203.2	Unidentified	1	4.0	
5	29	96	Main channel	26	208.5	Common carp	1	10.0	
5	29	96	Main channel	26	208.5	Freshwater drum	1	1.0	
5	29	96	Main channel	26	208.5	Clupeidae	1	190.0	
5	29	96	Main channel	26	208.5	Centrarchidae	1	7.0	
5	29	96	Main channel	26	208.5	Catostomidae	1	63.0	
5	29	96	Main channel	26	208.5	Moronidae	1	3.0	
5	29	96	Main channel	26	208.5	Percidae	1	1.0	
5	29	96	Main channel	26	211.2	Common carp	2	72.5	28.5
5	29	96	Main channel	26	211.2	Clupeidae	2	14.5	7.5
5	29	96	Main channel	26	211.2	Catostomidae	2	9.5	9.5
5	29	96	Main channel	26	211.2	Lepisosteidae	2	2.0	2.0
5	29	96	Main channel	26	211.2	Moronidae	2	1.0	1.0

Appendix Table C continued.

Month	Day	Year	Aquatic area	River	River mile	Taxon	N	Catch Mean	Catch SE
5	30	96	Main channel	IR	4.5	Common carp	2	259.0	84.0
5	30	96	Main channel	IR	4.5	Freshwater drum	2	29.5	22.5
5	30	96	Main channel	IR	4.5	Clupeidae	2	33.0	7.0
5	30	96	Main channel	IR	4.5	Catostomidae	2	0.5	0.5
5	30	96	Main channel	IR	4.5	Centrarchidae	2	9.5	6.5
5	30	96	Main channel	IR	4.5	Moronidae	2	2.0	2.0
5	30	96	Main channel	IR	4.5	Unidentified	2	4.5	4.5
5	30	96	Main channel	IR	9.3	Common carp	2	109.5	12.5
5	30	96	Main channel	IR	9.3	Freshwater drum	2	15.0	6.0
5	30	96	Main channel	IR	9.3	Clupeidae	2	42.5	11.5
5	30	96	Main channel	IR	9.3	Catostomidae	2	2.5	0.5
5	30	96	Main channel	IR	9.3	Centrarchidae	2	10.0	2.0
5	30	96	Main channel	IR	9.3	Unidentified	2	3.5	3.5
5	30	96	Main channel	IR	13.5	Common carp	2	211.5	31.5
5	30	96	Main channel	IR	13.5	Freshwater drum	2	18.0	12.0
5	30	96	Main channel	IR	13.5	Clupeidae	2	115.0	5.0
5	30	96	Main channel	IR	13.5	Catostomidae	2	11.0	11.0
5	30	96	Main channel	IR	13.5	Centrarchidae	2	23.5	14.5
5	30	96	Main channel	IR	13.5	Lepisosteidae	2	1.0	1.0
5	30	96	Main channel	IR	13.5	Moronidae	2	6.5	3.5
5	30	96	Main channel	IR	13.5	Unidentified	2	0.5	0.5
5	30	96	Main channel	IR	18.7	Common carp	2	84.5	11.5
5	30	96	Main channel	IR	18.7	Freshwater drum	2	9.0	2.0
5	30	96	Main channel	IR	18.7	Clupeidae	2	104.5	3.5
5	30	96	Main channel	IR	18.7	Catostomidae	2	9.5	0.5
5	30	96	Main channel	IR	18.7	Centrarchidae	2	14.5	0.5
5	30	96	Main channel	IR	18.7	Lepisosteidae	2	1.0	0.0
5	30	96	Main channel	IR	18.7	Moronidae	2	4.0	3.0
6	3	96	Main channel	26	203.2	Bowfin	2	0.5	0.5
6	3	96	Main channel	26	203.2	Clupeidae	2	189.0	123.0
6	3	96	Main channel	26	203.2	Centrarchidae	2	20.0	13.0
6	3	96	Main channel	26	203.2	Hiodontidae	2	1.5	1.5
6	3	96	Main channel	26	203.2	Moronidae	2	3.5	0.5
6	3	96	Main channel	26	203.2	Percidae	2	0.5	0.5
6	3	96	Main channel	26	203.2	Unidentified	2	1.5	1.5

Appendix Table C continued.

Month	Day	Year	Aquatic area	River	River mile	Taxon	N	Catch Mean	Catch SE
6	3	96	Main channel	26	207.1	Common carp	2	89.5	63.5
6	3	96	Main channel	26	207.1	Freshwater drum	2	7.0	2.0
6	3	96	Main channel	26	207.1	Clupeidae	2	74.0	40.0
6	3	96	Main channel	26	207.1	Catostomidae	2	6.0	2.0
6	3	96	Main channel	26	207.1	Hiodontidae	2	1.0	0.0
6	3	96	Main channel	26	207.1	Centrarchidae	2	8.0	3.0
6	3	96	Main channel	26	207.1	Moronidae	2	2.0	0.0
6	3	96	Main channel	26	207.1	Unidentified	2	1.0	0.0
6	3	96	Main channel	26	208.5	Common carp	2	65.0	30.0
6	3	96	Main channel	26	208.5	Freshwater drum	2	3.5	2.5
6	3	96	Main channel	26	208.5	Clupeidae	2	64.5	22.5
6	3	96	Main channel	26	208.5	Catostomidae	2	2.5	1.5
6	3	96	Main channel	26	208.5	Hiodontidae	2	0.5	0.5
6	3	96	Main channel	26	207.1	Lepisosteidae	2	1.5	0.5
6	3	96	Main channel	26	208.5	Centrarchidae	2	3.0	3.0
6	3	96	Main channel	26	208.5	Moronidae	2	0.5	0.5
6	3	96	Main channel	26	208.5	Unidentified	2	1.5	1.5
6	3	96	Main channel	26	211.2	Common carp	2	41.0	20.0
6	3	96	Main channel	26	211.2	Freshwater drum	2	1.5	1.5
6	3	96	Main channel	26	211.2	Clupeidae	2	46.5	3.5
6	3	96	Main channel	26	211.2	Catostomidae	2	5.5	3.5
6	3	96	Main channel	26	211.2	Hiodontidae	2	1.0	1.0
6	3	96	Main channel	26	211.2	Centrarchidae	2	2.0	2.0
6	3	96	Main channel	26	213.5	Common carp	2	55.0	37.0
6	3	96	Main channel	26	213.5	Freshwater drum	2	4.5	0.5
6	3	96	Main channel	26	213.5	Clupeidae	2	242.5	8.5
6	3	96	Main channel	26	213.5	Catostomidae	2	7.5	3.5
6	3	96	Main channel	26	213.5	Centrarchidae	2	5.0	5.0
6	3	96	Main channel	26	213.5	Lepisosteidae	2	0.5	0.5
6	3	96	Main channel	26	213.5	Moronidae	2	1.5	1.5
6	3	96	Main channel	26	213.5	Unidentified	2	1.5	1.5
6	4	96	Main channel	26	215.7	Common carp	2	61.5	15.5
6	4	96	Main channel	26	215.7	Freshwater drum	2	1.5	1.5
6	4	96	Main channel	26	215.7	Clupeidae	2	215.0	129.0
6	4	96	Main channel	26	215.7	Catostomidae	2	1.0	1.0

Appendix Table C continued.

Month	Day	Year	Aquatic area	River	River mile	Taxon	N	Catch Mean	Catch SE
6	4	96	Main channel	26	215.7	Percidae	2	1.0	1.0
6	4	96	Main channel	IR	4.5	Common carp	2	56.0	15.0
6	4	96	Main channel	IR	4.5	Freshwater drum	2	43.0	26.0
6	4	96	Main channel	IR	4.5	Clupeidae	2	1139.5	321.5
6	4	96	Main channel	IR	4.5	Centrarchidae	2	12.0	4.0
6	4	96	Main channel	IR	4.5	Moronidae	2	4.0	0.0
6	4	96	Main channel	IR	4.5	Unidentified	2	2.5	2.5
6	4	96	Main channel	IR	9.3	Common carp	2	30.0	3.0
6	4	96	Main channel	IR	9.3	Freshwater drum	2	15.5	1.5
6	4	96	Main channel	IR	9.3	Clupeidae	2	99.5	6.5
6	4	96	Main channel	IR	9.3	Catostomidae	2	3.5	2.5
6	4	96	Main channel	IR	9.3	Centrarchidae	2	6.0	4.0
6	4	96	Main channel	IR	9.3	Moronidae	2	1.5	1.5
6	4	96	Main channel	IR	9.3	Unidentified	2	1.0	0.0
6	4	96	Main channel	IR	13.5	Common carp	2	12.5	4.5
6	4	96	Main channel	IR	13.5	Freshwater drum	2	3.5	0.5
6	4	96	Main channel	IR	13.5	Clupeidae	2	232.0	12.0
6	4	96	Main channel	IR	13.5	Catostomidae	2	7.5	0.5
6	4	96	Main channel	IR	13.5	Centrarchidae	2	2.5	1.5
6	4	96	Main channel	IR	13.5	Moronidae	2	2.0	0.0
6	4	96	Main channel	IR	18.7	Common carp	2	31.5	5.5
6	4	96	Main channel	IR	18.7	Freshwater drum	2	17.5	4.5
6	4	96	Main channel	IR	18.7	Clupeidae	2	284.0	171.0
6	4	96	Main channel	IR	18.7	Catostomidae	2	5.0	5.0
6	4	96	Main channel	IR	18.7	Centrarchidae	2	3.0	1.0
6	5	96	Main channel	26	225.8	Common carp	2	10.0	0.0
6	5	96	Main channel	26	225.8	Freshwater drum	2	0.5	0.5
6	5	96	Main channel	26	225.8	Clupeidae	2	3.0	1.0
6	5	96	Main channel	26	225.8	Lepisosteidae	2	0.5	0.5
6	5	96	Main channel	26	227.5	Common carp	2	6.0	4.0
6	5	96	Main channel	26	227.5	Catostomidae	2	2.0	2.0
6	5	96	Main channel	26	227.5	Hiodontidae	2	1.5	1.5
6	5	96	Main channel	26	227.5	Lepisosteidae	2	0.5	0.5
6	5	96	Main channel	26	227.5	Unidentified	2	0.5	0.5
6	5	96	Main channel	26	230.5	Common carp	2	8.0	1.0

Appendix Table C continued.

Month	Day	Year	Aquatic area	River	River mile	Taxon	N	Catch Mean	Catch SE
6	5	96	Main channel	26	230.5	Clupeidae	2	0.5	0.5
6	5	96	Main channel	26	230.5	Catostomidae	2	1.5	1.5
6	5	96	Main channel	26	230.5	Hiodontidae	2	0.5	0.5
6	5	96	Main channel	26	233.5	Common carp	2	13.0	1.0
6	5	96	Main channel	26	233.5	Clupeidae	2	0.5	0.5
6	5	96	Main channel	26	233.5	Catostomidae	2	1.0	1.0
6	5	96	Main channel	26	233.5	Lepisosteidae	2	0.5	0.5
6	17	96	Main channel	26	203.2	Common carp	2	6.0	2.0
6	17	96	Main channel	26	203.2	Freshwater drum	2	0.5	0.5
6	17	96	Main channel	26	203.2	Clupeidae	2	13.0	5.0
6	17	96	Main channel	26	203.2	Hiodontidae	2	0.5	0.5
6	17	96	Main channel	26	203.2	Centrarchidae	2	0.5	0.5
6	17	96	Main channel	26	203.2	Unidentified	2	0.5	0.5
6	17	96	Main channel	26	207.1	Common carp	2	15.5	5.5
6	17	96	Main channel	26	207.1	Clupeidae	2	18.5	14.5
6	17	96	Main channel	26	207.1	Catostomidae	2	5.5	2.5
6	17	96	Main channel	26	207.1	Hiodontidae	2	0.5	0.5
6	17	96	Main channel	26	207.1	Unidentified	2	0.5	0.5
6	20	96	Main channel	26	215.7	Common carp	1	229.0	
6	20	96	Main channel	26	215.7	Freshwater drum	1	160.0	
6	20	96	Main channel	26	215.7	Clupeidae	1	693.0	
6	20	96	Main channel	26	215.7	Catostomidae	1	76.0	
6	20	96	Main channel	26	215.7	Moronidae	1	7.0	
6	20	96	Main channel	26	215.7	Unidentified	1	14.0	
6	20	96	Main channel	IR	4.5	Common carp	2	728.0	375.0
6	20	96	Main channel	IR	4.5	Freshwater drum	2	35.0	18.0
6	20	96	Main channel	IR	4.5	Clupeidae	2	241.5	138.5
6	20	96	Main channel	IR	4.5	Unidentified	2	0.5	0.5
6	20	96	Main channel	IR	9.3	Common carp	2	568.0	197.0
6	20	96	Main channel	IR	9.3	Freshwater drum	2	67.5	45.5
6	20	96	Main channel	IR	9.3	Clupeidae	2	617.5	194.5
6	20	96	Main channel	IR	9.3	Catostomidae	2	2.5	0.5
6	20	96	Main channel	IR	9.3	Centrarchidae	2	0.5	0.5
6	20	96	Main channel	IR	9.3	Moronidae	2	8.5	6.5
6	20	96	Main channel	IR	9.3	Unidentified	2	87.5	2.5

Appendix Table C continued.

Month	Day	Year	Aquatic area	River	River mile	Taxon	N	Catch Mean	Catch SE
6	20	96	Main channel	IR	13.5	Common carp	2	456.5	2.5
6	20	96	Main channel	IR	13.5	Freshwater drum	2	4.5	14.5
6	20	96	Main channel	IR	13.5	Clupeidae	2	883.5	157.5
6	20	96	Main channel	IR	13.5	Catostomidae	2	1.0	0.0
6	20	96	Main channel	IR	13.5	Moronidae	2	6.5	5.5
6	20	96	Main channel	IR	13.5	Unidentified	2	6.0	5.0
6	20	96	Main channel	IR	18.7	Common carp	2	541.0	210.0
6	20	96	Main channel	IR	18.7	Freshwater drum	2	45.5	16.5
6	20	96	Main channel	IR	18.7	Clupeidae	2	487.0	124.0
6	20	96	Main channel	IR	18.7	Catostomidae	2	2.0	2.0
6	20	96	Main channel	IR	18.7	Moronidae	2	0.5	0.5
6	20	96	Main channel	IR	18.7	Unidentified	2	1.0	0.0
6	21	96	Main channel	26	223.0	Common carp	2	2.5	0.5
6	21	96	Main channel	26	223.0	Freshwater drum	2	152.0	85.0
6	21	96	Main channel	26	223.0	Clupeidae	2	3.5	0.5
6	21	96	Main channel	26	223.0	Catostomidae	2	1.5	0.5
6	21	96	Main channel	26	223.0	Hiodontidae	2	0.5	0.5
6	21	96	Main channel	26	223.0	Unidentified	2	0.5	0.5
6	21	96	Main channel	26	225.8	Common carp	2	2.0	0.0
6	21	96	Main channel	26	225.8	Freshwater drum	2	225.5	65.5
6	21	96	Main channel	26	225.8	Clupeidae	2	2.5	0.5
6	21	96	Main channel	26	225.8	Catostomidae	2	1.0	0.0
6	21	96	Main channel	26	225.8	Lepisosteidae	2	0.5	0.5
6	21	96	Main channel	26	225.8	Unidentified	2	0.5	0.5
6	21	96	Main channel	26	230.5	Common carp	2	12.0	1.0
6	21	96	Main channel	26	230.5	Freshwater drum	2	906.0	628.0
6	21	96	Main channel	26	230.5	Clupeidae	2	3.0	1.0
6	21	96	Main channel	26	230.5	Catostomidae	2	5.5	2.5
6	21	96	Main channel	26	230.5	Hiodontidae	2	1.0	1.0
6	21	96	Main channel	26	230.5	Centrarchidae	2	2.0	2.0
6	21	96	Main channel	26	230.5	Lepisosteidae	2	0.5	0.5
6	21	96	Main channel	26	230.5	Unidentified	2	4.5	4.5
6	21	96	Main channel	26	233.5	Common carp	2	4.0	0.0
6	21	96	Main channel	26	233.5	Freshwater drum	2	478.0	164.0
6	21	96	Main channel	26	233.5	Clupeidae	2	6.0	3.0

Appendix Table C continued.

Month	Day	Year	Aquatic area	River	River mile	Taxon	N	Catch Mean	Catch SE
6	21	96	Main channel	26	233.5	Catostomidae	2	4.0	2.0
6	21	96	Main channel	26	233.5	Hiodontidae	2	0.5	0.5
6	21	96	Main channel	26	233.5	Moronidae	2	2.5	2.5
6	21	96	Main channel	26	233.5	Unidentified	2	3.0	3.0
7	1	96	Main channel	26	207.1	Common carp	2	2.0	1.0
7	1	96	Main channel	26	207.1	Freshwater drum	2	240.5	72.5
7	1	96	Main channel	26	207.1	Clupeidae	2	27.0	10.0
7	1	96	Main channel	26	207.1	Catostomidae	2	4.0	2.0
7	1	96	Main channel	26	211.2	Freshwater drum	1	310.0	
7	1	96	Main channel	26	211.2	Clupeidae	1	1.0	
7	1	96	Main channel	26	211.2	Catostomidae	1	4.0	
7	1	96	Main channel	26	211.2	Unidentified	1	1.0	
7	1	96	Main channel	26	213.5	Common carp	2	4.0	0.0
7	1	96	Main channel	26	213.5	Freshwater drum	2	383.0	12.0
7	1	96	Main channel	26	213.5	Clupeidae	2	53.5	0.5
7	1	96	Main channel	26	213.5	Catostomidae	2	3.5	1.5
7	1	96	Main channel	26	213.5	Unidentified	2	1.0	1.0
7	2	96	Main channel	26	203.2	Common carp	2	0.5	0.5
7	2	96	Main channel	26	203.2	Freshwater drum	2	309.5	40.5
7	2	96	Main channel	26	203.2	Clupeidae	2	10.0	3.0
7	2	96	Main channel	26	203.2	Catostomidae	2	1.5	0.5
7	2	96	Main channel	26	203.2	Unidentified	2	1.5	1.5
7	2	96	Main channel	26	208.5	Common carp	1	1.0	
7	2	96	Main channel	26	208.5	Freshwater drum	1	558.0	
7	2	96	Main channel	26	208.5	Clupeidae	1	16.0	
7	2	96	Main channel	26	208.5	Catostomidae	1	9.0	
7	2	96	Main channel	26	208.5	Centrarchidae	1	1.0	
7	2	96	Main channel	26	208.5	Moronidae	1	1.0	
7	2	96	Main channel	26	208.5	Unidentified	1	1.0	
7	3	96	Main channel	26	223.0	Freshwater drum	2	99.5	34.5
7	3	96	Main channel	26	225.8	Freshwater drum	1	196.0	
7	3	96	Main channel	26	233.5	Common carp	2	0.5	0.5
7	3	96	Main channel	26	233.5	Freshwater drum	2	219.5	33.5
7	3	96	Main channel	26	240.2	Common carp	1	1.0	
7	3	96	Main channel	26	240.2	Freshwater drum	1	398.0	

Appendix Table C continued.

Month	Day	Year	Aquatic area	River	River mile	Taxon	N	Catch Mean	Catch SE
7	3	96	Main channel	26	240.2	Clupeidae	1	1.0	
7	3	96	Main channel	26	240.2	Unidentified	1	1.0	
7	5	96	Main channel	26	215.7	Common carp	2	1.0	1.0
7	5	96	Main channel	26	215.7	Freshwater drum	2	451.0	307.0
7	5	96	Main channel	26	215.7	Clupeidae	2	5.0	2.0
7	5	96	Main channel	26	215.7	Catostomidae	1	4.0	
7	5	96	Main channel	IR	4.5	Common carp	2	2.0	2.0
7	5	96	Main channel	IR	4.5	Freshwater drum	2	26.5	14.5
7	5	96	Main channel	IR	4.5	Clupeidae	2	13.0	7.0
7	5	96	Main channel	IR	4.5	Catostomidae	2	3.0	3.0
7	5	96	Main channel	IR	4.5	Unidentified	2	0.5	0.5
7	5	96	Main channel	IR	9.3	Freshwater drum	2	356.5	70.5
7	5	96	Main channel	IR	9.3	Clupeidae	2	23.5	9.5
7	5	96	Main channel	IR	9.3	Catostomidae	2	24.0	7.0
7	5	96	Main channel	IR	9.3	Moronidae	2	0.5	0.5
7	5	96	Main channel	IR	9.3	Unidentified	2	1.0	1.0
7	5	96	Main channel	IR	13.5	Common carp	2	1.5	1.5
7	5	96	Main channel	IR	13.5	Channel catfish	2	0.5	0.5
7	5	96	Main channel	IR	13.5	Freshwater drum	2	229.0	159.0
7	5	96	Main channel	IR	13.5	Clupeidae	2	38.5	18.5
7	5	96	Main channel	IR	13.5	Catostomidae	2	3.0	1.0
7	5	96	Main channel	IR	13.5	Moronidae	2	4.5	2.5
7	5	96	Main channel	IR	13.5	Unidentified	2	2.5	2.5
7	5	96	Main channel	IR	18.7	Common carp	2	2.0	0.0
7	5	96	Main channel	IR	18.7	Freshwater drum	2	697.0	342.0
7	5	96	Main channel	IR	18.7	Clupeidae	2	27.5	14.5
7	5	96	Main channel	IR	18.7	Catostomidae	2	8.0	3.0
7	5	96	Main channel	IR	18.7	Centrarchidae	2	1.5	1.5
7	5	96	Main channel	IR	18.7	Unidentified	2	5.5	5.5
4	23	97	Main channel	26	208.5	None	2	0.0	0.0
4	23	97	Main channel	26	215.7	*Gambusia* sp.	2	0.5	0.5
4	23	97	Main channel	26	233.0	Freshwater drum	2	1.5	1.5
4	23	97	Side channel	26	208.5	None	2	0.0	0.0
4	23	97	Side channel	26	215.7	None	2	0.0	0.0
4	23	97	Side channel	26	222.6	None	2	0.0	0.0

Appendix Table C continued.

Month	Day	Year	Aquatic area	River	River mile	Taxon	N	Catch Mean	Catch SE
4	29	97	Main channel	26	208.5	Percidae	2	0.5	0.5
4	29	97	Main channel	26	215.7	Common carp	2	0.5	0.5
4	29	97	Main channel	26	215.7	Freshwater drum	2	2.0	2.0
4	29	97	Main channel	26	215.7	Catostomidae	2	2.5	2.5
4	29	97	Main channel	26	215.7	Hiodontidae	2	2.0	2.0
4	29	97	Main channel	26	222.6	Percidae	2	0.5	0.5
4	29	97	Main channel	26	233.5	None	2	0.0	0.0
4	29	97	Side channel	26	208.5	None	2	0.0	0.0
4	29	97	Side channel	26	215.7	None	2	0.0	0.0
4	29	97	Side channel	26	222.6	Percidae	2	1.0	1.0
4	29	97	Side channel	26	233.5	None	2	0.0	0.0
5	1	97	Side channel	IR	13.5	Catostomidae	2	0.5	0.5
5	2	97	Backwater	26	222.0	None	2	0.0	0.0
5	13	97	Main channel	26	208.5	Common carp	2	1.0	1.0
5	13	97	Main channel	26	208.5	Catostomidae	2	16.0	5.0
5	13	97	Main channel	26	208.5	Percidae	2	5.5	2.5
5	13	97	Main channel	26	208.5	Unidentified	2	1.0	1.0
5	13	97	Main channel	26	223.0	Common carp	2	0.5	0.5
5	13	97	Main channel	26	223.0	Catostomidae	2	14.0	0.0
5	13	97	Main channel	26	223.0	Percidae	2	6.0	1.0
5	13	97	Main channel	26	233.5	*Gambusia* sp.	1	1.0	
5	13	97	Main channel	26	233.5	Catostomidae	1	10.0	
5	13	97	Main channel	26	233.5	Hiodontidae	1	1.0	
5	13	97	Main channel	26	233.5	Percidae	1	3.0	
5	13	97	Side channel	26	208.5	Common carp	2	0.5	0.5
5	13	97	Side channel	26	208.5	Catostomidae	2	25.0	6.0
5	13	97	Side channel	26	208.5	Percidae	2	14.0	14.0
5	13	97	Side channel	26	222.6	Common carp	2	0.5	0.5
5	13	97	Side channel	26	222.6	Catostomidae	2	10.5	3.5
5	13	97	Side channel	26	222.6	Percidae	2	1.0	0.0
5	13	97	Side channel	26	233.2	Common carp	2	1.5	0.5
5	13	97	Side channel	26	233.2	Catostomidae	2	13.5	4.5
5	13	97	Side channel	26	233.2	Centrarchidae	2	0.5	0.5
5	13	97	Side channel	26	233.2	Lepisosteidae	2	1.0	1.0
5	13	97	Side channel	26	233.2	Percidae	2	3.5	0.5

Appendix Table C continued.

Month	Day	Year	Aquatic area	River	River mile	Taxon	N	Catch Mean	Catch SE
5	13	97	Side channel	26	233.2	Unidentified	2	2.0	1.0
5	16	97	Backwater	26	222.0	Clupeidae	2	97.0	36.0
5	16	97	Backwater	26	222.0	Cyprinidae	2	0.5	0.5
5	16	97	Backwater	26	222.0	Centrarchidae	2	10.0	3.0
5	16	97	Backwater	26	222.0	Moronidae	2	2.5	2.5
5	16	97	Backwater	26	222.0	Percidae	2	4.0	1.0
5	16	97	Backwater	IR	9.3	*Gambusia* sp.	2	0.5	0.5
5	16	97	Backwater	IR	9.3	Clupeidae	2	875.0	112.0
5	16	97	Backwater	IR	9.3	Catostomidae	2	0.5	0.5
5	16	97	Backwater	IR	9.3	Unidentified	2	2.0	2.0
5	19	97	Main channel	IR	13.5	Common carp	2	0.5	0.5
5	19	97	Main channel	IR	13.5	Clupeidae	2	201.0	199.0
5	19	97	Main channel	IR	13.5	Moronidae	2	30.5	26.5
5	19	97	Main channel	IR	13.5	Unidentified	2	3.0	1.0
5	19	97	Side channel	IR	13.5	Freshwater drum	2	24.0	18.0
5	19	97	Side channel	IR	13.5	Clupeidae	2	140.5	97.5
5	19	97	Side channel	IR	13.5	Unidentified	2	1.0	1.0
5	27	97	Main channel	IR	13.5	Common carp	1	1.0	
5	27	97	Main channel	IR	13.5	Freshwater drum	1	101.0	
5	27	97	Main channel	IR	13.5	Clupeidae	1	30.0	
5	27	97	Main channel	IR	13.5	Moronidae	1	12.0	
5	28	97	Backwater	26	222.0	Common carp	2	5.5	1.5
5	28	97	Backwater	26	222.0	Freshwater drum	2	0.5	0.5
5	28	97	Backwater	26	222.0	Clupeidae	2	473.5	74.5
5	28	97	Backwater	26	222.0	Cyprinidae	2	1.5	0.5
5	28	97	Backwater	26	222.0	Centrarchidae	2	80.0	76.0
5	28	97	Backwater	26	222.0	Moronidae	2	0.5	0.5
5	28	97	Backwater	26	222.0	Unidentified	2	3.5	3.5
5	28	97	Backwater	IR	9.3	BKSS	2	0.5	0.5
5	28	97	Backwater	IR	9.3	*Gambusia* sp.	2	0.5	0.5
5	28	97	Backwater	IR	9.3	Clupeidae	2	253.0	101.0
5	28	97	Backwater	IR	9.3	Catostomidae	2	0.5	0.5
5	28	97	Backwater	IR	9.3	Centrarchidae	2	6.5	5.5
5	28	97	Backwater	IR	9.3	Unidentified	2	0.5	0.5
5	29	97	Side channel	IR	13.5	Common carp	2	0.5	0.5

Appendix Table C continued.

Month	Day	Year	Aquatic area	River	River mile	Taxon	N	Catch Mean	SE
5	29	97	Side channel	IR	13.5	Freshwater drum	2	420.0	122.0
5	29	97	Side channel	IR	13.5	Clupeidae	2	9.0	4.0
5	29	97	Side channel	IR	13.5	Catostomidae	2	0.5	0.5
5	29	97	Side channel	IR	13.5	Cyprinidae	2	2.5	2.5
5	29	97	Side channel	IR	13.5	Moronidae	2	9.5	9.5
5	29	97	Side channel	IR	13.5	Unidentified	2	4.5	4.5
5	30	97	Main channel	26	215.7	Clupeidae	2	0.5	0.5
5	30	97	Main channel	26	215.7	Hiodontidae	2	0.5	0.5
5	30	97	Main channel	26	223.0	Catostomidae	2	10.0	5.0
5	30	97	Main channel	26	223.0	Hiodontidae	2	7.5	2.5
5	30	97	Main channel	26	223.0	Centrarchidae	2	1.0	1.0
5	30	97	Main channel	26	223.0	Moronidae	2	0.5	0.5
5	30	97	Main channel	26	233.5	Catostomidae	1	7.0	
5	30	97	Main channel	26	233.5	Cyprinidae	1	2.0	
5	30	97	Main channel	26	233.5	Hiodontidae	1	19.0	
5	30	97	Main channel	26	233.5	Percidae	1	2.0	
5	30	97	Side channel	26	215.7	Common carp	1	2.0	
5	30	97	Side channel	26	215.7	Clupeidae	1	8.0	
5	30	97	Side channel	26	215.7	Catostomidae	1	15.0	
5	30	97	Side channel	26	215.7	Hiodontidae	1	6.0	
5	30	97	Side channel	26	215.7	Centrarchidae	1	4.0	
5	30	97	Side channel	26	215.7	Moronidae	1	1.0	
5	30	97	Side channel	26	215.7	Percidae	1	3.0	
5	30	97	Side channel	26	222.6	Common carp	2	2.0	0.0
5	30	97	Side channel	26	222.6	Freshwater drum	2	1.0	1.0
5	30	97	Side channel	26	222.6	Clupeidae	2	2.0	1.0
5	30	97	Side channel	26	222.6	Catostomidae	2	16.5	12.5
5	30	97	Side channel	26	222.6	Hiodontidae	2	11.0	3.0
5	30	97	Side channel	26	222.6	Centrarchidae	2	6.5	4.5
5	30	97	Side channel	26	222.6	Moronidae	2	0.5	0.5
5	30	97	Side channel	26	222.6	Unidentified	2	1.5	1.5
5	30	97	Side channel	26	233.5	Catostomidae	2	2.0	2.0
5	30	97	Side channel	26	233.5	Cyprinidae	2	1.0	1.0
5	30	97	Side channel	26	233.5	Hiodontidae	2	4.5	1.5
6	10	97	Main channel	IR	13.5	Common carp	2	148.0	21.0

Appendix Table C continued.

Month	Day	Year	Aquatic area	River	River mile	Taxon	N	Catch Mean	Catch SE
6	10	97	Main channel	IR	13.5	Freshwater drum	2	1326.0	274.0
6	10	97	Main channel	IR	13.5	*Gambusia* sp.	2	0.5	0.5
6	10	97	Main channel	IR	13.5	Clupeidae	2	18.5	18.5
6	10	97	Main channel	IR	13.5	Catostomidae	2	6.0	6.0
6	10	97	Main channel	IR	13.5	Cyprinidae	2	1.0	1.0
6	10	97	Main channel	IR	13.5	Unidentified	2	2.5	2.5
6	10	97	Side channel	IR	13.5	Common carp	2	26.5	7.5
6	10	97	Side channel	IR	13.5	Freshwater drum	2	906.5	239.5
6	10	97	Side channel	IR	13.5	Clupeidae	2	4.0	0.0
6	10	97	Side channel	IR	13.5	Catostomidae	2	2.0	2.0
6	10	97	Side channel	IR	13.5	Cyprinidae	2	1.0	0.0
6	10	97	Side channel	IR	13.5	Unidentified	2	17.0	1.0
6	11	97	Backwater	26	222.0	Clupeidae	2	2144.0	169.0
6	11	97	Backwater	26	222.0	Cyprinidae	2	3.0	3.0
6	11	97	Backwater	26	222.0	Centrarchidae	2	28.0	28.0
6	11	97	Backwater	IR	9.3	Silversides	2	1.0	1.0
6	11	97	Backwater	IR	9.3	Common carp	2	0.5	0.5
6	11	97	Backwater	IR	9.3	Clupeidae	2	86.0	33.0
6	11	97	Backwater	IR	9.3	Centrarchidae	2	17.0	9.0
6	12	97	Main channel	26	208.5	Common carp	2	4.0	0.0
6	12	97	Main channel	26	208.5	Freshwater drum	2	515.5	92.5
6	12	97	Main channel	26	208.5	Clupeidae	2	92.5	75.5
6	12	97	Main channel	26	208.5	Catostomidae	2	16.0	4.0
6	12	97	Main channel	26	208.5	Hiodontidae	2	0.5	0.5
6	12	97	Main channel	26	215.7	Common carp	2	0.5	0.5
6	12	97	Main channel	26	215.7	Freshwater drum	2	169.0	101.0
6	12	97	Main channel	26	215.7	Clupeidae	2	6.5	4.5
6	12	97	Main channel	26	215.7	Catostomidae	2	5.0	5.0
6	12	97	Main channel	26	215.7	Hiodontidae	2	1.5	0.5
6	12	97	Main channel	26	223.0	Common carp	2	0.5	0.5
6	12	97	Main channel	26	223.0	Catostomidae	2	2.5	0.5
6	12	97	Main channel	26	223.0	Unidentified	2	0.5	0.5
6	12	97	Main channel	26	233.5	Common carp	1	1.0	
6	12	97	Main channel	26	233.5	Catostomidae	1	3.0	
6	12	97	Side channel	26	208.5	Common carp	2	16.0	2.0

Appendix Table C continued.

Month	Day	Year	Aquatic area	River	River mile	Taxon	N	Catch Mean	Catch SE
6	12	97	Side channel	26	208.5	Freshwater drum	2	1164.5	23.5
6	12	97	Side channel	26	208.5	Clupeidae	2	14.5	9.5
6	12	97	Side channel	26	208.5	Catostomidae	2	6.0	0.0
6	12	97	Side channel	26	208.5	Hiodontidae	2	2.5	0.5
6	12	97	Side channel	26	208.5	Moronidae	2	4.0	4.0
6	12	97	Side channel	26	208.5	Percidae	2	0.5	0.5
6	12	97	Side channel	26	222.6	Freshwater drum	2	2.0	2.0
6	12	97	Side channel	26	222.6	Catostomidae	2	5.0	3.0
6	12	97	Side channel	26	222.6	Hiodontidae	2	0.5	0.5
6	12	97	Side channel	26	222.6	Unidentified	2	3.5	3.5
6	12	97	Side channel	26	233.5	Common carp	2	0.5	0.5
6	12	97	Side channel	26	233.5	Freshwater drum	2	0.5	0.5
6	12	97	Side channel	26	233.5	Moronidae	2	1.0	1.0
6	24	97	Backwater	26	222.0	Bighead carp	2	0.5	0.5
6	24	97	Backwater	26	222.0	Silversides	2	1.0	0.0
6	24	97	Backwater	26	222.0	*Gambusia* sp.	2	119.0	31.0
6	24	97	Backwater	26	222.0	Clupeidae	2	81.0	12.0
6	24	97	Backwater	26	222.0	Cyprinidae	2	8.0	1.0
6	24	97	Backwater	26	222.0	Centrarchidae	2	1933.0	11.0
6	24	97	Backwater	IR	9.3	Silversides	1	23.0	
6	24	97	Backwater	IR	9.3	Clupeidae	1	9.0	
6	24	97	Backwater	IR	9.3	Centrarchidae	1	105.0	
6	24	97	Backwater	IR	9.3	Unidentified	1	1.0	
6	25	97	Main channel	IR	13.5	Common carp	2	32.5	3.5
6	25	97	Main channel	IR	13.5	Freshwater drum	2	2073.0	307.0
6	25	97	Main channel	IR	13.5	Clupeidae	2	46.5	8.5
6	25	97	Main channel	IR	13.5	Catostomidae	2	514.0	105.0
6	25	97	Main channel	IR	13.5	Centrarchidae	2	0.5	0.5
6	25	97	Main channel	IR	13.5	Moronidae	2	4.0	3.0
6	25	97	Main channel	IR	13.5	Unidentified	2	9.0	8.0
6	25	97	Side channel	IR	13.5	Common carp	2	42.5	4.5
6	25	97	Side channel	IR	13.5	Freshwater drum	2	5007.0	396.0
6	25	97	Side channel	IR	13.5	Clupeidae	2	24.0	1.0
6	25	97	Side channel	IR	13.5	Catostomidae	2	195.5	7.5
6	25	97	Side channel	IR	13.5	Cyprinidae	2	9.0	8.0

Appendix Table C continued.

Month	Day	Year	Aquatic area	River	River mile	Taxon	N	Catch Mean	SE
6	25	97	Side channel	IR	13.5	Centrarchidae	2	1.0	1.0
6	25	97	Side channel	IR	13.5	Moronidae	2	3.5	1.5
6	25	97	Side channel	IR	13.5	Unidentified	2	15.5	9.5
6	26	97	Main channel	26	208.5	Freshwater drum	2	37.5	27.5
6	26	97	Main channel	26	208.5	Clupeidae	2	30.0	24.0
6	26	97	Main channel	26	208.5	Catostomidae	2	89.0	40.0
6	26	97	Main channel	26	215.7	Common carp	2	1.5	0.5
6	26	97	Main channel	26	215.7	Freshwater drum	2	107.5	68.5
6	26	97	Main channel	26	215.7	Clupeidae	2	46.0	9.0
6	26	97	Main channel	26	215.7	Catostomidae	2	49.5	5.5
6	26	97	Main channel	26	215.7	Hiodontidae	2	1.5	1.5
6	26	97	Main channel	26	223.0	Common carp	2	1.0	0.0
6	26	97	Main channel	26	223.0	Freshwater drum	2	111.0	109.0
6	26	97	Main channel	26	223.0	Clupeidae	2	10.5	10.5
6	26	97	Main channel	26	223.0	Catostomidae	2	30.5	24.5
6	26	97	Main channel	26	223.0	Cyprinidae	2	7.0	7.0
6	26	97	Main channel	26	233.5	Common carp	2	2.0	1.0
6	26	97	Main channel	26	233.5	Freshwater drum	2	320.5	108.5
6	26	97	Main channel	26	233.5	Clupeidae	2	5.0	5.0
6	26	97	Main channel	26	233.5	Catostomidae	2	26.0	11.0
6	26	97	Main channel	26	233.5	Cyprinidae	2	6.5	1.5
6	26	97	Main channel	26	233.5	Moronidae	2	1.5	0.5
6	26	97	Main channel	26	233.5	Percidae	2	2.5	2.5
6	26	97	Side channel	26	208.5	Common carp	2	5.5	0.5
6	26	97	Side channel	26	208.5	Freshwater drum	2	509.0	166.0
6	26	97	Side channel	26	208.5	Clupeidae	2	91.0	51.0
6	26	97	Side channel	26	208.5	Catostomidae	2	21.5	4.5
6	26	97	Side channel	26	208.5	Centrarchidae	2	0.5	0.5
6	26	97	Side channel	26	208.5	Moronidae	2	3.5	3.5
6	26	97	Side channel	26	215.7	Common carp	2	5.5	3.5
6	26	97	Side channel	26	215.7	Freshwater drum	2	33.0	24.0
6	26	97	Side channel	26	215.7	Clupeidae	2	922.5	909.5
6	26	97	Side channel	26	215.7	Catostomidae	2	39.5	3.5
6	26	97	Side channel	26	215.7	Cyprinidae	2	22.0	22.0
6	26	97	Side channel	26	215.7	Centrarchidae	2	5.5	5.5

Appendix Table C continued.

Month	Day	Year	Aquatic area	River	River mile	Taxon	N	Catch Mean	Catch SE
6	26	97	Side channel	26	215.7	Unidentified	2	2.5	2.5
6	26	97	Side channel	26	222.6	Common carp	2	3.0	1.0
6	26	97	Side channel	26	222.6	Freshwater drum	2	107.5	60.5
6	26	97	Side channel	26	222.6	Clupeidae	2	12.5	0.5
6	26	97	Side channel	26	222.6	Catostomidae	2	74.5	37.5
6	26	97	Side channel	26	222.6	Cyprinidae	2	0.5	0.5
6	26	97	Side channel	26	222.6	Moronidae	2	1.0	1.0
6	26	97	Side channel	26	222.6	Unidentified	2	9.0	9.0
6	26	97	Side channel	26	233.5	Common carp	2	2.5	1.5
6	26	97	Side channel	26	233.5	Freshwater drum	2	71.0	11.0
6	26	97	Side channel	26	233.5	Clupeidae	2	9.0	7.0
6	26	97	Side channel	26	233.5	Catostomidae	2	9.0	1.0
6	26	97	Side channel	26	233.5	Cyprinidae	2	1.5	1.5
6	26	97	Side channel	26	233.5	Centrarchidae	2	0.5	0.5
6	26	97	Side channel	26	233.5	Moronidae	2	0.5	0.5
6	26	97	Side channel	26	233.5	Unidentified	2	1.5	1.5
7	8	97	Main channel	26	208.5	Common carp	2	0.5	0.5
7	8	97	Main channel	26	208.5	Clupeidae	2	2.0	0.0
7	8	97	Main channel	26	208.5	Catostomidae	2	2.0	2.0
7	8	97	Main channel	26	208.5	Cyprinidae	2	10.5	3.5
7	8	97	Main channel	26	215.7	Freshwater drum	2	1.0	0.0
7	8	97	Main channel	26	215.7	Clupeidae	2	1.0	0.0
7	8	97	Main channel	26	215.7	Catostomidae	2	5.5	2.5
7	8	97	Main channel	26	215.7	Cyprinidae	2	25.5	6.5
7	8	97	Main channel	26	223.0	Clupeidae	1	11.0	
7	8	97	Main channel	26	223.0	Catostomidae	1	5.0	
7	8	97	Main channel	26	223.0	Cyprinidae	1	32.0	
7	8	97	Main channel	26	223.0	Lepisosteidae	1	1.0	
7	8	97	Main channel	26	233.5	Freshwater drum	2	4.5	1.5
7	8	97	Main channel	26	233.5	*Gambusia* sp.	2	1.0	0.0
7	8	97	Main channel	26	233.5	Clupeidae	2	3.5	1.5
7	8	97	Main channel	26	233.5	Catostomidae	2	2.5	0.5
7	8	97	Main channel	26	233.5	Cyprinidae	2	30.5	7.5
7	8	97	Main channel	26	233.5	Centrarchidae	2	0.5	0.5
7	8	97	Side channel	26	208.5	Freshwater drum	1	4.0	

Appendix Table C continued.

Month	Day	Year	Aquatic area	River	River mile	Taxon	N	Catch Mean	Catch SE
7	8	97	Side channel	26	208.5	Clupeidae	1	20.0	
7	8	97	Side channel	26	208.5	Catostomidae	1	13.0	
7	8	97	Side channel	26	208.5	Cyprinidae	1	20.0	
7	8	97	Side channel	26	208.5	Hiodontidae	1	1.0	
7	8	97	Side channel	26	215.7	Cyprinidae	2	26.0	26.0
7	8	97	Side channel	26	222.6	Freshwater drum	2	4.0	3.0
7	8	97	Side channel	26	222.6	Clupeidae	2	7.0	2.0
7	8	97	Side channel	26	222.6	Catostomidae	2	10.5	10.5
7	8	97	Side channel	26	222.6	Cyprinidae	2	19.0	6.0
7	8	97	Side channel	26	233.5	Clupeidae	2	4.0	1.0
7	8	97	Side channel	26	233.5	Catostomidae	2	1.0	1.0
7	8	97	Side channel	26	233.5	Cyprinidae	2	44.5	5.5
7	9	97	Backwater	IR	9.3	Silversides	2	48.5	42.5
7	9	97	Backwater	IR	9.3	Clupeidae	2	5.0	0.0
7	9	97	Backwater	IR	9.3	Centrarchidae	2	495.5	161.5
7	10	97	Main channel	IR	13.5	Clupeidae	1	24.0	
7	10	97	Main channel	IR	13.5	Catostomidae	1	48.0	
7	10	97	Side channel	IR	13.5	Freshwater drum	2	2.0	1.0
7	10	97	Side channel	IR	13.5	Clupeidae	2	8.0	4.0
7	10	97	Side channel	IR	13.5	Cyprinidae	2	2.0	0.0
7	22	97	Main channel	26	208.5	Common carp	2	0.5	0.5
7	22	97	Main channel	26	208.5	Clupeidae	2	1.0	1.0
7	22	97	Main channel	26	208.5	Catostomidae	2	4.5	0.5
7	22	97	Main channel	26	208.5	Cyprinidae	2	26.0	3.0
7	22	97	Main channel	26	208.5	Centrarchidae	2	0.5	0.5
7	22	97	Main channel	26	215.7	Freshwater drum	2	1.0	1.0
7	22	97	Main channel	26	215.7	*Gambusia* sp.	2	0.5	0.5
7	22	97	Main channel	26	215.7	Catostomidae	2	0.5	0.5
7	22	97	Main channel	26	215.7	Cyprinidae	2	8.5	4.5
7	22	97	Main channel	26	223.0	Freshwater drum	2	1.0	0.0
7	22	97	Main channel	26	223.0	Clupeidae	2	0.5	0.5
7	22	97	Main channel	26	223.0	Catostomidae	2	3.5	1.5
7	22	97	Main channel	26	223.0	Cyprinidae	2	44.0	3.0
7	22	97	Main channel	26	233.5	Freshwater drum	2	1.0	1.0
7	22	97	Main channel	26	233.5	*Gambusia* sp.	2	0.5	0.5

Appendix Table C continued.

Month	Day	Year	Aquatic area	River	River mile	Taxon	N	Catch Mean	Catch SE
7	22	97	Main channel	26	233.5	Catostomidae	2	5.0	3.0
7	22	97	Main channel	26	233.5	Cyprinidae	2	48.0	1.0
7	22	97	Main channel	26	233.5	Hiodontidae	2	0.5	0.5
7	22	97	Side channel	26	215.7	Freshwater drum	2	1.5	0.5
7	22	97	Side channel	26	215.7	Clupeidae	2	0.5	0.5
7	22	97	Side channel	26	215.7	Cyprinidae	2	75.0	10.0
7	22	97	Side channel	26	215.7	Unidentified	2	2.0	1.0
7	22	97	Side channel	26	222.6	Freshwater drum	2	3.5	3.5
7	22	97	Side channel	26	222.6	Catostomidae	2	14.0	1.0
7	22	97	Side channel	26	222.6	Cyprinidae	2	72.0	9.0
7	22	97	Side channel	26	222.6	Hiodontidae	2	0.5	0.5
7	22	97	Side channel	26	222.6	Centrarchidae	2	0.5	0.5
7	22	97	Side channel	26	222.6	Unidentified	2	0.5	0.5
7	22	97	Side channel	26	233.5	Freshwater drum	1	5.0	
7	22	97	Side channel	26	233.5	Catostomidae	1	5.0	
7	22	97	Side channel	26	233.5	Cyprinidae	1	140.0	
7	22	97	Side channel	26	233.5	Unidentified	1	1.0	
7	23	97	Main channel	IR	13.5	Clupeidae	2	17.0	6.0
7	23	97	Main channel	IR	13.5	Cyprinidae	2	4.5	4.5
7	23	97	Main channel	IR	13.5	Centrarchidae	2	1.0	1.0
7	23	97	Side channel	IR	13.5	Clupeidae	2	12.0	1.0
7	23	97	Side channel	IR	13.5	Cyprinidae	2	0.5	0.5
7	25	97	Backwater	IR	9.3	Silversides	2	40.0	29.0
7	25	97	Backwater	IR	9.3	*Gambusia* sp.	2	2.5	0.5
7	25	97	Backwater	IR	9.3	Clupeidae	2	5.5	5.5
7	25	97	Backwater	IR	9.3	Centrarchidae	2	197.5	24.5

Appendix D. Catch per unit effort (CPUE; number/h) for each species of small fish collected using a bottom beam trawl in the lower Illinois River and in Pool 26 of the Mississippi River during July and September 1997. DNT=did not trawl.

Appendix Table D. Catch per unit effort (CPUE; number/h) for each species of small fish collected using a bottom beam trawl in the lower Illinois River and in Pool 26 of the Mississippi River during July and September 1997. DNT=did not trawl.

River		CPUE (number/h)	
mile	Species	August	September
	Illinois River		
5.5	Blue catfish	DNT	0.0
	Channel catfish	DNT	7.8
	Common carp	DNT	7.8
	Freshwater drum	DNT	100.2
	Gizzard shad	DNT	43.8
	River carpsucker	DNT	4.2
	Smallmouth buffalo	DNT	4.2
9.3	Blue catfish	DNT	0.0
	Channel catfish	DNT	12.0
	Common carp	DNT	0.0
	Freshwater drum	DNT	64.2
	Gizzard shad	DNT	4.2
	River carpsucker	DNT	0.0
	Smallmouth buffalo	DNT	4.2
13.5	Blue catfish	DNT	4.2
	Channel catfish	DNT	7.8
	Common carp	DNT	0.0
	Freshwater drum	DNT	91.8
	River carpsucker	DNT	0.0
	Smallmouth buffalo	DNT	4.2

Appendix Table D continued.

River mile	Species	CPUE (number/h) August	CPUE (number/h) September
	Mississippi River		
203.2	Channel catfish	54.0	0.0
	Freshwater drum	18.0	0.0
	Gizzard shad	0.0	4.2
	Goldeye	6.0	0.0
	Mooneye	30.0	0.0
	Skipjack herring	0.0	0.0
	Unidentified sunfish	0.0	4.2
	White bass	0.0	0.0
207.1	Channel catfish	0.0	9.0
	Freshwater drum	0.0	3.0
	Gizzard shad	0.0	0.0
	Goldeye	0.0	0.0
	Mooneye	0.0	0.0
	Skipjack herring	0.0	0.0
	Unidentified sunfish	0.0	0.0
	White bass	0.0	0.0
211.2	Channel catfish	DNT	0.0
	Freshwater drum	DNT	0.0
	Gizzard shad	DNT	0.0
	Goldeye	DNT	4.2
	Mooneye	DNT	4.2
	Skipjack herring	DNT	0.0
	Unidentified sunfish	DNT	0.0

River		CPUE (number/h)	
mile	Species	August	September
	White bass	DNT	4.2
213.6	Channel catfish	DNT	30.0
	Freshwater drum	DNT	3.0
	Gizzard shad	DNT	0.0
	Goldeye	DNT	0.0
	Mooneye	DNT	0.0
	Skipjack herring	DNT	0.0
	Unidentified sunfish	DNT	0.0
	White bass	DNT	0.0
215.7	Channel catfish	42.0	DNT
	Freshwater drum	66.0	DNT
	Gizzard shad	0.0	DNT
	Goldeye	0.0	DNT
	Mooneye	12.0	DNT
	Skipjack herring	0.0	DNT
	Unidentified sunfish	0.0	DNT
	White bass	0.0	DNT
223.0	Channel catfish	138.0	0.0
	Freshwater drum	0.0	0.0
	Gizzard shad	0.0	0.0
	Goldeye	0.0	0.0
	Mooneye	6.0	0.0
	Skipjack herring	0.0	3.0
	Unidentified sunfish	0.0	0.0

River mile	Species	CPUE (number/h) August	CPUE (number/h) September
223.0	White bass	0.0	0.0
227.1	Channel catfish	72.0	0.0
	Freshwater drum	12.0	0.0
	Gizzard shad	0.0	0.0
	Goldeye	6.0	3.0
	Mooneye	6.0	3.0
	Skipjack herring	0.0	0.0
	Unidentified sunfish	0.0	0.0
	White bass	0.0	0.0
233.5	Channel catfish	108.0	0.0
	Freshwater drum	6.0	0.0
	Gizzard shad	0.0	0.0
	Goldeye	0.0	0.0
	Mooneye	6.0	0.0
	Skipjack herring	0.0	0.0
	Unidentified sunfish	0.0	0.0
	White bass	0.0	0.0
238.2	Channel catfish	96.0	0.0
	Freshwater drum	0.0	0.0
	Gizzard shad	0.0	0.0
	Goldeye	0.0	0.0
	Mooneye	12.0	0.0
	Skipjack herring	0.0	0.0
	Unidentified sunfish	0.0	0.0

River		CPUE (number/h)	
mile	Species	August	September
238.2	White bass	0.0	0.0

Appendix E. Catch per unit effort (CPUE; number/h) of adult fishes collected using the rockhopper bottom trawl in the lower Illinois River and in Pool 26 of the Mississippi River, 1996-1997.

Appendix Table E-1. Catch per unit effort, CPUE (1 SE) expressed as catch per hour of rockhopper trawling of all species captured in the lower Illinois River during August-December, 1996. DNT=did not trawl. One trawl sample was conducted at River Mile 16.5 in August, yielding a CPUE of 4.0 fish per hour.

	Mean CPUE (1 SE)			
River mile	August	October	November	December
5.5	DNT	370.93(118.07)	941.25	15.00
9.3	DNT	222.00(90.00)	414.00	27.69
13.5	6.0	436.50(211.50)	927.00	24.00
18.7	3.0	196.25(70.75)	96.00	0.00

Appendix Table E-2. Catch per unit effort, CPUE (1 SE) expressed as catch per hour of rockhopper trawling for individual species at each sampling location during August-December, 1996. DNT=did not trawl. One trawl sample was conducted at River Mile 16.5 in August, yielding a CPUE of 4.0 freshwater drum per hour.

	River	Mean CPUE (1 SE)			
Species	mile	Aug	Oct	Nov	Dec
Bigmouth buffalo	5.5	DNT	0	0	0
	9.3	DNT	4.5(4.5)	0	0
	13.5	0	0	3.0	0
	18.7	0	1.5(1.5)	0	0
Blue catfish	5.5	DNT	2.1(2.1)	3.8	0
	9.3	DNT	0	0	0
	13.5	0	0	6.0	0
	18.7	0	3.0(3.0)	0	0
Channel catfish	5.5	DNT	66.0(36.0)	45.0	6.0
	9.3	DNT	10.5(1.5)	60.0	4.6
	13.5	0	19.5(4.5)	189.0	12.0
	18.7	0	25.5(1.5)	24.0	0
Common carp	5.5	DNT	6.0(6.0)	18.8	0
	9.3	DNT	12.0(6.0)	6.0	0
	13.5	0	6.0(0.0)	6.0	0
	18.7	3.0	6.8(2.3)	6.0	0

Appendix Table E-2, continued

Flathead catfish	5.5	DNT	0	0	0
	9.3	DNT	0	0	9.2
	13.5	0	0	0	0
	18.7	0	1.5(1.5)	0	0
Freshwater Drum	5.5	DNT	284.4(78.6)	847.5	3.0
	9.3	DNT	133.5(103.5)	309.0	4.6
	13.5	3.0	403.5(205.5)	678.0	3.0
	18.7	0	143.8(54.3)	51.0	0
Gizzard shad	5.5	DNT	3.0(3.0)	0	3.0
	9.3	DNT	21.0(15.0)	3.0	0
	13.5	3.0	3.0(3.0)	27.0	6.0
	18.7	0	6.0(6.0)	3.0	0
Highfin carpsucker	5.5	DNT	0	0	0
	9.3	DNT	0	0	0
	13.5	0	0	0	0
	18.7	0	0	6.0	0
Sauger	5.5	DNT	0	7.5	0
	9.3	DNT	0	0	0
	13.5	0	1.5(1.5)	0	3.0
	18.7	0	1.5(1.5)	0	0

Appendix Table E-2, continued

Shorthead redhorse	5.5	DNT	0	3.8	0
	9.3	DNT	0	0	0
	13.5	0	0	0	0
	18.7	0	0	3.0	0
Shortnose gar	5.5	DNT	1.5(1.5)	0	0
	9.3	DNT	0	0	0
	13.5	0	0	0	0
	18.7	0	0	0	0
Smallmouth buffalo	5.5	DNT	3.6(0.6)	15.0	3.0
	9.3	DNT	40.5(25.5)	36.0	4.6
	13.5	0	1.5(1.5)	18.0	0
	18.7	0	3.0(3.0)	0	0
White bass	5.5	DNT	4.3(4.3)	0	0
	9.3	DNT	0	0	4.6
	13.5	0	1.5(1.5)	0	0
	18.7	0	6.8(2.3)	0	0

Appendix Table E-3. Catch per unit effort, CPUE (1 SE) expressed as catch per hour of rockhopper trawling for all species captured in lower Illinois River during June-November, 1997. DNT=did not trawl

	Mean CPUE (1 SE)			
River mile	June	July	September	November
5.5	90.0	255.0(65.0)	253.5(106.5)	1432.0
9.3	34.3	69.0	157.5(28.5)	576.0
13.5	DNT	210.0	138.0(69.0)	DNT
18.7	DNT	387.0	90.0	DNT

Appendix Table E-4. Catch per unit effort, CPUE (1 SE) expressed as catch per hour of rockhopper trawling for each species captured in the lower Illinois River during June-November, 1997. DNT=did not trawl

	River	Mean CPUE (± 1 SE)			
Species	mile	June	July	September	November
Blue catfish	5.5	0	0	1.5(1.5)	0
	9.3	0	0	6.0(3.0)	0
	13.5	DNT	0	0	DNT
	18.7	DNT	0	0	DNT
Channel catfish	5.5	69.0	6.5(1.5)	12.0(0.0)	0
	9.3	34.3	0	9.0(3.0)	36.0
	13.5	DNT	6.0	6.0(3.0)	DNT
	18.7	DNT	24.0	3.0	DNT
Common carp	5.5	0	8.0(8.0)	25.5(16.5)	0
	9.3	0	3.0	12.0(0.0)	0
	13.5	DNT	3.0	1.5(1.5)	DNT
	18.7	DNT	0	0	DNT
Flathead	5.5	0	2.0(2.0)	1.5(1.5)	0
catfish	9.3	0	3.0	0	0
	13.5	DNT	0	3.0(3.0)	DNT
	18.7	DNT	0	0	DNT
Freshwater drum	5.5	12.0	194.0(74.0)	153.0(45.0)	12.0
	9.3	0	51.0	88.5(16.5)	516.0
	13.5	DNT	153.0	123.0(66.0)	DNT
	18.7	DNT	351.0	81.0	DNT

Appendix Table E-4, continued

Gizzard shad	5.5	0	0	25.5(19.5)	1412.0
	9.3	0	0	1.5(1.5)	24.0
	13.5	DNT	3.0	1.5(1.5)	DNT
	18.7	DNT	0	6.0	DNT
Mooneye	5.5	0	0	0	4.0
	9.3	0	0	0	0
	13.5	DNT	0	0	DNT
	18.7	DNT	0	0	DNT
River carpsucker	5.5	0	2.0(2.0)	1.5(1.5)	0
	9.3	0	0	0	0
	13.5	DNT	0	1.5(1.5)	DNT
	18.7	DNT	0	0	DNT
Smallmouth	5.5	9.0	42.5(22.5)	33.0(21.0)	0
buffalo	9.3	0	12.0	40.5(40.5)	0
	13.5	DNT	45.0	1.5(1.5)	DNT
	18.7	DNT	12.0	0	DNT
White bass	5.5	0	0	0	4.0
	9.3	0	0	0	0
	13.5	DNT	0	0	DNT
	18.7	DNT	0	0	DNT

Appendix Table E-5. Catch per unit effort, CPUE (1 SE) expressed as catch per hour of rockhopper trawling for all species captured in Pool 26 of the Mississippi River during August-December, 1996. DNT=did not trawl

	Mean CPUE (1 SE)			
River mile[a]	August	October	November	December
203.2	DNT	109.4(20.7)	45.0	3.0
207.1	69.00	425.5(62.6)	44.5(36.5)	3.0
213.6	63.8(27.8)	162.3(55.2)	12.0(6.0)	18.0
215.7	24.0(3.0)	165.0(78.0)	15.0(6.0)	6.0
223.0	9.0	30.7(17.3)	16.5(4.5)	6.32
227.2	135.0(45.0)	720.6(115.8)	68.7(3.3)	12.0
230.5	39.0	1492.0	64.0(1.0)	27.0
233.5	DNT	821.0(601.0)	30.0	54.0
238.2	DNT	432.5(284.5)	66.0(33.0)	6.0

[a] Data from one trawl sample taken at river mile 211.2 is included in the mean for river mile 213.6 and data from one trawl sample taken at river mile 225.8 is included in the mean for river mile 227.2.

Appendix Table E-6. Catch per unit effort, CPUE (1 SE) expressed as catch per hour of rockhopper trawling for each species captured collected by rockhopper trawling in the navigation channel of Pool 26 of the Mississippi River during August-December 1996. DNT=did not trawl.

		Mean CPUE (1 SE)			
Species	River mile[a]	Aug	Oct	Nov	Dec
Bigmouth	203.2	DNT	3.6(1.8)	0	0
buffalo	207.1	0	23.2(12.8)	0	0
	213.6	0	1.9(1.9)	0	0
	215.7	0	0	0	0
	223.0	0	0	0	0
	227.2	0	5.0(2.6)	0	0
	230.5	0	0	0	0
	233.5	DNT	36.0(36.0)	0	0
	238.2	DNT	3.5(0.5)	0	0
Black crappie	203.2	DNT	0	0	0
	207.1	0	0	0	0
	213.6	0	0	0	0
	215.7	0	0	0	0
	223.0	0	0	0	0
	227.2	0	1.0(1.0)	0	0
	230.5	0	0	0	0
	233.5	DNT	0	0	0
	238.2	DNT	0	0	0

Appendix Table E-6, continued

Black buffalo	203.2	DNT	0.8(0.8)	0	0
	207.1	0	0	0	0
	213.6	0	0	0	0
	215.7	6.0(6.0)	0	0	0
	223.0	0	0	0	0
	227.2	0	0	0	0
	230.5	0	0	0	0
	233.5	DNT	0	0	0
	238.2	DNT	0	0	0
Blue catfish	203.2	DNT	7.5(4.5)	6.0	0
	207.1	0	29.9(9.2)	5.4(5.4)	0
	213.6	4.6(1.4)	1.9(1.9)	0	0
	215.7	0	1.5(1.5)	0	0
	223.0	0	0	0	0
	227.2	0	5.0(3.6)	0	0
	230.5	0	0	0	0
	233.5	DNT	0	0	0
	238.2	DNT	0	0	0
Blue sucker	203.2	DNT	0	0	0
	207.1	0	0	0	0
	213.6	0	0	0	0
	215.7	0	0	0	0
	223.0	0	2.3(1.2)	0	0

Appendix Table E-6, continued

	227.2	0	0	0	0
	230.5	0	0	0	3.0
	233.5	DNT	0	0	0
	238.2	DNT	0	0	0
Channel	203.2	DNT	14.8(5.9)	30.0	3.0
catfish	207.1	69.0	83.5(27.3)	11.5(11.5)	3.0
	213.6	15.4(0.4)	7.0(3.1)	3.0(3.0)	3.0
	215.7	3.0(3.0)	4.5(4.5)	3.0(3.0)	0
	223.0	0	0	4.5(1.5)	0
	227.2	11.6(0.4)	26.8(10.7)	19.9(1.1)	0
	230.5	0	0	17.0(8.0)	0
	233.5	DNT	3.0(3.0)	6.0	0
	238.2	DNT	1.5(1.5)	9.0(9.0)	0
Common carp	203.2	DNT	0.8(0.8)	0	0
	207.1	0	4.4(1.5)	0	0
	213.6	0	15.0(11.1)	0	0
	215.7	0	6.0(3.0)	1.5(1.5)	0
	223.0	3.0	2.3(1.2)	0	0
	227.2	8.3(0.8)	82.6(14.8)	4.0(4.0)	0
	230.5	0	4.0	0	0
	233.5	DNT	0	0	0
	238.2	DNT	11.0(7.0)	0	0

Appendix Table E-6, continued

Flathead	203.2	DNT	1.5(1.5)	0	0
catfish	207.1	0	1.5(0.9)	0	0
	213.6	0	0.7(0.7)	0	0
	215.7	0	1.5(1.5)	0	0
	223.0	0	1.0(1.0)	0	0
	227.2	1.9(1.9)	0	1.5(1.5)	0
	230.5	0	0	0	0
	233.5	DNT	0	0	0
	238.2	DNT	0	0	0
Freshwater	203.2	DNT	61.4(22.7)	3.0	0
drum	207.1	0	186.3(60.3)	22.6(19.3)	0
	213.6	42.2(27.2)	87.0(40.8)	3.0(3.0)	0
	215.7	12.0(3.0)	117.0(63.0)	6.0(6.0)	0
	223.0	3.0	0	1.5(1.5)	0
	227.2	80.6(24.4)	212.2(67.6)	20.4(8.4)	0
	230.5	24.0	8.0	0	0
	233.5	DNT	0	0	0
	238.2	DNT	5.0(1.0)	0	0
Gizzard shad	203.2	DNT	10.4(5.8)	3.0	0
	207.1	0	22.7(9.9)	0.8(0.8)	0
	213.6	0	5.2(3.7)	0	3.0
	215.7	0	3.0(3.0)	4.5(1.5)	0
	223.0	0	3.0(3.0)	10.5(7.5)	0

Appendix Table E-6, continued

	227.2	0	311.6(173.7)	1.5(1.5)	0
	230.5	0	1456.0	0	0
	233.5	DNT	675.0(519.0)	3.0	3.0
	238.2	DNT	195.0(123.0)	6.0(0.0)	0
Goldeye	203.2	DNT	0	0	0
	207.1	0	2.1(1.3)	0	0
	213.6	0	0	0	0
	215.7	0	0	0	0
	223.0	0	0	0	0
	227.2	0	0	0	0
	230.5	0	0	2.5(2.5)	3.0
	233.5	DNT	0	0	0
	238.2	DNT	1.5(1.5)	0	0
Highfin carpsucker	203.2	DNT	0	0	0
	207.1	0	0.8(0.8)	0	0
	213.6	0	0	0	0
	215.7	0	0	0	0
	223.0	0	0	0	0
	227.2	0	0	0	0
	230.5	0	0	0	0
	233.5	DNT	0	0	6.0
	238.2	DNT	0	0	0

Appendix Table E-6, continued

Lake sturgeon	203.2	DNT	0	0	0
	207.1	0	0.8(0.8)	0	0
	213.6	0	0	0	0
	215.7	0	0	0	0
	223.0	0	0	0	0
	227.2	3.4(0.4)	1.0(1.0)	1.5(1.5)	3.0
	230.5	0	0	0	0
	233.5	DNT	0	0	0
	238.2	DNT	3.0(3.0)	0	0
Mooneye	203.2	DNT	0	0	0
	207.1	0	2.0(2.0)	0	0
	213.6	0	0	0	3.0
	215.7	0	0	0	0
	223.0	0	3.0(3.0)	0	3.2
	227.2	0	12.8(8.6)	3.0(3.0)	3.0
	230.5	0	0	0	0
	233.5	DNT	42.0(6.0)	0	27.0
	238.2	DNT	155.5(123.5)	0	0
Quillback	203.2	DNT	1.4(1.4)	0	0
	207.1	0	2.9(1.2)	0	0
	213.6	0	1.3(0.8)	0	0
	215.7	0	1.5(1.5)	0	0
	223.0	0	2.7(2.7)	0	0

Appendix Table E-6, continued

	227.2	0	1.0(1.0)	0	0
	230.5	0	4.0	0	0
	233.5	DNT	0	0	0
	238.2	DNT	3.0(3.0)	0	0
River	203.2	DNT	0	0	0
carpsucker	207.1	0	0.8(0.8)	2.3(0.8)	0
	213.6	0	0	0	0
	215.7	0	0	0	0
	223.0	0	0	0	0
	227.2	1.5(1.5)	2.0(2.0)	0	0
	230.5	0	0	0	0
	233.5	DNT	0	0	0
	238.2	DNT	0	0	0
Sauger	203.2	DNT	0	0	0
	207.1	0	5.9(2.8)	0.8(0.8)	0
	213.6	0	0	1.5(1.5)	0
	215.7	0	0	0	0
	223.0	0	1.3(1.3)	0	0
	227.2	0.8(0.8)	1.0(1.0)	3.5(0.5)	0
	230.5	0	0	0	0
	233.5	DNT	0	3.0	0
	238.5	DNT	1.5(1.5)	1.5(1.5)	0

Appendix Table E-6, continued

Shorthead	203.2	DNT	0	3.0	0
redhorse	207.1	0	0	0	0
	213.6	0	0	0	6.0
	215.7	0	0	0	0
	223.0	0	0	0	0
	227.2	0	1.0(1.0)	4.5(4.5)	0
	230.5	0	0	5.0(5.0)	3.0
	233.5	DNT	0	0	6.0
	238.2	DNT	0	1.5(1.5)	0
Shortnose gar	203.2	DNT	0	0	0
	207.1	0	0	0	0
	213.6	0	0	0	0
	215.7	0	1.5(1.5)	0	0
	223.0	0	0	0	0
	227.2	0	0	0	0
	230.5	0	0	0	0
	233.5	DNT	0	0	0
	238.2	DNT	0	0	0
Shovelnose	203.2	DNT	0	0	0
sturgeon	207.1	0	0	0	0
	213.6	0	1.3(1.3)	1.5(1.5)	3.0
	215.7	1.5(1.5)	6.0(3.0)	0	6.0
	223.0	0	0	0	3.2

Appendix Table E-6, continued

	227.2	16.5(9.0)	2.8(1.6)	16.0(4.0)	6.0
	230.5	12.0	0	38.0(13.0)	21.0
	233.5	DNT	7.0(1.0)	18.0	6.0
	238.2	DNT	12.0(0.0)	42.0(24.0)	6.0
Silver chub	203.2	DNT	0	0	0
	207.1	0	0	0	0
	213.6	0	0	0	0
	215.7	0	0	0	0
	223.0	0	0	0	0
	227.2	0	0	0	0
	230.5	0	0	0	0
	233.5	DNT	0	0	0
	238.2	DNT	0	3.0(0.0)	0
Smallmouth buffalo	203.2	DNT	7.3(0.9)	0	0
	207.1	0	58.0(19.0)	1.1(1.1)	0
	213.6	1.6(1.6)	41.1(10.8)	3.0(3.0)	0
	215.7	1.5(1.5)	22.5(4.5)	0	0
	223.0	3.0	12.7(9.0)	0	0
	227.2	10.5(10.5)	52.0(5.3)	2.0(2.0)	0
	230.5	3.0	20.0	0	0
	233.5	DNT	51.0(39.0)	0	3.0
	238.2	DNT	29.0(13.0)	3.0(0.0)	0

Appendix Table E-6, continued

White bass	203.2	DNT	0	0	0
	207.1	0	0.7(0.7)	0	0
	213.6	0	0	0	0
	215.7	0	0	0	0
	223.0	0	2.3(1.2)	0	0
	227.2	0	2.8(1.6)	0	0
	230.5	0	0	0	0
	233.5	DNT	7.0(1.0)	0	0
	238.2	DNT	11.0(7.0)	0	0

[a] Data from one trawl sample taken at river mile 211.2 are included in the mean for river mile 213.6 and data from one trawl sample taken at river mile 225.8 are included in the mean for river mile 227.2.

Appendix Table E-7. Catch per unit effort, CPUE (1 SE), expressed as catch per hour of rockhopper trawling, of all species captured in Navigation Pool 26 of the Mississippi River during March-November, 1997. DNT=did not trawl

River	Mean CPUE (1 SE)						
mile[a]	March	April	June	July	Sept	Oct	Nov
203.2	54.0(21.0)	75.0	6.3	18.0	241.5(76.5)	DNT	66.0
207.1	6.0	9.0	15.0	100.0	288.7(133.3)	144.0	DNT
213.6	6.0	DNT	18.0	175.5(127.5)	307.5(16.5)	81.0	DNT
215.7	DNT	DNT	3.0	18.0	DNT	DNT	DNT
223.0	3.0	DNT	30.0	6.0	22.5(1.5)	DNT	DNT
227.2	15.0	DNT	60.0	9.0	27.0	30.0	DNT
233.5	9.0	3.0	33.0	3.0	DNT	24.0	DNT
238.5	15.0	DNT	69.0	66.0	21.0	78.0	DNT

[a] Data from river mile 211.2 is included with the mean from river mile 213.6, data from river mile 225.8 is included with the mean from river mile 227.2, and data from river mile 240.2 is included with the mean from river mile 238.5.

Appendix Table E-8. Catch per unit effort, CPUE (1 SE), expressed as catch per hour of rockhopper trawling, for each species captured in the navigation channel of Pool 26 of the Mississippi River during March-November, 1997. DNT=did not trawl

	River	Mean CPUE (± 1 SE)						
Species	mile[a]	March	April	June	July	Sept	Oct	Nov
Bighead	203.2	0	0	0	0	0	DNT	0
carp	207.1	0	0	0	4.0	0	0	DNT
	213.6	0	DNT	0	0	0	0	DNT
	215.7	DNT	DNT	0	0	DNT	DNT	DNT
	223.0	0	DNT	0	0	0	DNT	DNT
	227.2	0	DNT	0	0	0	0	DNT
	233.5	0	0	0	0	DNT	0	DNT
	238.5	0	DNT	0	0	0	0	DNT
Bigmouth	203.2	0	0	0	3.0	7.5(7.5)	DNT	3.0
buffalo	207.1	0	0	0	0	3.0(1.7)	6.0	DNT
	213.6	0	DNT	0	0	0	0	DNT
	215.7	DNT	DNT	0	0	DNT	DNT	DNT
	223.0	0	DNT	0	0	0	DNT	DNT
	227.2	0	DNT	0	0	0	0	DNT
	233.5	0	0	0	0	DNT	0	DNT

Appendix Table E-8, continued

	238.5	0	DNT	0	0	0	0	DNT
Black	203.2	0	0	0	0	0	DNT	0
buffalo	207.1	0	0	0	0	1.5(1.5)	0	DNT
	213.6	0	DNT	0	0	0	0	DNT
	215.7	DNT	DNT	0	0	DNT	DNT	DNT
	223.0	0	DNT	0	0	0	DNT	DNT
	227.2	0	DNT	0	0	0	0	DNT
	233.5	0	0	0	0	DNT	0	DNT
	238.5	0	DNT	0	0	0	0	DNT
Blue	203.2	0	0	0	3.0	1.5(1.5)	DNT	0
catfish	207.1	0	0	0	0	14.6(8.2)	6.0	DNT
	213.6	0	DNT	0	4.5(4.5)	4.5(1.5)	3.0	DNT
	215.7	DNT	DNT	0	0	DNT	DNT	DNT
	223.0	0	DNT	0	0	0	DNT	DNT
	227.2	0	DNT	0	0	0	6.0	DNT
	233.5	0	0	0	0	DNT	0	DNT
	238.5	0	DNT	0	0	0	0	DNT

Appendix Table E-8, continued

Blue	203.2	0	0	0	0	0	DNT	0
sucker	207.1	0	0	0	0	0	0	DNT
	213.6	0	DNT	0	0	0	0	DNT
	215.7	DNT	DNT	0	0	DNT	DNT	DNT
	223.0	0	DNT	0	0	0	DNT	DNT
	227.2	0	DNT	0	0	0	6.0	DNT
	233.5	0	0	0	0	DNT	0	DNT
	238.5	0	DNT	0	0	0	0	DNT
Channel	203.2	15.0(15.0)	30.0	3.2	0	10.5(1.5)	DNT	3.0
catfish	207.1	0	6.0	9.0	56.0	28.7(12.8)	18.0	DNT
	213.6	0	DNT	9.0	36.5(20.5)	54.0(27.0)	18.0	DNT
	215.7	DNT	DNT	0	0	DNT	DNT	DNT
	223.0	3.0	DNT	0	0	0	DNT	DNT
	227.2	3.0	DNT	3.0	3.0	0	9.0	DNT
	233.5	0	0	3.0	0	DNT	18.0	DNT
	238.5	0	DNT	0	0	0	0	DNT

Appendix Table E-8, continued

Common	203.2	0	0	0	0	6.0(3.0)	DNT	0
carp	207.1	0	0	0	0	4.5(2.9)	0	DNT
	213.6	0	DNT	0	0	0	0	DNT
	215.7	DNT	DNT	0	0	DNT	DNT	DNT
	223.0	0	DNT	0	0	0	DNT	DNT
	227.2	0	DNT	0	0	3.0	0	DNT
	233.5	0	0	0	0	DNT	0	DNT
	238.5	0	DNT	0	0	0	0	DNT
Flathead	203.2	1.5(1.5)	0	0	0	3.0(3.0)	DNT	0
catfish	207.1	0	0	0	0	2.1(0.7)	6.0	DNT
	213.6	0	DNT	0	0	0	0	DNT
	215.7	DNT	DNT	0	0	DNT	DNT	DNT
	223.0	0	DNT	0	0	0	DNT	DNT
	227.2	0	DNT	0	0	3.0	0	DNT
	233.5	0	0	0	0	DNT	0	DNT
	238.5	0	DNT	0	0	0	0	DNT

Appendix Table E-8

Freshwater	203.2	3.0(0.0)	0	0	3.0	85.5(19.5)	DNT	3.0
drum	207.1	0	0	6.0	32.0	192.8(70.4)	36.0	DNT
	213.6	0	DNT	9.0	94.5(70.5)	181.5(22.5)	27.0	DNT
	215.7	DNT	DNT	3.0	18.0	DNT	DNT	DNT
	223.0	0	DNT	15.0	0	1.5(1.5)	DNT	DNT
	227.2	0	DNT	12.0	0	0	0	DNT
	233.5	0	0	3.0	0	DNT	6.0	DNT
	238.5	0	DNT	6.0	6.0	0	12.0	DNT
Gizzard	203.2	30.0(3.0)	33.0	0	0	45.0(33.0)	DNT	42.0
Shad	207.1	0	3.0	0	0	12.6(10.8)	0	DNT
	213.6	3.0	DNT	0	1.5(1.5)	0	3.0	DNT
	215.7	DNT	DNT	0	0	DNT	DNT	DNT
	223.0	0	DNT	3.0	0	1.5(1.5)	DNT	DNT
	227.2	0	DNT	3.0	0	9.0	0	DNT
	233.5	0	0	0	0	DNT	0	DNT
	238.5	0	DNT	0	0	0	0	DNT

Appendix Table E-8, continued

Goldeye	203.2	1.5(1.5)	0	0	3.0	0	DNT	6.0
	207.1	0	0	0	0	2.3(1.4)	0	DNT
	213.6	0	DNT	0	1.5(1.5)	0	0	DNT
	215.7	DNT	DNT	0	0	DNT	DNT	DNT
	223.0	0	DNT	0	0	0	DNT	DNT
	227.2	0	DNT	0	0	0	0	DNT
	233.5	0	0	0	0	DNT	0	DNT
	238.5	0	DNT	0	0	0	0	DNT
Highfin	203.2	0	0	0	0	1.5(1.5)	DNT	0
carpsucker	207.1	0	0	0	0	1.4(0.8)	0	DNT
	213.6	0	DNT	0	0	4.5(1.5)	0	DNT
	215.7	DNT	DNT	0	0	DNT	DNT	DNT
	223.0	0	DNT	0	0	0	DNT	DNT
	227.2	0	DNT	0	0	0	0	DNT
	233.5	0	0	0	0	DNT	0	DNT
	238.5	0	DNT	0	0	0	0	DNT

Appendix Table E-8, continued

Lake	203.2	0	0	0	0	0	DNT	0
sturgeon	207.1	0	0	0	0	0	0	DNT
	213.6	0	DNT	0	0	1.5(1.5)	0	DNT
	215.7	DNT	DNT	0	0	DNT	DNT	DNT
	223.0	0	DNT	0	0	0	DNT	DNT
	227.2	0	DNT	0	0	0	0	DNT
	233.5	0	0	0	0	DNT	0	DNT
	238.5	0	DNT	0	0	0	0	DNT
Mooneye	203.2	0	0	0	3.0	13.5(13.5)	DNT	3.0
	207.1	0	0	0	0	5.3(3.1)	0	DNT
	213.6	0	DNT	0	1.5(1.5)	6.0(6.0)	0	DNT
	215.7	DNT	DNT	0	0	DNT	DNT	DNT
	223.0	0	DNT	0	0	4.5(1.5)	DNT	DNT
	227.2	0	DNT	0	0	6.0	0	DNT
	233.5	0	0	3.0	0	DNT	0	DNT
	238.5	0	DNT	0	0	0	0	DNT

Appendix Table E-8, continued

Quillback	203.2	0	0	0	0	4.5(4.5)	DNT	0
	207.1	0	0	0	0	17.0(11.4)	42.0	DNT
	213.6	0	DNT	0	0	13.5(7.5)	6.0	DNT
	215.7	DNT	DNT	0	0	DNT	DNT	DNT
	223.0	0	DNT	0	0	1.5(1.5)	DNT	DNT
	227.2	0	DNT	0	0	3.0	0	DNT
	233.5	0	0	0	0	DNT	0	DNT
	238.5	0	DNT	0	0	0	0	DNT
River	203.2	0	0	0	3.0	24.0(6.0)	DNT	0
carpsucker	207.1	0	0	0	0	29.0(15.6)	0	DNT
	213.6	0	DNT	0	0	9.0(9.0)	0	DNT
	215.7	DNT	DNT	0	0	DNT	DNT	DNT
	223.0	0	DNT	0	0	0	DNT	DNT
	227.2	0	DNT	0	0	0	0	DNT
	233.5	0	0	0	0	DNT	0	DNT
	238.5	0	DNT	0	0	0	0	DNT

Appendix Table E-8, continued

Sauger	203.2	0	0	0	0	1.5(1.5)	DNT	0
	207.1	0	0	0	0	1.4(0.8)	6.0	DNT
	213.6	0	DNT	0	1.5(1.5)	4.5(1.5)	0	DNT
	215.7	DNT	DNT	0	0	DNT	DNT	DNT
	223.0	0	DNT	0	0	3.0(3.0)	DNT	DNT
	227.2	0	DNT	0	0	0	0	DNT
	233.5	3.0	0	0	0	DNT	0	DNT
	238.5	0	DNT	0	0	0	0	DNT
Shorthead	203.2	0	0	0	0	0	DNT	0
redhorse	207.1	0	0	0	0	0	6.0	DNT
	213.6	0	DNT	0	1.5(1.5)	0	0	DNT
	215.7	DNT	DNT	0	0	DNT	DNT	DNT
	223.0	0	DNT	3.0	0	0	DNT	DNT
	227.2	0	DNT	0	0	0	0	DNT
	233.5	0	0	0	0	DNT	0	DNT
	238.5	0	DNT	0	0	0	0	DNT

Appendix Table E-8, continued

Shortnose	203.2	0	0	0	0	0	DNT	0
gar	207.1	0	0	0	0	0	0	DNT
	213.6	0	DNT	0	0	0	0	DNT
	215.7	DNT	DNT	0	0	DNT	DNT	DNT
	223.0	0	DNT	0	0	0	DNT	DNT
	227.2	0	DNT	0	0	0	0	DNT
	233.5	0	0	0	0	DNT	0	DNT
	238.5	0	DNT	0	0	3.0	0	DNT
Shovelnose	203.2	1.5(1.5)	0	0	0	0	DNT	0
sturgeon	207.1	0	0	0	4.0	0	6.0	DNT
	213.6	3.0	DNT	0	3.5(0.5)	1.5(1.5)	3.0	DNT
	215.7	DNT	DNT	0	0	DNT	DNT	DNT
	223.0	0	DNT	6.0	0	0	DNT	DNT
	227.2	12.0	DNT	36.0	6.0	0	6.0	DNT
	233.5	6.0	3.0	24.0	3.0	DNT	0	DNT
	238.5	15.0	DNT	60.0	45.0	18.0	57.0	DNT

Appendix Table E-8, continued

Skipjack	203.2	0	0	0	0	0	DNT	0
herring	207.1	0	0	0	0	0	0	DNT
	213.6	0	DNT	0	0	0	0	DNT
	215.7	DNT	DNT	0	0	DNT	DNT	DNT
	223.0	0	DNT	0	0	4.5(1.5)	DNT	DNT
	227.2	0	DNT	0	0	3.0	0	DNT
	233.5	0	0	0	0	DNT	0	DNT
	238.5	0	DNT	0	0	0	0	DNT
Speckled	203.2	0	0	0	0	0	DNT	0
chub	207.1	0	0	0	0	0	0	DNT
	213.6	0	DNT	0	0	0	0	DNT
	215.7	DNT	DNT	0	0	DNT	DNT	DNT
	223.0	0	DNT	0	0	0	DNT	DNT
	227.2	0	DNT	0	0	0	0	DNT
	233.5	0	0	0	0	DNT	0	DNT
	238.5	0	DNT	0	12.0	0	0	DNT

Appendix Table E-8, continued

Smallmouth	203.2	1.5(1.5)	0	3.2	0	37.5(4.5)	DNT	6.0
buffalo	207.1	6.0	0	0	4.0	72.2(25.8)	12.0	DNT
	213.6	0	DNT	0	29.0(25.0)	24.0(6.0)	21.0	DNT
	215.7	DNT	DNT	0	0	DNT	DNT	DNT
	223.0	0	DNT	3.0	6.0	6.0(3.0)	DNT	DNT
	227.2	0	DNT	6.0	0	0	3.0	DNT
	233.5	0	DNT	0	0	DNT	0	DNT
	238.5	0	0	3.0	3.0	0	6.0	DNT
White bass	203.2	0	0	0	0	0	DNT	0
	207.1	0	0	0	0	0.8(0.8)	0	DNT
	213.6	0	DNT	0	0	3.0(3.0)	0	DNT
	215.7	DNT	DNT	0	0	DNT	DNT	DNT
	223.0	0	DNT	0	0	0	DNT	DNT
	227.2	0	DNT	0	0	0	0	DNT
	233.5	0	0	0	0	DNT	0	DNT
	238.5	0	DNT	0	0	0	0	DNT

[a] Data from river mile 211.2 is included with the mean from river mile 213.6, data from river mile 225.8 is included with the mean from river mile 227.2, and data from river mile 240.2 is included with the mean from river mile 238.5.

Appendix F. Input files for the DIFFLAR2 program used to estimate the distributions of mass concentration of water entrained through the propellers of leading towboats. Sample barcodes and output file names, given by the second lines of the listing, contain the sample identification numbers.

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000002.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                     Sample barcode: 17000002
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
306   841   1376   1911

'Inputs for barge
u        'direction of barge movement; u=upriver; d=downriver
2.928    'Vb[m/s] = speed of barges relative to the water
0.8      'w[-] = wake fraction
0.28     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
150.8    'T[kN] = thrust of one propeller
2.78     'D[m] = propeller diameter
1        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.39     'Ds[m] = vert distance from surface to prop shaft
6.12     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
0.82     'Vriver[m/s] = flow velocity
7        'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000009.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                     Sample barcode: 17000009
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
306   813   1320   1826

'Inputs for barge
u        'direction of barge movement; u=upriver; d=downriver
2.928    'Vb[m/s] = speed of barges relative to the water
0.3      'w[-] = wake fraction
0.05     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
5.2      'T[kN] = thrust of one propeller
1.86     'D[m] = propeller diameter
2        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
0.93     'Ds[m] = vert distance from surface to prop shaft
4.09     'Bs[m] = horizontal distance between prop. shafts.
10.7     'Bb[m] = total width of barge tow

'Inputs for river
0.52     'Vriver[m/s] = flow velocity
6.1      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000014.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                    Sample barcode: 17000014
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
306   2108   3910   5713

'Inputs for barge
d        'direction of barge movement; u=upriver; d=downriver
2.928    'Vb[m/s] = speed of barges relative to the water
0.8      'w[-] = wake fraction
0.36     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
114.4    'T[kN] = thrust of one propeller
2.43     'D[m] = propeller diameter
2        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.22     'Ds[m] = vert distance from surface to prop shaft
5.35     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
0.24     'Vriver[m/s] = flow velocity
6.7      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000018.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                     Sample barcode: 17000018
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
306   938   1570   2203

'Inputs for barge
u        'direction of barge movement; u=upriver; d=downriver
2.928    'Vb[m/s] = speed of barges relative to the water
0.3      'w[-] = wake fraction
0.13     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
72.8     'T[kN] = thrust of one propeller
2.80     'D[m] = propeller diameter
1        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.4      'Ds[m] = vert distance from surface to prop shaft
6.16     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
0.31     'Vriver[m/s] = flow velocity
5.5      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000024.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                     Sample barcode: 17000024
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
306   2102   3898   5693

'Inputs for barge
d        'direction of barge movement; u=upriver; d=downriver
2.928    'Vb[m/s] = speed of barges relative to the water
0.8      'w[-] = wake fraction
5.57     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
171.6    'T[kN] = thrust of one propeller
1.36     'D[m] = propeller diameter
2        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
0.68     'Ds[m] = vert distance from surface to prop shaft
2.99     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
0.52     'Vriver[m/s] = flow velocity
7.3      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000026.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                     Sample barcode: 17000026
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
306   698   1090   1481

'Inputs for barge
u        'direction of barge movement; u=upriver; d=downriver
2.928    'Vb[m/s] = speed of barges relative to the water
0.3      'w[-] = wake fraction
0.27     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
72.8     'T[kN] = thrust of one propeller
2.33     'D[m] = propeller diameter
2        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.17     'Ds[m] = vert distance from surface to prop shaft
5.13     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
0.49     'Vriver[m/s] = flow velocity
4.6      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000030.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                     Sample barcode: 17000030
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
306   2147   3988   5828

'Inputs for barge
d        'direction of barge movement; u=upriver; d=downriver
2.928    'Vb[m/s] = speed of barges relative to the water
0.8      'w[-] = wake fraction
0.4      'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
150.8    'T[kN] = thrust of one propeller
2.55     'D[m] = propeller diameter
2        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.28     'Ds[m] = vert distance from surface to prop shaft
5.61     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
0.31     'Vriver[m/s] = flow velocity
7        'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000031.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                     Sample barcode: 17000031
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
306   898   1490   2083

'Inputs for barge
u        'direction of barge movement; u=upriver; d=downriver
2.928    'Vb[m/s] = speed of barges relative to the water
0.3      'w[-] = wake fraction
0.12     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
62.4     'T[kN] = thrust of one propeller
2.78     'D[m] = propeller diameter
1        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.39     'Ds[m] = vert distance from surface to prop shaft
6.12     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
0.31     'Vriver[m/s] = flow velocity
8.2      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000032.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                     Sample barcode: 17000032
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
306   1914   3522   5130

'Inputs for barge
d        'direction of barge movement; u=upriver; d=downriver
2.928    'Vb[m/s] = speed of barges relative to the water
0.5      'w[-] = wake fraction
0.33     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
114.4    'T[kN] = thrust of one propeller
2.49     'D[m] = propeller diameter
1        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.25     'Ds[m] = vert distance from surface to prop shaft
5.48     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
0.1      'Vriver[m/s] = flow velocity
7.6      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000033.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                     Sample barcode: 17000033
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
306   1174   2042   2909

'Inputs for barge
u        'direction of barge movement; u=upriver; d=downriver
2.928    'Vb[m/s] = speed of barges relative to the water
0.8      'w[-] = wake fraction
0.28     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
156      'T[kN] = thrust of one propeller
2.81     'D[m] = propeller diameter
1        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.41     'Ds[m] = vert distance from surface to prop shaft
6.18     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
0.24     'Vriver[m/s] = flow velocity
7        'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000038.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                    Sample barcode: 17000038
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
306   758   1210   1663

'Inputs for barge
u        'direction of barge movement; u=upriver; d=downriver
2.928    'Vb[m/s] = speed of barges relative to the water
0.8      'w[-] = wake fraction
0.71     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
166.4    'T[kN] = thrust of one propeller
2.26     'D[m] = propeller diameter
1        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.13     'Ds[m] = vert distance from surface to prop shaft
4.97     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
0.4      'Vriver[m/s] = flow velocity
6.4      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000040.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                     Sample barcode: 17000040
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
306   2160   4014   5869

'Inputs for barge
d        'direction of barge movement; u=upriver; d=downriver
2.928    'Vb[m/s] = speed of barges relative to the water
0.8      'w[-] = wake fraction
0.21     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
145.6    'T[kN] = thrust of one propeller
2.95     'D[m] = propeller diameter
1        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.48     'Ds[m] = vert distance from surface to prop shaft
6.49     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
0.15     'Vriver[m/s] = flow velocity
6.7      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000046.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                     Sample barcode: 17000046
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
306   955   1604   2254

'Inputs for barge
u        'direction of barge movement; u=upriver; d=downriver
2.257    'Vb[m/s] = speed of barges relative to the water
0.8      'w[-] = wake fraction
0.72     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
234      'T[kN] = thrust of one propeller
2.45     'D[m] = propeller diameter
2        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.23     'Ds[m] = vert distance from surface to prop shaft
5.39     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
0.1      'Vriver[m/s] = flow velocity
4.3      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000049.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                     Sample barcode: 17000049
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
306   612   918   1223

'Inputs for barge
u        'direction of barge movement; u=upriver; d=downriver
2.257    'Vb[m/s] = speed of barges relative to the water
0.3      'w[-] = wake fraction
0.44     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
10.4     'T[kN] = thrust of one propeller
1.27     'D[m] = propeller diameter
2        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
0.64     'Ds[m] = vert distance from surface to prop shaft
2.79     'Bs[m] = horizontal distance between prop. shafts.
21.4     'Bb[m] = total width of barge tow

'Inputs for river
0.15     'Vriver[m/s] = flow velocity
4.6      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000055.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                     Sample barcode: 17000055
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
306   2137   3968   5799

'Inputs for barge
d        'direction of barge movement; u=upriver; d=downriver
2.928    'Vb[m/s] = speed of barges relative to the water
0.8      'w[-] = wake fraction
0.39     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
182      'T[kN] = thrust of one propeller
2.69     'D[m] = propeller diameter
1        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.35     'Ds[m] = vert distance from surface to prop shaft
5.92     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
0.73     'Vriver[m/s] = flow velocity
6.1      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000056.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                     Sample barcode: 17000056
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
306   2134   3962   5789

'Inputs for barge
d        'direction of barge movement; u=upriver; d=downriver
2.928    'Vb[m/s] = speed of barges relative to the water
0.8      'w[-] = wake fraction
0.37     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
182      'T[kN] = thrust of one propeller
2.72     'D[m] = propeller diameter
1        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.36     'Ds[m] = vert distance from surface to prop shaft
5.98     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
0.64     'Vriver[m/s] = flow velocity
7.3      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000057.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                     Sample barcode: 17000057
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
306   2209   4112   6015

'Inputs for barge
d        'direction of barge movement; u=upriver; d=downriver
2.928    'Vb[m/s] = speed of barges relative to the water
0.8      'w[-] = wake fraction
0.46     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
228.8    'T[kN] = thrust of one propeller
2.72     'D[m] = propeller diameter
1        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.36     'Ds[m] = vert distance from surface to prop shaft
5.98     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
0.76     'Vriver[m/s] = flow velocity
4.6      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000067.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                     Sample barcode: 17000067
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
403   1208   2013   2818

'Inputs for barge
u        'direction of barge movement; u=upriver; d=downriver
3.8125   'Vb[m/s] = speed of barges relative to the water
0.3      'w[-] = wake fraction
0.04     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
20.8     'T[kN] = thrust of one propeller
2.80     'D[m] = propeller diameter
1        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.4      'Ds[m] = vert distance from surface to prop shaft
6.16     'Bs[m] = horizontal distance between prop. shafts.
10.7     'Bb[m] = total width of barge tow

'Inputs for river
0.7      'Vriver[m/s] = flow velocity
6.1      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000070.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                    Sample barcode: 17000070
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
322   912   1502   2094

'Inputs for barge
u        'direction of barge movement; u=upriver; d=downriver
3.2025   'Vb[m/s] = speed of barges relative to the water
0.8      'w[-] = wake fraction
0.44     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
150.8    'T[kN] = thrust of one propeller
2.49     'D[m] = propeller diameter
1        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.25     'Ds[m] = vert distance from surface to prop shaft
5.48     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
0.34     'Vriver[m/s] = flow velocity
7.6      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000073.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                      Sample barcode: 17000073
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
403   671   939   1208

'Inputs for barge
u        'direction of barge movement; u=upriver; d=downriver
3.538    'Vb[m/s] = speed of barges relative to the water
0.3      'w[-] = wake fraction
0.42     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
114.4    'T[kN] = thrust of one propeller
2.35     'D[m] = propeller diameter
2        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.18     'Ds[m] = vert distance from surface to prop shaft
5.17     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
0.24     'Vriver[m/s] = flow velocity
4.3      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000075.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                     Sample barcode: 17000075
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
306   1249   2192   3135

'Inputs for barge
d        'direction of barge movement; u=upriver; d=downriver
2.257    'Vb[m/s] = speed of barges relative to the water
0.8      'w[-] = wake fraction
0.63     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
166.4    'T[kN] = thrust of one propeller
2.33     'D[m] = propeller diameter
2        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.17     'Ds[m] = vert distance from surface to prop shaft
5.13     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
0.31     'Vriver[m/s] = flow velocity
6.4      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000076.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                     Sample barcode: 17000076
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
161   268   375   483

'Inputs for barge
u        'direction of barge movement; u=upriver; d=downriver
1.7995   'Vb[m/s] = speed of barges relative to the water
0.3      'w[-] = wake fraction
0.11     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
31.2     'T[kN] = thrust of one propeller
2.35     'D[m] = propeller diameter
2        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.18     'Ds[m] = vert distance from surface to prop shaft
5.17     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
0.31     'Vriver[m/s] = flow velocity
4.9      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000081.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                     Sample barcode: 17000081
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
322   617   912   1208

'Inputs for barge
u        'direction of barge movement; u=upriver; d=downriver
2.4705   'Vb[m/s] = speed of barges relative to the water
0.5      'w[-] = wake fraction
0.14     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
67.6     'T[kN] = thrust of one propeller
2.69     'D[m] = propeller diameter
2        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.35     'Ds[m] = vert distance from surface to prop shaft
5.92     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
0.61     'Vriver[m/s] = flow velocity
8.2      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000085.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                     Sample barcode: 17000085
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
306   2117   3928   5739

'Inputs for barge
d        'direction of barge movement; u=upriver; d=downriver
2.928    'Vb[m/s] = speed of barges relative to the water
0.8      'w[-] = wake fraction
0.54     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
182      'T[kN] = thrust of one propeller
2.47     'D[m] = propeller diameter
1        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.24     'Ds[m] = vert distance from surface to prop shaft
5.43     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
0.64     'Vriver[m/s] = flow velocity
6.1      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000086.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                    Sample barcode: 17000086
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
306   2182   4058   5935

'Inputs for barge
d        'direction of barge movement; u=upriver; d=downriver
2.928    'Vb[m/s] = speed of barges relative to the water
0.8      'w[-] = wake fraction
0.53     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
176.8    'T[kN] = thrust of one propeller
2.47     'D[m] = propeller diameter
1        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.24     'Ds[m] = vert distance from surface to prop shaft
5.43     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
0.76     'Vriver[m/s] = flow velocity
7.3      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000094.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                     Sample barcode: 17000094
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
242   698   1154   1610

'Inputs for barge
u        'direction of barge movement; u=upriver; d=downriver
3.294    'Vb[m/s] = speed of barges relative to the water
0.8      'w[-] = wake fraction
0.43     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
213.2    'T[kN] = thrust of one propeller
2.72     'D[m] = propeller diameter
1        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.36     'Ds[m] = vert distance from surface to prop shaft
5.98     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
0.76     'Vriver[m/s] = flow velocity
6.4      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000097.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                     Sample barcode: 17000097
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
306   2471   4636   6801

'Inputs for barge
d        'direction of barge movement; u=upriver; d=downriver
2.928    'Vb[m/s] = speed of barges relative to the water
0.8      'w[-] = wake fraction
0.46     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
145.6    'T[kN] = thrust of one propeller
2.43     'D[m] = propeller diameter
2        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.22     'Ds[m] = vert distance from surface to prop shaft
5.35     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
1.34     'Vriver[m/s] = flow velocity
7.6      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000105.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                     Sample barcode: 17000105
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
306   896   1486   2076

'Inputs for barge
d        'direction of barge movement; u=upriver; d=downriver
2.257    'Vb[m/s] = speed of barges relative to the water
0.3      'w[-] = wake fraction
0.06     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
15.6     'T[kN] = thrust of one propeller
2.31     'D[m] = propeller diameter
2        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.16     'Ds[m] = vert distance from surface to prop shaft
5.08     'Bs[m] = horizontal distance between prop. shafts.
21.4     'Bb[m] = total width of barge tow

'Inputs for river
0.88     'Vriver[m/s] = flow velocity
6.4      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000106.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                    Sample barcode: 17000106
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
242   484   726   966

'Inputs for barge
u        'direction of barge movement; u=upriver; d=downriver
2.745    'Vb[m/s] = speed of barges relative to the water
0.3      'w[-] = wake fraction
0.18     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
57.2     'T[kN] = thrust of one propeller
2.43     'D[m] = propeller diameter
2        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.22     'Ds[m] = vert distance from surface to prop shaft
5.35     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
0.61     'Vriver[m/s] = flow velocity
6.4      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000123.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                     Sample barcode: 17000123
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
322   644   966   1288

'Inputs for barge
u        'direction of barge movement; u=upriver; d=downriver
2.501    'Vb[m/s] = speed of barges relative to the water
0.8      'w[-] = wake fraction
0.19     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
104      'T[kN] = thrust of one propeller
2.80     'D[m] = propeller diameter
1        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.4      'Ds[m] = vert distance from surface to prop shaft
6.16     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
0.37     'Vriver[m/s] = flow velocity
6.7      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000172.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                     Sample barcode: 17000172
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
306   2028   3750   5472

'Inputs for barge
d        'direction of barge movement; u=upriver; d=downriver
2.928    'Vb[m/s] = speed of barges relative to the water
0.8      'w[-] = wake fraction
0.37     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
156      'T[kN] = thrust of one propeller
2.62     'D[m] = propeller diameter
1        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.31     'Ds[m] = vert distance from surface to prop shaft
5.76     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
0.61     'Vriver[m/s] = flow velocity
7        'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000181.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                     Sample barcode: 17000181
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
161   376   591   805

'Inputs for barge
u        'direction of barge movement; u=upriver; d=downriver
1.891    'Vb[m/s] = speed of barges relative to the water
0.8      'w[-] = wake fraction
0.13     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
62.4     'T[kN] = thrust of one propeller
2.72     'D[m] = propeller diameter
1        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.36     'Ds[m] = vert distance from surface to prop shaft
5.98     'Bs[m] = horizontal distance between prop. shafts.
32       'Bb[m] = total width of barge tow

'Inputs for river
0.21     'Vriver[m/s] = flow velocity
5.8      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water
'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```

```
'Output file name
"y:\users\shared\steveg\nav\difflar2\output\17000184.out"

'Descriptive information
4       'Ntitle[-] = number of lines of descriptive information.
DIFFLAR2                                     Sample barcode: 17000184
Estimated mass concentration distributions for water that passed
  through the propellers of a leading towboat.  Difflar2 was
  developed by E.R. Holley (1997).

'Inputs for calculations
0.0001   'converge[-] = convergence tolerance for bisection method
0.20     'Vtrans[-] = (max jet vel)/(river vel) for end of jet region
40       'Ny%[-] = no. of vertical strips across width of river (<=50)
1        'dx[m] = length increment for integration of momentum eq. up
4        'NDist%[-] = no. of distances from trawler to towboat (<=20)
List x values [m] on next line(s) from smaller to larger x (NDist%):
483   1020   1557   2094

'Inputs for barge
u        'direction of barge movement; u=upriver; d=downriver
2.7145   'Vb[m/s] = speed of barges relative to the water
0.3      'w[-] = wake fraction
0.09     'Kt[-] = thrust coefficient
3        'n[rev/s] = rotational speed of propellers
31.2     'T[kN] = thrust of one propeller
2.47     'D[m] = propeller diameter
1        'zprop[-] = 1 for Kort nozzles and 2 for open propellers
1.24     'Ds[m] = vert distance from surface to prop shaft
5.43     'Bs[m] = horizontal distance between prop. shafts.
21.4     'Bb[m] = total width of barge tow

'Inputs for river
0.27     'Vriver[m/s] = flow velocity
7.6      'H[m] = river depth
200      'B[m] = channel width
0.03     'Mann = Mannings coefficient
0.40     'alphay = dimensionless ambient transverse diffusion coeff.
1000     'rho[kg/m^3] = density of river water

'Inputs for jet
0.052    'C2[-] = spreading coefficient for co-flowing jets
```