Distribution and Density of Zebra Mussel Veligers at Sites in the Upper Mississippi River System and its Major Tributaries, 2004

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Abstract
Concern over the proliferation of zebra mussels throughout much of the Upper Mississippi River System has resulted in annual efforts to monitor summer densities of zebra mussel veligers. The purpose of this study was to estimate veliger densities (individuals/L) at 22 sites along the UMR mainstem (head of navigation to Pool 22), 8 sites in 7 major tributaries of the UMR, and three sites within the Illinois River system during summer 2004. Overall, density estimates were greater in the lower Upper Mississippi River (UMR) pools than in previous years, especially in Pools 13-22 during August. Densities in the upper portion of the UMR were similar to 2003 estimates. Samples from the St. Croix, Cedar, and Iowa Rivers indicated very few live veligers present. Similarly relatively few live veligers were found in samples collected at the three Illinois River sites.

Distribution and Density of Zebra Mussel Veligers at Sites in the Upper Mississippi River System and Selected Tributaries, 2004

Background

Zebra mussels were introduced to North American waters during the 1980s (Hebert et al. 1989) and eventually spread inland throughout much of the Upper Mississippi River Waterway (Illinois and Mississippi Rivers - UMRW) (O'Neill and Dextrase 1994). Concern regarding the potential negative effects of zebra mussels on native unionid populations (Ricciardi et al. 1995; Ricciardi et al. 1996), particularly Federally threatened and endangered species, has resulted in increased monitoring of both native unionid and zebra mussel populations throughout the system.

In 2001 the U.S. Army Engineer Rock Island and St. Paul Districts initiated an annual monitoring program to examine summer trends in the distribution and density of zebra mussel veligers (*Driessena polymorpha*) along the upper Mississippi River (UMR) mainstem and near the mouths of selected major tributaries. In summer 2004 three additional sites within the Illinois River drainage were included to estimate veliger abundance within that system. Fewer resources are required to monitor abundance of zebra mussel veligers than adults. For this reason, a veliger-monitoring program represents a cost-effective alternative for evaluating and detecting the relative expansion of zebra mussel populations in the UMRS.

Purpose and Scope

The Rock Island District requested that personnel of the invertebrate team at the Engineering Research and Development Center process veliger samples collected during summer 2004 from the UMR, selected UMR tributaries, and 3 Illinois River drainage sites. For each sample, data describing density (individuals/L) and size of veligers were obtained. Results of this study may be considered when making decisions regarding mussel conservation efforts within the UMRS.

Methods

Veliger samples were collected during July, August, and September 2004, at 22 UMR mainstem sites and 12 major UMR tributary sites; samples also were collected at three sites within the Illinois River drainage: near RM 285.5 of the Des Plaines River, at the LaGrange Lock and Dam (L&D), and near RM 5.5 of the Illinois River at Alton (Figure 1). All samples were collected by personnel from the Departments of Natural Resources of Illinois, Iowa, Minnesota, and Wisconsin as well as the U.S. Army Corps of Engineer, Saint Paul District.

Diaphragm pumps (manual and automatic) were used to collect water samples at each site. Sites along the main channel were usually located near the downstream side of lock and dams (L&D). At these sites, at least 10 L of water were collected from mid-depth at three separate locations across the channel (i.e., 25%, 50% and 75% of river width) to create a composite sample of approximately no less than 30 L. Separate equipment was used to collect samples at UMR tributary sites to prevent cross-contamination. Most tributaries were sampled by collecting at least 10 L at each of three depths (0.2, 0.5 and 0.8 of total depth) and at three locations across the river channel (i.e., 25%, 50% and 75% of river width). A

mid-depth cross-sectional composite sample was collected at the mouth of the Wisconsin River. Mid-depth thalweg samples were collected at sites on the Chippewa and Black Rivers. This resulted in composite samples of up to 90 L for each tributary site per sampling date. Sampled material was poured through a 53 μm mesh nylon filter. Filtered material was washed into a sample container and preserved using a 10% buffered sugar formalin solution.

Zebra mussel veligers were enumerated and measured using crossed polarized lighting and an ocular micrometer. Each sample was thoroughly mixed to suspend contents, then a 5 ml subsample was removed for examination. Veligers with flesh present were considered "live" at the time of sampling, whereas empty shells were considered evidence of "dead" individuals at the time of sampling. Veligers were enumerated within consecutive subsamples until either 60% of the total sample volume or more than 100 live veligers were examined. Shell height (μm) was obtained for 100 live individuals per sample when possible. Veliger density (individuals/L) and size distribution were calculated for each sample.

Percent maximum density (PMD) estimates were used to examine variability in longitudinal abundance patterns of veligers among UMR mainstem sites. PMD provides an estimate of relative veliger density at a particular site compared to results from all other sites sampled at approximately the same time. For each sampling date, PMD was calculated as:

$$VD_1/VD_{max}\ldots\ VD_2/VD_{max}\ldots\ VD_n/VD_{max}$$

where VD_n is veliger density at a particular site (n), and VD_{max} is the maximum density among sites on a particular sampling date. For each set of monthly samples, relative veliger density (VD_n) at each site was calculated as a percentage of the greatest site-specific density (VD_{max}). For each site, the three monthly relative density estimates were then used to calculate mean density and standard deviation estimates for comparisons across all sites during the study period.

Veliger "flux" was calculated for UMR mainstem sites by multiplying veliger density and discharge (measured or estimated by local Corps personnel) at each lock and dam. Veliger flux is an estimate the total number of veligers passing below a lock and dam per second.

Measured veligers were classified by both predetermined size limits (SC1, SC2, and SC3) and developmental stage (D-stage, umbonal, intermediate, and pediveliger). SC1 individuals (<100 μm) were those considered to be only recently detectable with cross-polarized lighting because of their newly developed shell. SC3 comprised veligers >200 μm; defined as "competent to settle". SC2 comprised veligers 100-200 μm; these were detectable by cross-polarized lighting, yet not of sufficient size to settle. Veligers were identified by developmental stage based on morphological differences (as depicted in Farr and Alley 2003).

Results and Discussion

UMR Main Channel Densities. Veliger density was spatially and temporally variable along the main stem gradient (Figure 2). There were no live veligers in any samples collected above L&D 2. As in previous years, peak abundance of veligers at most sites generally occurred in July and August then decreased (or remained relatively low) by the time samples were collected in September. Unlike previous years, there was no clear bi-modal pattern of

veliger densities along the latitudinal gradient (Figures 2 & 3). Although estimates did noticeably vary among all sites during July, data collected from August samples indicated an abrupt and substantial increase in veliger density occurring between L&D 11 (28.6 veligers/L) and L&D 12 (244.3/L). In fact, density estimates in the lower pools (14-23) were greater during August and September than in previous years, although there is no way to ascertain a mechanistic explanation for this trend. Relatively low veliger densities in the upper pools could be the result of depressed adult densities in Lake Pepin, whereas elevated densities in the lower pools could indicate one or more self-sustaining populations in Pools 9-12 and perhaps further downriver. The trend of increased veliger densities in the lower portion of the study area is also reflected in the percent maximum density (Figure 3) and veliger flux figures (Figure 4).

Tributaries. Live zebra mussel veligers were present in the St. Croix, Cedar, and Iowa Rivers (Table 1). Veligers were most abundant within the St. Croix River at the Prescott site, although density estimates never exceeded 10.0/L; densities at the Hudson site were very low (< 1.0/L). No veligers were found in samples collected at the Stillwater or St. Croix Falls sites. Very few veligers were found in the August Cedar River sample as well as the September Iowa River sample. Similar evidence of a limited adult presence in these systems has been found in previous years. There was no evidence of live or dead veligers in samples collected in the Chippewa, Black, Wapsinicon, or Wisconsin Rivers; no evidence of veligers has ever been found in samples from the Chippewa and Black Rivers.

Size Class Frequencies. Veligers in each sample collected during 2004 comprised a greater proportion of SC2 individuals (100-200 μm) than other size classes (Figure 5). It is possible that a certain proportion of veligers do not demonstrate clear D-stage characteristics until reaching a size exceeding 100 μm. SC 1 comprised mostly D-stage veligers, whereas both D-stage (smaller) and intermediate (larger) individuals were included in SC 2. SC 3 consisted of mostly umbonal veligers.

Illinois River Samples. Evidence of low veliger densities was found in one or more monthly samples from each of the three Illinois River sites. Live veligers were only present in the August sample from the Des Plaines/Chicago Area site (1.81/L). At the Peoria/LaGrange site, veliger densites ranged from 0.06/L in July to 5.78/L in August before decreasing to 3.33 in September. Densities at the Alton site were similarly low in July (1.69) and August (1.74); no live veligers were found in the September sample. Although zebra mussels have inhabited the Illinois River for some time, veliger abundances at these three sites appear to indicate considerably lower numbers of adults within the Illinois River system compared with much of the Upper Mississippi River system.

Summary

Results of the 2004 veliger monitoring program indicate both similarities and differences from previous year's efforts. Overall, 2004 data reinforce the indication from previous years that veligers are most abundant throughout the UMR during July and August. Also veliger densities in the upper pools remained relatively low for the second consecutive year. Although densities at many sites were greater than in 2003, these estimates generally fall within the range of estimates from previous years. Exceptions to this trend most notably

included July and August samples at L&D's 19 and 22 as well as August samples at L&D 13 and downriver from L&D 14. Veliger densities in these lower pools were in some cases much greater than expected based on sampling in previous years. Future sampling will help determine whether these estimates reflect significant change in the spatial dynamics of veliger abundance or only a natural fluctuation in annual trends in the lower portion of the UMR. Continued monitoring of veliger abundance in the UMR tributaries and at Illinois River sites also will provide important background data with which to gauge a "normal" amount of temporal variability in low-density populations.

Acknowledgement
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Table 1. Density (individuals/L) of zebra mussel veligers in selected major tributaries of the UMR (2001-2004).

	Veliger Abundance (#/L)											
	July				August				September			
	2001	2002	2003	2004	2001	2002	2003	2004	2001	2002	2003	2004
Tributaries	**Live Veligers**											
Chippewa River	0	0	0	0	0	0	0	0	0	0	0	0
St. Croix R. (Hudson)	0.07*	0	0	0.70	0.60*	0	0	0.50	0.22*	0	-	0.22
St. Croix R. (Prescott)	0.10	4.53	0	5.94	2.39	0	0.62	5.69	2.03	0.17	0.64	9.03
St. Croix (Stillwater)	-	-	-	0	-	-	-	0	-	-	-	0
St. Croix Falls	-	-	-	0	-	-	-	0	-	-	-	0
Black River	0.00	0	0	0	0	0	0	0	0	0	0	0
Wapsinicon River	0.93	0.02	0	0	3.71	0.02	0	0	0	0.14	-	0
Wisconsin River	-	0.39	0	0	0.02	0	0	0	0	0.03	0	0
Iowa R. - mouth	0	0.11	0	0	0.35	0	0	0	0	0	-	0.42
Cedar R. - mouth	0	0	0	0	0	0	0	0.03	0.20	0	-	0
Snake River	-	-	-	0	-	-	-	0	-	-	-	0
Sunrise River	-	-	-	0	-	-	-	0	-	-	-	0
	Dead Veligers											
Chippewa River	0	0	0	0	0	0	0	0	0	0	0	0
St. Croix R. (Hudson)	0.01*	0	0	0.13	0.06*	0	0	0.04	0.02*	0	-	0
St. Croix R. (Prescott)	0.01	0.47	0	0.78	0.02	0	0.12	0.83	0.08	0.07	0.06	0.64
St. Croix (Stillwater)	-	-	-	0	-	-	-	0	-	-	-	0
St. Croix Falls	-	-	-	0	-	-	-	0	-	-	-	0
Black River	0	0	0	0	0.02	0	0	0	0	0	0	0
Wapsinicon River	9.42	0.04	0	0	0.20	0.02	0	0	0.20	0.07	-	0
Wisconsin River	-	0.12	0	0	0.36	0	0	0	0.02	0.06	0	0
Iowa R. - mouth	0.13	0.11	0	0	0.07	0	0	0	0.23	0	-	0
Cedar R. - mouth	0	0	0	0	0	0.17	0	0	0.60	0.25	-	0
Snake River	-	-	-	0	-	-	-	0	-	-	-	0
Sunrise River	-	-	-	0	-	-	-	0	-	-	-	0

* represents sample from Kinnickinnic R. mouth

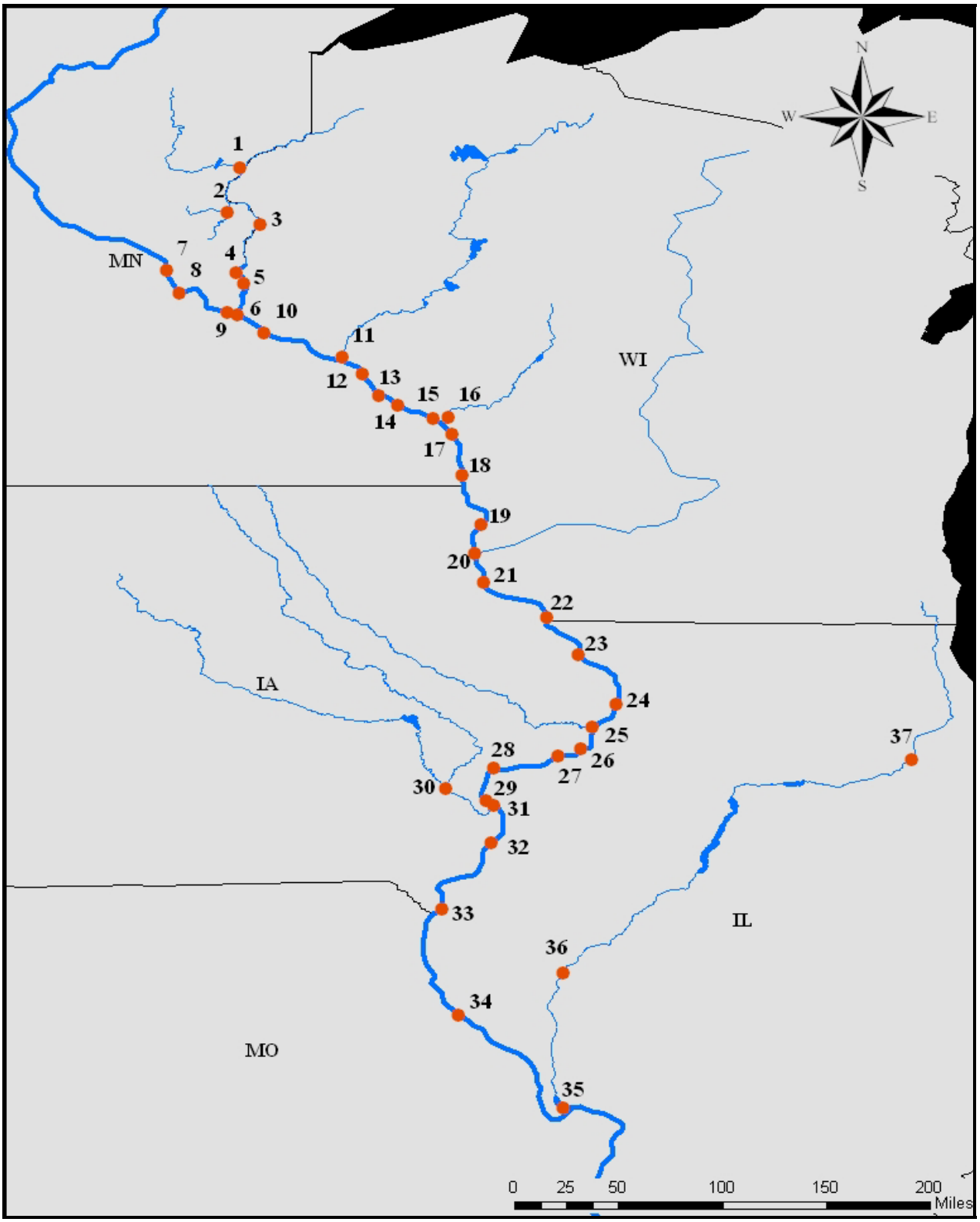

Figure 1. Locations of veliger sampling stations along the Upper Mississippi and Illinois Rivers; 8 additional stations were located in selected Mississippi River tributaries.

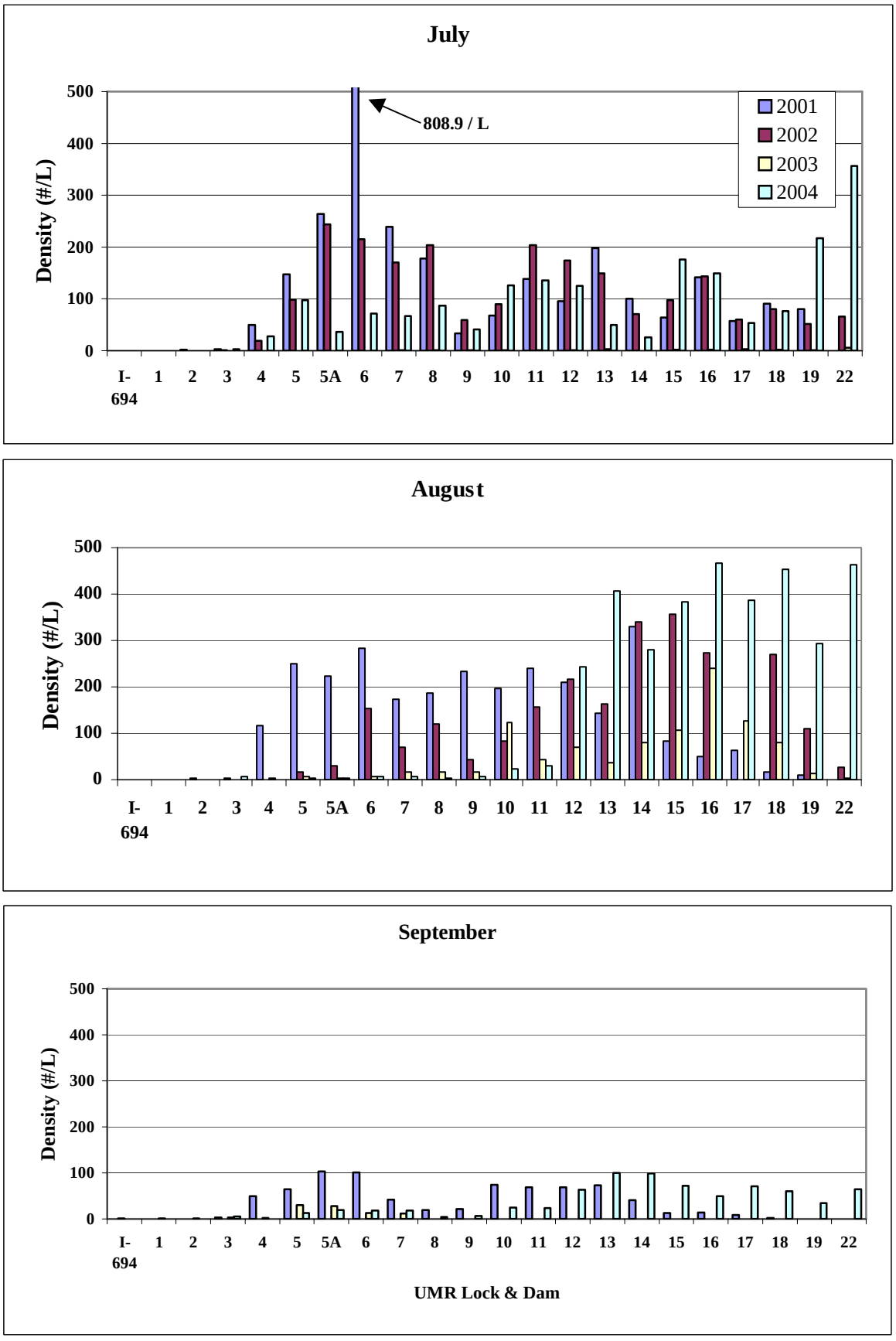

Figure 2. Summary of zebra mussel veliger densities (#/L) in tailwater areas of Upper Mississippi River Locks & Dams (L&D) from 2001-2004.

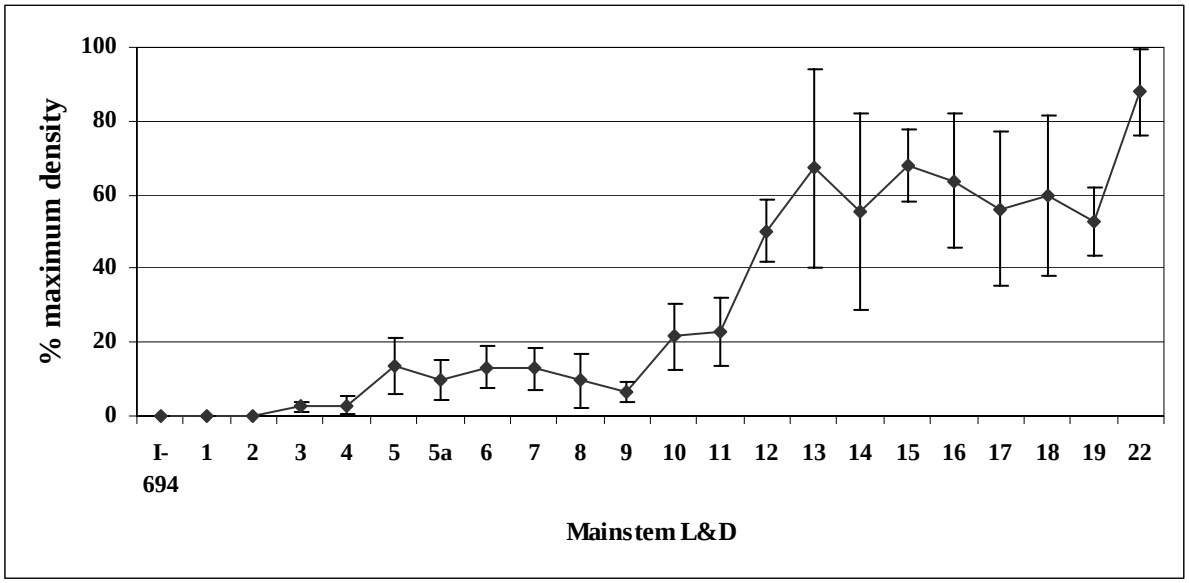

Figure 3. Percent maximum density of zebra mussel veligers in the UMR during Jul-Sept 2004. Results indicate a mean estimate (± 1 SD) of veliger relative density among all sites.

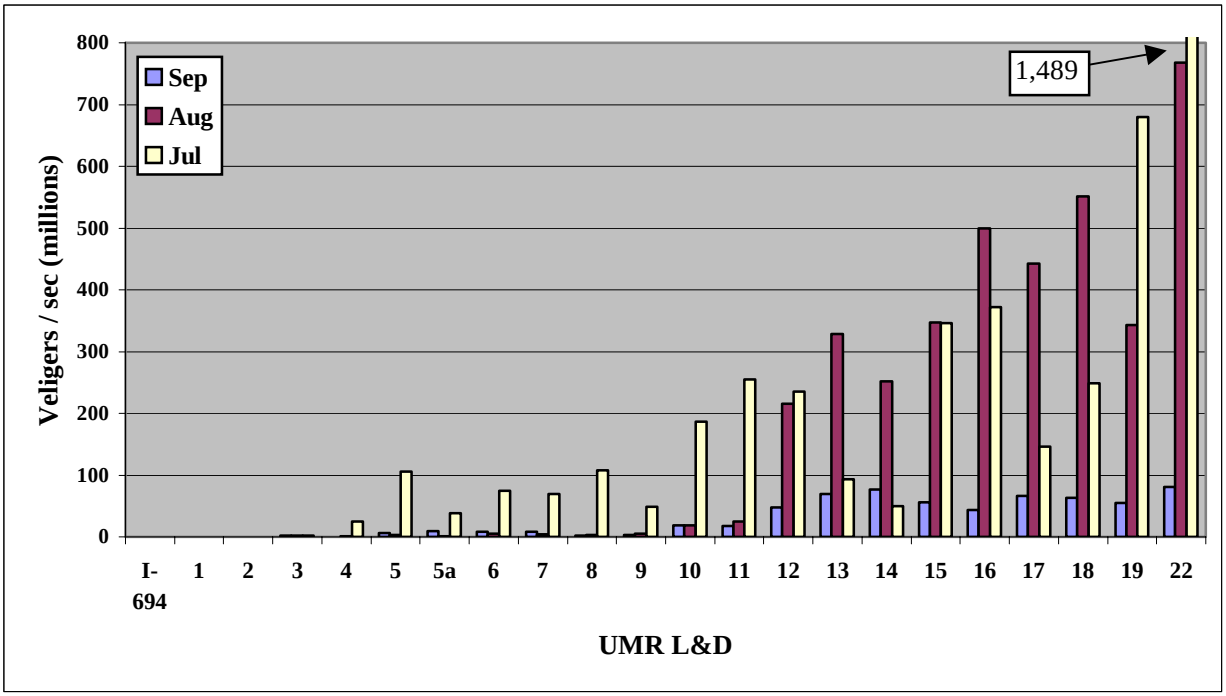

Figure 4. Estimated veliger flux at each sampling location along the Upper Mississippi River during summer 2004.

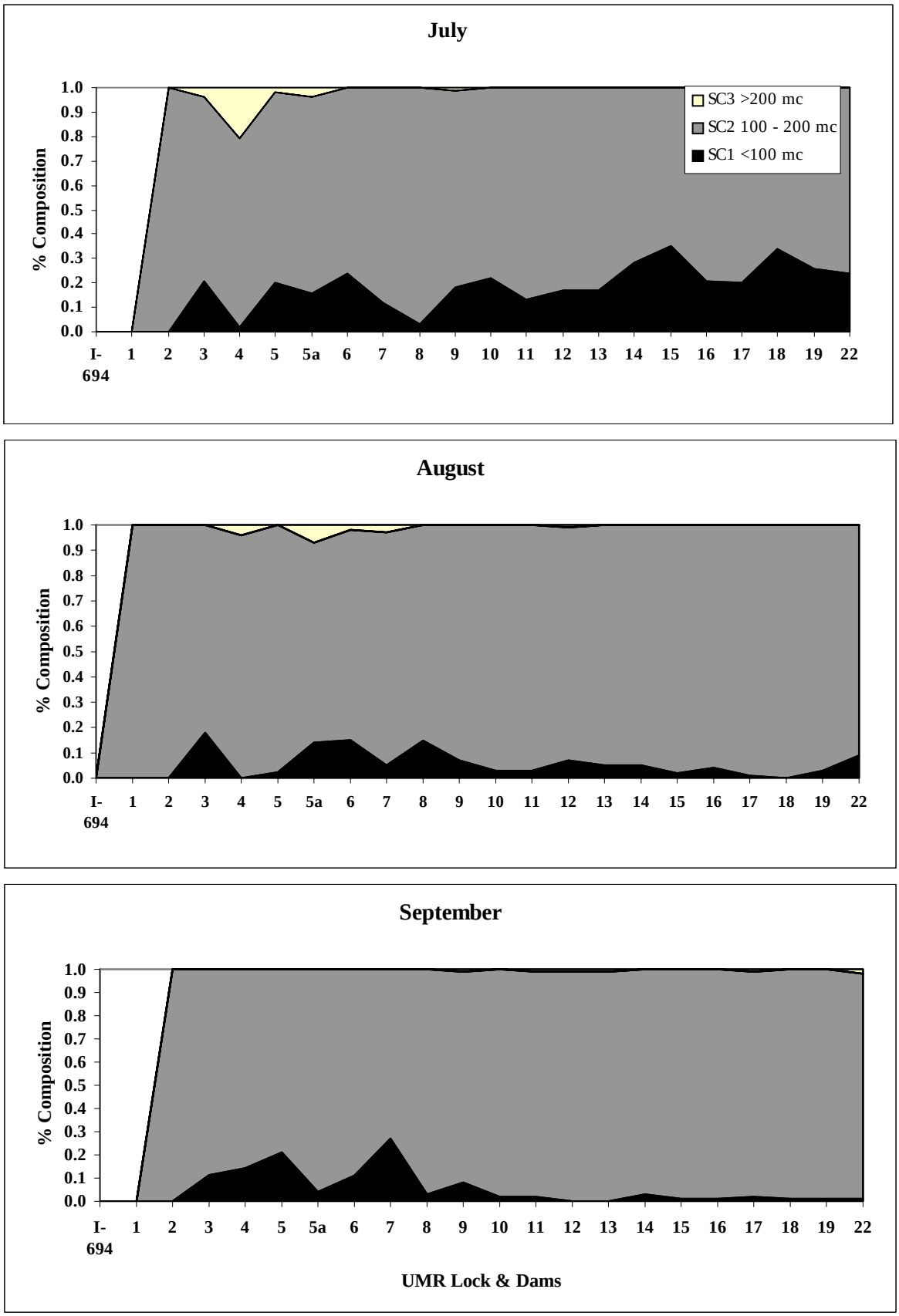

Figure 5. Relative abundance of each size class in veliger samples collected in the UMR during summer 2004.