Results of 2004 Monitoring of Freshwater Mussel Communities of the Saint Croix National Scenic Riverway, Minnesota and Wisconsin.

By

Wisconsin Department of Natural Resources,

U. S. National Park Service

and U. S. Fish and Wildlife Service

Wisconsin Department of Natural Resources.

La Crosse, WI. 54601.

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A large number of people helped on the project. These generous people include:

Byron Karns, U. S. National Park Service, St. Croix Falls, Wisconsin.

Greg Plotz, Wisconsin Department of Natural Resources, La Crosse, Wisconsin.

Patrick Short, Wisconsin Department of Natural Resources, La Crosse, Wisconsin.

Mark Endris, Wisconsin Department of Natural Resources, Eau Claire, Wisconsin.

Michelle Marron, Wisconsin Department of Natural Resources, Alma, Wisconsin.

Kenneth Von Ruden, Wisconsin Department of Natural Resources, La Crosse, Wisconsin.

Liesel Virchow, U. S. National Park Service, St. Croix Falls, Wisconsin.

Gary Wege, U. S. Fish and Wildlife Service, Bloomington, Minnesota.

Mandy Beall, Department of Natural Resources and Univ. of Wisconsin Extension.

Nick Rowse, U. S. Fish and Wildlife Service, Bloomington, Minnesota.

Ron Benjamin, Wisconsin Department of Natural Resources, La Crosse, Wisconsin.

Susan Oetker, U. S. Fish and Wildlife Service, Bloomington, Minnesota.

David J. Heath, Wisconsin Department of Natural Resources, La Crosse, Wisconsin.

Randy Ferrin, U. S. National Park Service, St. Croix Falls, Wisconsin.

Bob Whaley, U. S. National Park Service, St. Croix Falls, Wisconsin.

Scott Yess, U. S. Fish and Wildlife Service, La Crosse, Wisconsin.

Sara Southworth, U. S. National Park Service, St. Croix Falls, Wisconsin.

Allison Pierce, U. S. National Park Service, St. Croix Falls, Wisconsin.

Tony Brady, U. S. Fish and Wildlife Service, Genoa, Wisconsin.

ABSTRACT

In 2004, we repeated freshwater mussel samples at two of five long-term monitoring sites located on the St. Croix River and Namekagon rivers, Minnesota and Wisconsin. These two sites included Interstate Parks and Hudson on the lower St. Croix River. The purpose was to determine population and community characteristics over time for long-term monitoring. The questions we wanted answered were 1) Has population density changed? 2) Has size or age structure changed? 3) Was there a change in taxa richness? 4) How has community composition changed? 5) Has there been a change in living/dead or sex ratios?

From 1988-2004, mean population densities of total mussels (#/m^2) changed only at Interstate and not at Hudson. Interstate densities ranged from 16.1-19.7 during 1988, 1996 and 2000 and dropped to 9.5 in 2004. In general, density of taxa deemed "sensitive" to environmental changes decreased as well from about 2.73 to 1.74. "Indifferent" taxa changed during 2004. Densities were 7.54 in 2004 compared to 13.5 to 16.1 in previous years. Most of this change was due to the drop in densities since 2000 of the dominant taxa, *T. truncata*. "Exploitive" taxa changed little although the power of this test was less sensitive than all previous ones.

Although the power of our tests for individual rare species was poor, we compared mean population densities for two federally endangered species, *Q. fragosa* and *L. higginsii. Q. fragosa,* which was found only at Interstate, had a mean population density of 0.028, 0.027, 0.020 and 0.000 in 1988, 1996, 2000 and 2004, respectively. Mean densities were not significantly different among all four years but the 2004 density was significantly different from all previous years combined. Also, there was a steady trend in declining densities for this rare species over years.

The federally endangered *L. higginsii* was found in quadrat samples at Interstate and Hudson. In 2004, the mean density at Interstate was 0.0122 and 0.1340 at Hudson. Population densities at Hudson have steadily increased since 1988, from 0.014. The difference was significant at Hudson. There is no apparent change in mean population density at Interstate.

Both *T. truncata* and *T. donaciformis* continued to decline at both sites and these declines were statistically significant. In 1988, there were 0.03/m^2 and 1.02/m^2 *T. donaciformis* at Hudson and Interstate, respectively. By at least 2004, none were present in quadrat samples. *T. truncata* densities dropped from 0.51/m^2 to 0.06/m^2 at Hudson and 9.6/m^2 to 3.7/m^2 at Interstate.

For six taxa at Interstate, gradually decreasing young recruitment relative to adults was seen. These taxa included *E. lineolata, F. flava, L. cardium, Q. metanevra, T. verrucosa* and *T. truncata.* None had an increasing trend in young recruitment. At Hudson, four of the six taxa measured had decreasing relative recruitment. These were *A. p. plicata*, *O. reflexa*, *P. coccineum* and *Q. p. pustulosa*. There were no apparent trends in the remaining two taxa.

At Hudson, four taxa had increasing living/dead ratio trends from 1988, 2000 and 2004. These taxa were *A. p. plicata* (1.31 to 3.52), *F. flava* (0.59 to 3.43), *L. fragilis* (0.43 to 1.00) and *L. higginsii* (0.04 to 0.75). Two taxa had decreasing ratios; these included *P. grandis* (2.00 to 0.20) and *T. donaciformis* (0.02 to 0.00). At Interstate, three taxa had decreasing living/dead ratio trends. These taxa were *E. triquetra* (4.00 to 0.33), *F. flava* (2.77 to 1.20) and *T. donaciformis* (1.62 to 0.00).

For sexually dimorphic taxa, only *E. lineolata* showed any four-year trend of females relative to males at each monitoring site. At Interstate, the ratio changed from 2.14 to 0.71 and at Hudson from 1.2 to 0.3 from 1988 to 2004. This indicates a steadily declining number of females relative to males at both locations.

Detectible native taxa richness may have slightly increased at Interstate. Richness was 27, 26, 26 and 29 taxa per 1800 individuals during 1988, 1996, 2000 and 2004. At Hudson, richness may have slightly decreased from 24 and 25 per 1000 individuals in 1988 and 2000, respectively, to 22 in 2004.

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INTRODUCTION

This report briefly summarizes year 2004 results of continued long-term monitoring of freshwater mussels in the St. Croix River. This monitoring was begun in 1988 when five locations on the St. Croix and Namekagon rivers were sampled (see Heath and Rasmussen, 1990). During 1995 and 1996, four of the five monitoring sites were re-sampled (Doolittle and Heath, 1997; Doolittle, Heath and Rasmussen, 1995). In 2000, three of the five long-term monitoring locations were re-sampled including Hudson, Marine2 and Interstate. In 2004, two of the sites, Hudson and Interstate were sampled. The purpose of this 2004 investigation was to repeat the sampling protocols used in 1988 and following years and compare results through time.

METHODS AND MATERIALS

A complete description of monitoring site locations and sampling methods are included in Heath and Rasmussen, 1990. In summary, at each of the two monitoring sites, we hand collected all mussels from randomly-placed 1m^2 quadrats, counted and identified to species both living and dead unionids, margaritiferids, *Corbicula* and *Dreissena*, measured and aged them, and determined gravidity status. We also determined the sex of taxa that were sexually dimorphic concholoigically. In 2004, we took 112 quadrat samples at Hudson and 164 at Interstate. The Hudson quadrat samples comprised a total of 0.077% of the total Hudson surface area while the Interstate comprised a total of 0.048%. In addition to quadrat sampling, we randomly hand-collected mussels (relative abundance collections) to complement comparisons of relative abundance and age and total length distributions between years and sites, particularly if quadrat samples provided insufficient numbers of mussels. Finally, we searched microhabitats with the best potential of harboring rare species like *Simpsonaias ambigua* and *Cumberlandia monodonta*. Locations of quantitative randomly selected stations are given in Figures 1 and 2. The dates sampled at each of the two 2004 study areas are given below.

Interstate: 6, 20-22 July; 23-25 August 2004
Hudson: 7, 23, 27-29 July 2004.

Numerical relative abundance trends over years was determined by the following rules: 1) If relative abundance values increased from the previous year among all years, then the trend was considered “increasing”. 2) If relative abundance values decreased from the previous year among all years, then the trend was considered “decreasing”. 3) If the value in 2004 was a factor of three or more of the 1988 value, then the trend was considered either “decreasing” or “increasing” depending on the direction of the change and regardless of the values from the interim years. 4) All others were considered to have no trend.

RESULTS AND DISCUSSION

TAXA RICHNESS

The cumulative number of native taxa collected using methods whose results are representative of the community (i.e. quadrat and relative abundance collection methods) was influenced by the total number of individuals collected. Per 1000 native individuals, Hudson had 24, 25 and 22 taxa during 1988, 2000 and 2004, respectively. Interstate had 27, 26, 26 and 29 taxa per 1800 individuals during 1988, 1996, 2000 and 2004, respectively (Figures 3, 4). Based on these numbers, measured native taxa richness may have slightly decreased over the years at Hudson and slightly increased at Interstate. These differences may not be real considering the rarity of some mussel taxa whose probability of appearing in a limited sample is low, but when they do appear can significantly raise richness values.

In addition to the native taxa, changes have occurred in taxa richness for exotics. Zebra mussels (*Dreissena polymorpha*) were absent from Hudson in 1988, but present since at least 2000. Asian clams (*Corbicula fluminea*) have been present in our Hudson samples since 1988. Neither exotic was found at Interstate until 2004 when one living *D. polymorpha* was found by field staff. Another staff member did not verify the identification of this specimen and it was not retained or vouchered. The animal was destroyed and a later search for the remains proved negative. This single find should not be interpreted as an indicator of an existing, local, viable population. A list of taxa found using all collection methods at each site is given in Table 1.

NUMERICAL RELATIVE ABUNDANCE

Some trends in numerical relative abundance were apparent. At most, four trend points were available and therefore, these "trends" should be interpreted cautiously. More definitive trends can be established using six temporal points.

At Interstate, a total of six taxa had increasing trends in relative abundance (Table 2). These included *Actinonaias ligamentina carinata, D. polymorpha, Lampsilis cardium, Ligumia recta, Obovaria olivaria* and *Tritogonia verrucosa*. A total of three taxa had decreasing relative abundance trends. These included *Alasmidonta marginata, Quadrula fragosa* and *Truncilla donaciformis*.

At Hudson, a total of six taxa had increasing trends in relative abundance (Table 3). These included *A. l. carinata, C. fluminea, D. polymorpha, Ellipsaria lineolata, Fusconaia flava* and *Lampsilis higginsii*. A total of 11 taxa had decreasing relative abundance trends. These included *Lasmigona complanata, L. recta, Obliquaria reflexa, Pyganodon grandis, Quadrula metanevra, S. ambigua, Strophitus u. undulatus, T. donaciformis, Truncilla truncata, T. verrucosa* and *Utterbackia imbecillis*.

Taxa increasing in relative abundance common to both sites included *A. l. carinata* and *D. polymorpha*. One taxa, *T. donaciformis,* uniformly decreased in abundance at both sites. This species declined 6.1 percentage points at Interstate and 0.5 at Hudson. This species was entirely absent from our 2004 samples at both sites. This decline appears to be ongoing since 1988 and was noted in previous monitoring reports.

POPULATION DENSITY

Arithmetic population densities by taxa, total mussels and taxa groups for the two monitoring sites are given in Tables 4 and 5. Summaries of tests of significance among all years for the mean of the natural log transformed data for total mussels and taxa groups are given in Table 6.

At the Hudson site, total mussel population densities were not significantly different among years. Densities were 7.13, 6.57 and 7.55/m² during 1988 (n=69), 2000 (n=152) and 2004 (n=112), respectively. None of the taxa groupings ("sensitive", "indifferent" or "exploitive") were different among years as well. With the number of 2004 samples we took, we could detect a 19% change in mean total mussel density.

At the Interstate site, total mussel population densities were not significantly different among years except for 2004 when the density dropped to 9.5/m² (n=164) from 16.1-19.7/m² in previous years (n=108, 149 and 150). This represents about a 46% reduction in total mussel density at the site from all previous years combined. With the number of 2004 samples collected, we could detect a minimum of 14% change in mean total mussel density.

A similar decline in total mussel density at selected subsites in Interstate was noted by Macalester College (Hornbach, 2004). He found that total mussel densities had dropped about 62% from 1992 to 2002.

Mean density of taxa groups at Interstate changed between some years for some groups (Table 5). Density of "sensitive" taxa in 2004 (1.74/m²) was different from 1996 and 2000 (2.54 and 3.14/m², respectively) but not from 1988 (2.51/m²). There was no difference in density among years 1988, 1996 and 2000. With the number of 2004 samples obtained, we could detect a 20% change in mean "sensitive" taxa group mussel density.

In 2004 density of "Indifferent" taxa at Interstate was different from each previous year and all previous years were not different among themselves. In 2004, the mean density was 7.54/m² compared to 13.5 to 16.1/m² in previous years. Most of this change was due to the drop in densities since 2000 of the dominant taxa, *T. truncata*. With the number of 2004 samples we took, we could detect a 16% change in mean "indifferent" taxa group mussel density.

Mean densities among years for "exploitive" taxa at Interstate were different only for 2000 compared to other years, and were similar for the years 1988, 1996 and 2004. The density in 2000 (0.38) was different than the densities in 1988 (0.21), 1996 (0.11) and 2004 (0.21). With the number of 2004 samples attained, we could detect a 47% change in mean "exploitive" taxa group mussel density.

The federally endangered *Q. fragosa,* currently present only at Interstate, had a mean population density of 0.00/m² in 2004. This compares to 0.028, 0.027, and 0.020/m² during 1988, 1996 and 2000, respectively. Mean densities were not significantly different among all four years although the power of our tests for rare species is quite poor. We would have to take about 2000 quadrat samples to detect a 50% change in mean population densities among years. Although mean densities across years were not different, the 2004 density was significantly different from all previous years combined. In other words, the population density of *Q. fragosa* has changed in 2004 compared to a pooled mean from 1988, 1996 and 2000 (~0.025 to 0.00/m²). Also, mean densities do appear to be trending downwards over years. *Q. fragosa* is still present, although it did not appear in our quadrat samples. During fall

2004 collections to aggregate mussels for propagation, we were able to find a total of 51 specimens during 1.5 days of searching.

The federally endangered *L. higginsii* was found in quadrat samples at Interstate and Hudson. In 2004, the mean density at Interstate was 0.012/ m^2. This compares to 0.028, 0.00 and 0.013/m^2 during 1988, 1996 and 2000, respectively. Densities were not significantly different among years although the power of our tests for rare species is quite poor. We would have to take about 3150 quadrat samples to detect a 50% change in mean population densities among years. Mean densities do not appear to be trending in any direction over years although densities of this species may have declined mirroring the change in total mussel densities.

In 2004, the mean density of *L. higginsii* at Hudson was 0.134/m^2. This compares to 0.015 and 0.086/m^2 during 1988 and 2000, respectively. Densities were not significantly different among years although the power of our tests for rare species is quite poor. We would have to take about 1400 quadrat samples to detect a 50% change in mean population densities among years. Based on the trend over years, mean densities may be increasing.

Mean density of *T. donaciformis* in number/m^2 differed significantly among most years within each site. At Hudson it dropped from 0.03 in 1988 to 0.00 in 2000 and 2004. At Interstate, it was 1.02, 0.62, 0.05 and 0.00 during 1988, 1996, 2000 and 2004 respectively. These differences were significant among years except for the latter two years at each site where densities were near zero.

Mean density of *T. truncata* in number/m^2 appears to be declining at both sites. At Hudson it dropped from 0.51 in 1988 to 0.13 in 2000 and 0.06 in 2004. There was a significant decline between 1988 and later years. At Interstate, 2004 densities were significantly lower than any previous year. Densities were 8.50, 9.23, 11.05 and 3.70 during 1988, 1996, 2000 and 2004, respectively. This represents about a 61% decline in 2004 from previous years. The 2004 values were significantly different than each previous year.

Other taxa that have significantly changed over years at Hudson include: *Elliptio dilatata* 1988 to later years (1.49 to ~0.63); *F. flava* from 1988 to 2004 (0.70 to 1.41); *Leptodea fragilis* from 1988 to later years (0.13 to ~0.04); *D. polymorpha* from earlier years to 2004 (~0.01 to 0.18); and *Pleurobema coccineum* between 1988 and 2004 (0.39 to 0.18).

Other taxa that have significantly changed over years at Interstate include: *A. marginata* between 1988 and 2004 (0.21 to 0.03); *E. dilatata* between 1988 and later years (0.83 to ~0.49); *Epioblasma triquetra* between 2004 and all previous years (0.13 to 0.68); and *L. cardium* between the earlier pair of years and the latter pair (0.13 to ~0.27).

The large 2004 Interstate decline in densities of *T. truncata*, the dominant taxa, did have a limited influence on results of density tests for total mussels. When we excluded this species from total mussel density tests among years, the 2004 value (5.81/m^2) was still significantly different from 1988 and 2000, but not 1996. It was also significantly different from all previous years pooled. From this we concluded that generally, total mussels excluding *T. truncata* have declined as well, and the dominant taxa did not significantly influence the observed change in total mussels.

SPATIAL DENSITY PATTERNS

We spatially mapped densities at both sites. At Hudson, no large-scale obvious patterns were seen (Figure 5). There were small, low-density areas seen at two locations: the upstream 250m of the study area and from 50 to 300m downstream of the railroad bridge. At Interstate, the upstream half of the study area had a higher population density over the years than the downstream half (19.6 vs. 10.4). Also, high population densities seem to be associated with the thalweg, or at least the edge of the thalweg although there was not a strong relationship between depth and population density overall (Figure 6).

LIVING/DEAD AND SEX RATIOS

At Interstate, three taxa had decreasing living/dead ratio trends among the four years (Table 7). These taxa were *E. triquetra* (4.00 to 0.33), *F. flava* (2.77 to 1.20) and *T. donaciformis* (1.62 to 0.00). There was no apparent four-year trend for all other taxa. Total mussels may have decreased over time. They were 1.7, 2.2, 1.46 and 0.82 during 1988, 1996, 2000 and 2004, respectively.

At Hudson, four taxa had increasing living/dead ratio trends from 1988, 2000 and 2004 (Table 7). These taxa were *Amblema p. plicata* (1.31 to 3.52), *F. flava* (0.59 to 3.43), *L. fragilis* (0.43 to 1.00) and *L. higginsii* (0.04 to 0.75). Two taxa had decreasing ratios. These included *P. grandis* (2.00 to 0.20) and *T. donaciformis* (0.02 to 0.00). There was no apparent four-year trend for all other taxa and total mussels.

We were only able to calculate sex ratio (# of females/# of males) for six taxa. These taxa were *Ellipsaria lineolata, E. triquetra, L. higginsi, L. siliquoidea, L. cardium*, *L. recta,* and *T. verrucosa* (Table 8). Only *E. lineolata* showed any four-year trend of females relative to males at each monitoring site. At Interstate, the ratio changed from 2.14 to 0.71 and at Hudson from 1.2 to 0.3 from 1988 to 2004. This indicates a steadily declining number of females relative to males at both locations for this species.

POPULATION LENGTH AND AGE STRUCTURES

We used the first quartile (Q_1) of the length distribution as a measure of relative recruitment. The first quartile is that length below which the lowest 25% of the lengths lay. In a year of good young recruitment, the Q_1 should be small because of the large proportion of small individuals; in a year of low recruitment, on the other hand, the Q_1 should be larger because of the larger proportion of large individuals.

Some taxa at some locations had a three to four-year Q_1 trend (Table 9) in relative recruitment. At Interstate, *E. lineolata* (40 to 57mm), *F. flava* (35 to 47mm), *L. cardium* (40 to 81mm), *Q. metanevra* (38 to 71mm), *T. truncata* (27 to 38mm) and *T. verrucosa* (51 to 101mm) had increasingly greater Q_1 from 1988 to 2004. This indicates a reduction in long-term young recruitment over time.

At Hudson, Q_1 increased for *A. p. plicata* (42 to 61mm), *O. reflexa* (37 to 42mm), *P. coccineum* (42 to 67mm) and *Quadrula p. pustulosa* (52 to 55mm). This indicates a reduction in long-term young recruitment over time. There were no other obvious long-term trends.

SUMMARY AND CONCLUSIONS

Table 10 presents a summary of the items we measured at Hudson and Interstate and their general trend over years. The mussel community at Hudson appears stable. One measured category is increasing, two are decreasing and the remaining seven are stable.

The recent situation at Interstate suggests some changes in the mussel community and within populations. One measured category is increasing, but only slightly, six are decreasing and the remaining three may be stable. The most dramatic change is total mussel density, which dropped about 46% over the last 16 years. Total mussel density is the most important indicator that we measure and should receive the greatest weight of all ten categories.

The cause(s) for these declines at Interstate are unknown. Over the last 8 years there has been significant soil runoff from nearby highway reconstruction, an accidental milk spill and a few short-term low discharge events from the hydropower facility located 1.4 river miles upstream. A 2001 record spring flood and associated scouring and sedimentation may have affected mussels. During late April 2001, the St. Croix R. at Intestate reached 60,900 cubic feet per second (cfs), which is the record discharge for the 103-year period of record (USGS data). This discharge mobilized and deposited an unusual amount of sand. Hornbach (2004) found that sediment particle size had decreased significantly from 1992 to 2002 although this change may have occurred as early as 1998.

During the fall of 2001, one location visited since 1997 and which had a relatively high density of *Q. fragosa*, was covered with several feet of sand and had a relatively low density of all mussels. Another location, periodically visited since 1988 and which contained several hundred tagged *C. monodonta*, contained an unusually large proportion of dead individuals *in situ* and very few living ones. The few found living were taken from slightly higher elevations than the dead. All these mussels were unable to move, since they were almost completely surrounded by large boulders or other mussels. Another location, less impacted by direct floodwaters due to its protected location adjacent to an island, had relatively few dead *C. monodonta*. Therefore, the cause of mortality at the first location does not appear to be a systemic agent, but rather something local. It could possibly be from local sand deposition, resulting in direct mortality followed by gradual erosion of sand and uncovering of mussels.

Although Hudson is located 35.5 river miles downstream of Interstate, it did not have the same changes in community characteristics although it experienced the same 2001 flood. There were fewer community changes seen at Hudson because it was not susceptible to the same sediment loads as Intestate. Hudson is located at river mile 16.7 of the 25.9 mile-long Lake St. Croix, a natural riverine impoundment. Therefore, there was 9.2 upstream river miles for sediment to deposit before arriving at Hudson.

We suspect that the sediment load at Hudson was much less than was observed at Interstate and therefore, the direct effects of the flood were less. In addition, it appears the recent arrival of zebra mussels to the Hudson site have not had an adverse impact on the mussel community.

If the cause for the decline at Interstate was the 2001 flood, one would expect high recent recruitment relative to remaining adults evident in the community during 2004. We have seen the phenomenon of relatively large numbers of recent recruits at aggregations that are periodically subjected to substrate disturbing floods on many occasions. At Interstate, this was not the case, although there were 2.5 years between the 2001 flood and our sampling – sufficient time for young recruits to appear. Similarly, Hornbach (2004) saw significantly declining population densities of smaller mussels from 1992 to 2002 and the lowest population densities were in 2002. Possibly new recruits will be more evident in the next few years. This unexpected lower relative recruitment rate suggests that some other factors may be influencing the Interstate mussel community other than a major flood, unless major floods have a longer than expected impact on recruitment.

The decrease in densities along with the trends in other parameters suggests some reason for concern about the future stability of mussel communities and globally rare species populations at Interstate. Possibly these declines are short-term and will be reversed in future years or we are simply observing a short period of the normal dynamic equilibrium that may affect mussel communities. Clearly, monitoring should continue and should possibly be done during a more compressed time period rather than a 4-year interval. In addition, the upstream sites on the St. Croix (Narrows) and Namekagon (CTH K) rivers need to be re-sampled to determine if the problem is systemic. These locations have not been sampled since 1995.

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Figure 1. Location of 112 randomly selected 1m² quadrats at Hudson, 2004.

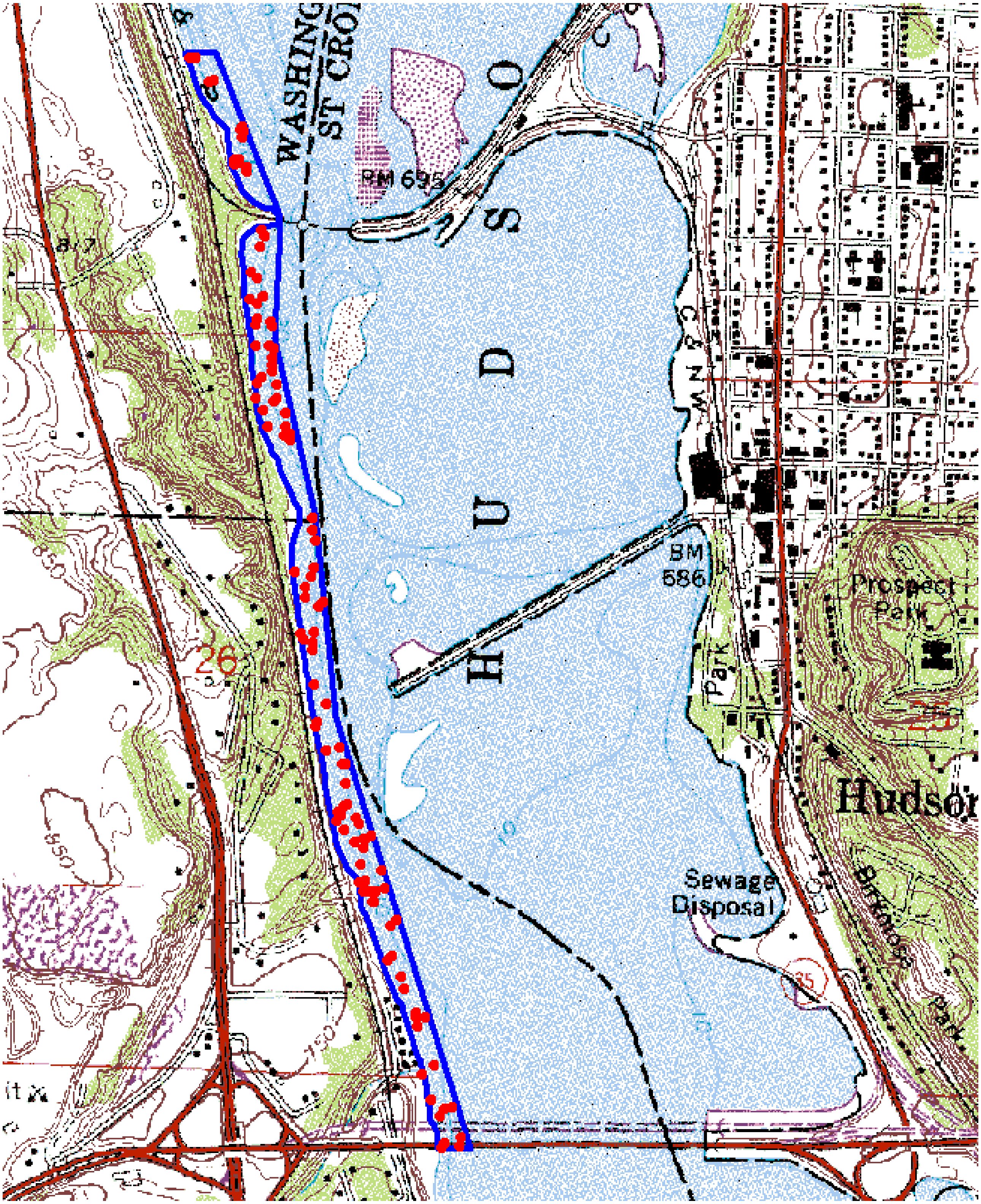

Figure 2. Location of 164 randomly selected 1m² quadrats at Interstate, 2004.

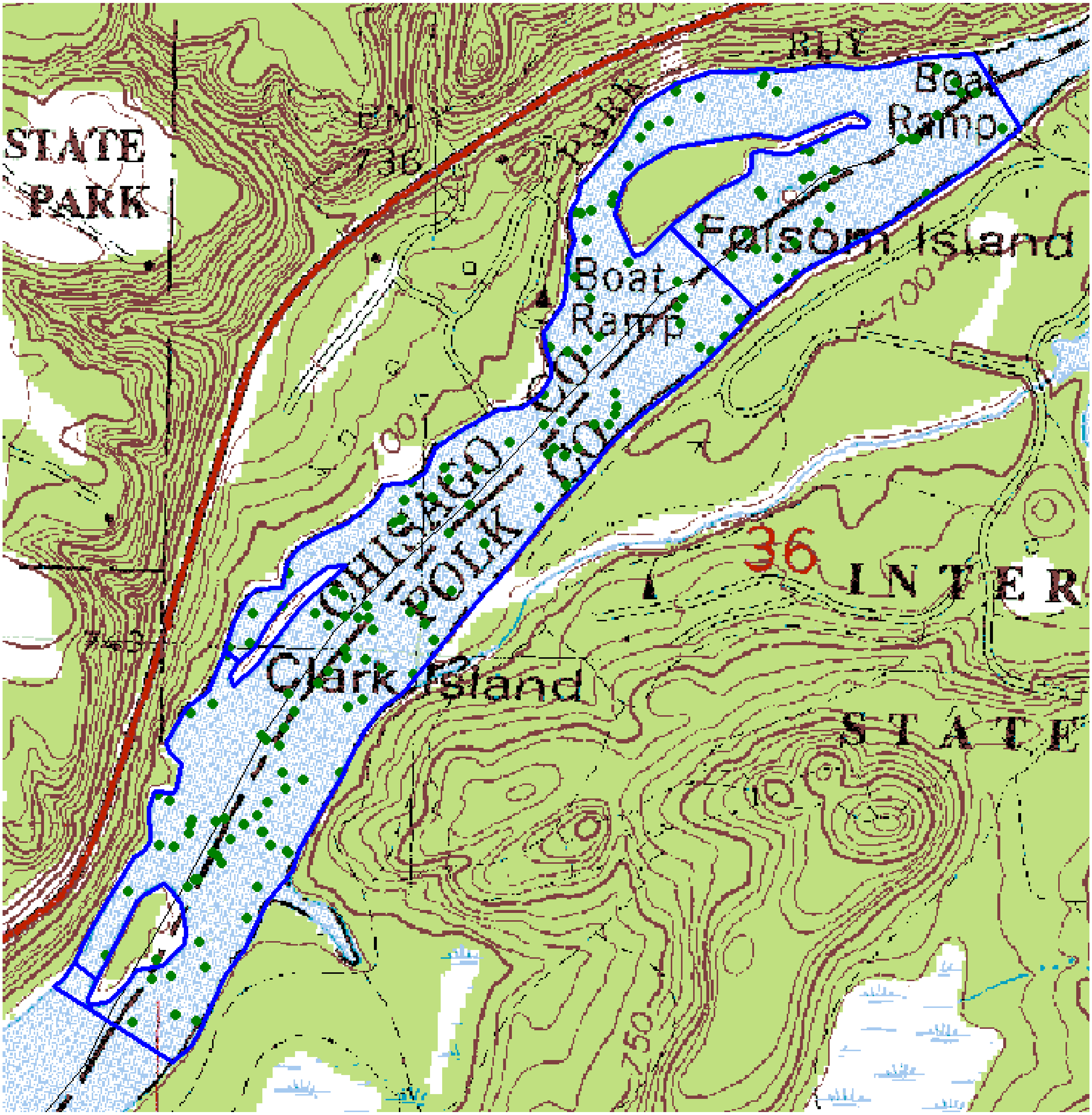

Figure 3. Taxa Richness, Hudson, 1988-2004.

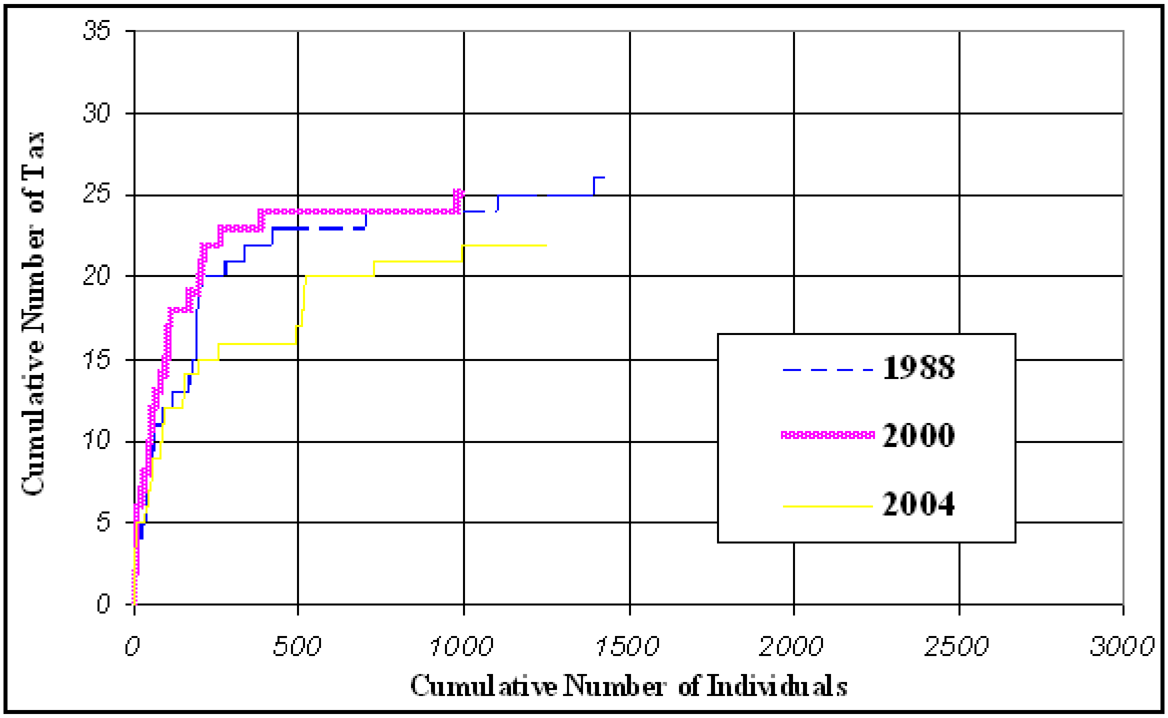

Figure 4. Taxa Richness, interstate, 1988-2004.

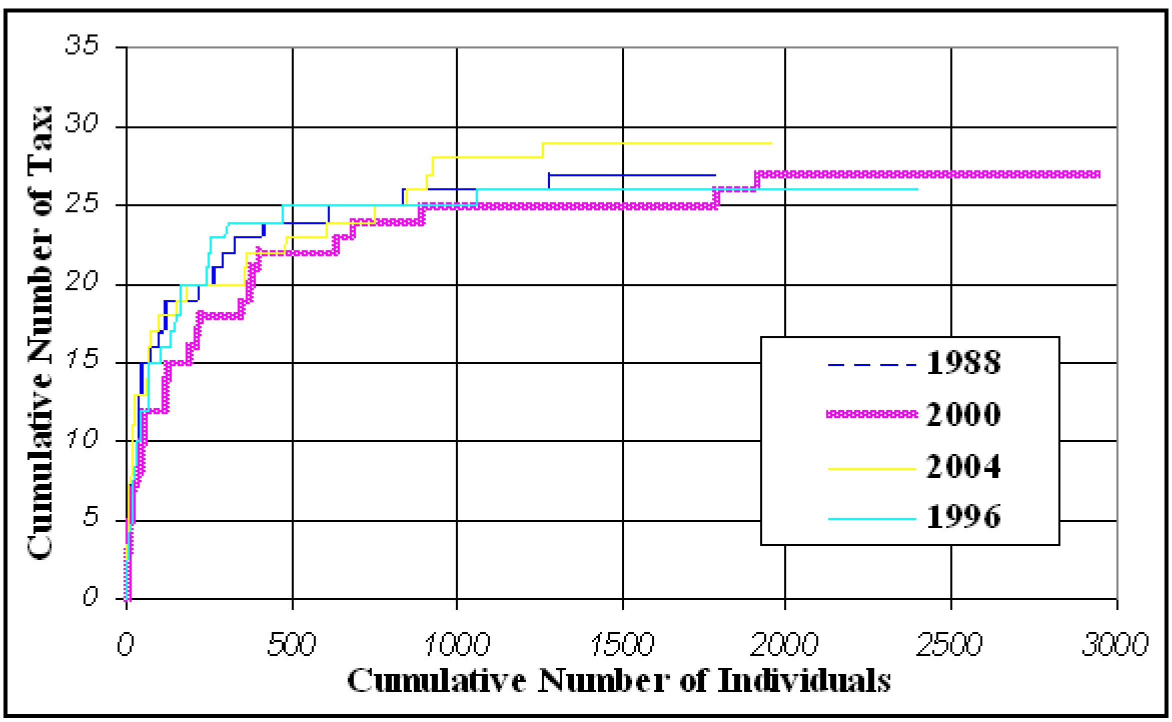

Table 1. List of all living and dead unionids found at Hudson and Interstate, 2004.

	Interstate		Hudson	
TAXON	**LIVE**	**DEAD**	**LIVE**	**DEAD**
A. l. carinata	108	48	15	44
A. marginata	5	5	0	0
A. p. plicata	50	11	472	104
C. fluminea	0	0	19	91
C. monodonta	328	272	0	0
C. tuberculata	31	11	3	0
D. polymorpha	1	0	25	0
E. dilatata	94	86	242	188
E. lineolata	50	12	19	4
E. triquetra	71	66	0	0
F. ebena	0	0	0	68
F. flava	110	79	188	46
L. c. complanata	1	1	0	3
L. cardium	70	12	8	26
L. costata	5	2	0	1
L. fragilis	15	9	8	5
L. higginsii	7	4	28	20
L. recta	17	4	0	2
L. siliquoidea	3	0	3	22
M. nervosa	0	0	2	0
O. olivaria	66	32	0	1
O. reflexa	62	33	114	47
P. alatus	52	24	17	7
P. coccineum	110	31	50	36
P. grandis	3	0	3	10
P. ohiensis	1	0	0	0
Q. fragosa	51	8	0	0
Q. metanevra	74	10	9	3
Q. p. pustulosa	251	62	56	18
Q. quadrula	0	0	8	1
S. ambigua	0	0	0	1
S. u. undulatus	4	3	2	1
T. donaciformis	0	25	0	3
T. truncata	680	1180	10	35
T. verrucosa	68	15	1	3
U. imbecillis	1	1	1	0
unidentified	0	126	0	210
TOTAL	**2389**	**2172**	**1303**	**1000**

Table 2. Interstate Monitoring Site 1988-2004, % Numerical Relative Abundances.

TAXA	1988	1996	2000	2004	4 Yr Trend
A. l. carinata	2.0694	3.3292	3.3548	5.5102	Increasing
A. marginata	1.2864	0.6242	0.9488	0.2551	Decreasing
A. p. plicata	1.2304	0.541	1.6266	2.5510	No Trend
C. monodonta	0.000	0.000	0.0339	0.1531	No trend
C. tuberculata	1.4541	1.4981	1.9999	1.5816	No trend
D. polymorpha	0.000	0.000	0.000	0.0510	Increasing
E. dilatata	5.0336	2.5385	2.7787	4.7959	No trend
E. lineolata	1.3982	1.3317	1.8638	2.5510	No trend
E. triquetra	3.8031	4.6192	3.2870	1.8878	No trend
F. flava	4.0268	3.7453	3.9309	5.5612	No trend
L. c. complanata	0.000	0.0832	0.2711	0.0510	No trend
L. cardium	0.783	0.7907	1.2877	3.5714	Increasing
L. costata	0.1678	0.2497	0.1694	0.2551	No trend
L. fragilis	0.783	1.3317	1.457	0.7143	No trend
L. higginsi	0.1678	0.000	0.0678	0.2041	No trend
L. recta	0.1119	0.2497	0.1694	0.8673	Increasing
L. siliquoidea	0.000	0.0416	0.000	0.1531	No trend
O. olivaria	1.7897	1.9559	2.4737	3.3673	Increasing
O. reflexa	2.4049	1.0404	1.9315	3.1633	No trend
P. alatus	1.3423	0.9988	1.3216	2.5510	No trend
P. coccineum	2.7964	2.6633	3.4226	5.6122	No trend
P. grandis	0.0559	0.0832	0.0339	0.1530	No trend
P. ohiensis	0.0559	0.000	0.000	0.0510	No trend
Q. fragosa	0.1678	0.1665	0.102	0.000	Decreasing
Q. metanevra	2.9642	2.2056	2.2026	3.7755	No trend
Q. p. pustulosa	6.5436	6.8664	6.5063	12.5510	No trend
S. ambigua	0.000	0.000	0.000	0.000	No trend
S. u. undulatus	0.2796	0.2081	0.3728	0.2041	No trend
T. donaciformis	6.1521	3.8702	0.2711	0.000	Decreasing
T. truncata	51.3423	57.2201	56.1843	34.6429	No trend
T. verrucosa	1.7338	1.7478	1.9315	3.1633	Increasing
U. imbecillis	0.0559	0.000	0.000	0.0510	No trend

Table 3. Hudson Monitoring Site 1988-2004, % Numerical Relative Abundances.

TAXA	1988	2000	2004	3 Yr Trend
A. confragosus	0.0000	0.1001	0.0000	No trend
A. l. carinata	0.2096	0.6006	1.1547	Increasing
A. marginata	0.0000	0.1001	0.0000	No trend
A. p. plicata	37.1768	39.8398	36.1047	No trend
C. fluminea	0.4193	0.4004	1.4627	Increasing
C. *tuberculata*	0.3494	0.0000	0.2309	No trend
D. polymorpha	0.0000	0.3003	1.9246	Increasing
E. dilatata	13.9762	10.2102	18.6297	No trend
E. lineolata	0.6988	1.2012	1.3857	Increasing
F. flava	11.3208	14.3143	14.4727	Increasing
L. c. complanata	0.0699	0.0000	0.0000	Decreasing
L. higginsi	1.188	1.3013	2.1555	Increasing
L. siliquoidea	0.559	0.7007	0.2309	No trend
L. cardium	0.559	1.6016	0.6159	No trend
L. costata	0.0000	0.1001	0.0000	No trend
L. fragilis	0.7687	0.4004	0.6159	No trend
L. recta	0.2096	0.1001	0.0000	Decreasing
M. nervosa	0.1398	0.2002	0.1540	No trend
O. reflexa	11.4605	10.6106	8.7760	Decreasing
P. alatus	1.2579	2.8028	1.3087	No trend
P. coccineum	5.0314	5.4054	3.8491	No trend
P. grandis	1.3976	0.8008	0.2309	Decreasing
Q. metanevra	1.3277	0.8008	0.6928	Decreasing
Q. p. pustulosa	3.9832	4.7047	4.3110	No trend
Q. quadrula	0.6289	0.6006	0.6159	No trend
S. ambigua	0.0699	0.0000	0.0000	Decreasing
S. u. undulatus	0.9085	0.5005	0.1540	Decreasing
T. donaciformis	0.4892	0.0000	0.0000	Decreasing
T. truncata	4.8218	1.9019	0.7698	Decreasing
T. verrucosa	0.6289	0.2002	0.0770	Decreasing
U. imbecillis/s	0.3494	0.2002	0.0770	Decreasing

Table 4. Mean arithmetic population densities for Hudson & Interstate, St. Croix R., 1988-2004.

	Hudson						Interstate							
year	1988		2000		2004		1988		1996		2000		2004	
n=	69		152		112		108		149		150		164	
	#/m^2		#/m^2		#/m^2		#/m^2		#/m^2		#/m^2		#/m^2	
TAXON	LIVE	STD	LIVE	STD	LIVE	STD	LIVE	STD	LIVE	STD	LIVE	STD	LIVE	STD
A. confragosus			0.01	0.08										
A. l. carinata	0.03	0.17	0.04	0.20	0.04	0.21	0.34	0.89	0.54	0.84	0.66	1.21	0.57	1.07
A. marginata	0.00	0.00	0.01	0.08			0.21	0.49	0.10	0.32	0.19	0.47	0.03	0.17
A. p. plicata	2.06	2.54	2.62	3.22	3.21	4.30	0.20	0.53	0.09	0.33	0.32	0.68	0.20	0.53
C. fluminea	0.09	0.37	0.03	0.16	0.14	0.55								
C. tuberculata	0.01	0.12			0.02	0.13	0.24	0.71	0.24	0.59	0.39	0.84	0.18	0.65
C. monodonta											0.01	0.08	0.02	0.17
D. polymorpha			0.02	0.14	0.18	0.51							0.01	0.08
E. dilatata	1.49	3.42	0.67	2.02	0.60	2.19	0.83	1.49	0.41	0.70	0.55	1.28	0.52	1.43
E. lineolata	0.04	0.21	0.08	0.32	0.05	0.23	0.23	0.57	0.21	0.61	0.37	0.74	0.20	0.47
E. triquetra							0.63	0.91	0.75	1.03	0.65	0.98	0.13	0.41
F. ebena	0.00	0.00	0.00	0.00	0.00	0.00								
F. flava	0.70	1.08	0.94	1.62	1.41	2.30	0.67	1.14	0.60	0.97	0.77	1.31	0.58	1.08
L. c. complanata	0.00	0.00	0.00	0.00	0.00	0.00			0.01	0.12	0.05	0.23	0.01	0.08
L. cardium	0.09	0.33	0.11	0.37	0.06	0.28	0.13	0.36	0.13	0.37	0.25	0.51	0.30	0.54
L. costata	0.00	0.00	0.01	0.08	0.00	0.00	0.03	0.17	0.04	0.20	0.03	0.18	0.03	0.26
L. fragilis	0.13	0.45	0.03	0.16	0.04	0.25	0.13	0.39	0.21	0.49	0.29	0.74	0.07	0.32
L. higginsii	0.01	0.12	0.09	0.30	0.13	0.41	0.03	0.17			0.01	0.12	0.01	0.11
L. recta	0.01	0.12	0.01	0.08	0.00	0.00	0.02	0.14	0.04	0.23	0.03	0.18	0.07	0.27
L. siliquoidea	0.09	0.28	0.05	0.21	0.02	0.13	0.00	0.00	0.01	0.08			0.02	0.13
M. nervosa			0.01	0.11	0.01	0.09								
O. olivaria	0.00	0.00			0.00	0.00	0.30	0.58	0.32	0.63	0.49	0.98	0.32	0.64
O. reflexa	0.77	1.27	0.70	1.26	0.80	1.22	0.40	0.67	0.17	0.47	0.38	0.77	0.30	0.61
P. alatus	0.13	0.45	0.18	0.45	0.11	0.39	0.22	0.57	0.16	0.57	0.26	0.50	0.21	0.81
P. coccineum	0.39	0.77	0.36	0.66	0.18	0.52	0.46	0.88	0.43	0.76	0.67	1.12	0.35	0.99
P. grandis	0.09	0.33	0.05	0.25	0.02	0.13	0.01	0.10	0.01	0.12	0.01	0.08	0.01	0.11
P. ohiensis	0.00	0.00					0.01	0.10					0.01	0.08
Q. fragosa							0.03	0.17	0.03	0.16	0.02	0.14	0.00	0.00
Q. metanevra	0.07	0.26	0.05	0.22	0.07	0.29	0.49	0.89	0.36	0.64	0.43	0.86	0.37	0.82
Q. p. pustulosa	0.20	0.61	0.31	0.67	0.31	0.67	1.08	1.45	1.11	2.00	1.28	1.55	1.07	1.98
Q. quadrula	0.07	0.31	0.04	0.20	0.06	0.24								
S. ambigua					0.00	0.00	0.00	0.00						
S. u. undulatus	0.06	0.24	0.03	0.18	0.01	0.09	0.05	0.21	0.03	0.18	0.07	0.29	0.02	0.15
T. donaciformis	0.03	0.17	0.00	0.00	0.00	0.00	1.02	1.41	0.62	1.00	0.05	0.23	0.00	0.00
T. parvus	0.00	0.00												
T. truncata	0.51	0.95	0.13	0.35	0.06	0.24	8.50	9.49	9.23	10.32	11.05	13.14	3.70	4.65
T. verrucosa	0.03	0.17	0.01	0.11	0.01	0.09	0.29	0.55	0.28	0.59	0.38	0.90	0.20	0.52
U. imbecillis	0.03	0.17	0.01	0.11			0.01	0.10					0.01	0.08
ALL TAXA	7.13	7.19	6.57	6.63	7.55	7.94	16.56	14.79	16.13	14.09	19.67	18.42	9.51	9.30

Table 5 Arithmetic mean population densities (#/m²) for taxa groupings and total mussels for the St. Croix River.

Monitoring site	Taxa Grouping	Year			
		1988	1996	2000	2004
Interstate	n	108	149	150	164
	Total mussel	16.56	16.13	19.67	9.51
	Sensitive	2.51	2.54	3.14	1.74
	Indifferent	13.82	13.47	16.15	7.54
	Exploitive	0.21	0.11	0.38	0.21
Hudson	n	69		152	112
	Total mussel	7.13	NA	6.57	7.55
	Sensitive	0.20	NA	0.28	0.33
	Indifferent	4.62	NA	3.55	3.79
	Exploitive	2.30	NA	2.74	3.43

Table 6. Results of tests of significance among years (1988, 1996, 2000, 2004) within a monitoring site for n-log transformed total mussel mean population density. Years with the same letter within a site and taxa grouping are not significantly different, NA=not applicable.

Monitoring site	Taxa Grouping	Year			
		1988	1996	2000	2004
Interstate	Total mussel	A	A	A	B
	Sensitive	AB	A	A	B
	Indifferent	A	A	A	B
	Exploitive	A	A	B	A
Hudson	Total mussel	A	NA	A	A
	Sensitive	A	NA	A	A
	Indifferent	A	NA	A	A
	Exploitive	A	NA	A	A

Table 7. Living/Dead ratios, Interstate and Hudson Monitoring Sites, 1988 -2004.

	Interstate				Hudson		
TAXON	**1988**	**1996**	**2000**	**2004**	**1988**	**2000**	**2004**
A. l. carinata	1.23	2.22	1.41	1.94	0.06	0.13	0.11
A. marginata	2.88		4.00	1.00	0.00		
A. p. plicata	1.83	0.76	2.09	3.00	1.31	2.71	3.52
C. fluminea					0.05	0.25	0.18
C. monodonta	14.5	10.1	3.33	1.2	2.7	1.6	
C. tuberculata	4.33	12.00	7.38	2.73	0.33		
D. polymorpha							
E. dilatata	2.25	0.67	0.85	0.99	0.40	0.37	0.36
E. lineolata	8.33	2.29	6.88	2.67	0.43	1.71	1.50
E. triquetra	4.00	2.18	1.08	0.33			
F. ebena							0.00
F. flava	2.77	1.96	1.73	1.20	0.59	1.93	3.43
L. c. complanata			2.00	1.00	0.00	0.00	0.00
L. cardium	0.70	4.75	2.71	4.17	0.43	0.80	0.27
L. costata		3.00	0.83	2.50	0.00	0.13	0.00
L. fragilis	1.27	32.00	3.91	1.22	0.43	0.44	1.00
L. higginsi				0.50	0.04	0.59	0.75
L. recta	0.40	1.00	0.31	2.75	0.06	0.08	0.00
L. siliquoidea	0.00				0.09	0.19	0.09
M. nervosa						0.67	
O. olivaria	1.60	1.47	1.30	1.66	0.00		0.00
O. reflexa	3.58	0.89	1.33	1.52	1.04	2.30	1.91
P. alatus	2.00	6.00	3.90	1.46	4.50	2.00	1.71
P. coccineum	2.38	2.37	3.48	1.84	0.56	1.29	0.56
P. grandis	1.00		0.50		2.00	1.60	0.20
P. ohiensis					0.00		
Q. fragosa	0.43	1.00	0.75	0.00			
Q. metanevra	5.30	5.30	2.83	6.10	1.25	4.00	2.67
Q. p. pustulosa	4.03	1.60	1.75	2.82	0.34	2.14	1.94
Q. Quadrula					1.25	1.20	7.00
S. ambigua	0.00						0.00
S. u. undulatus	1.00	5.00	1.57	1.33	0.67	5.00	1.00
T. donaciformis	1.62	0.84	0.06	0.00	0.02	0.00	0.00
T. parvus					0.00		
T. truncata	1.37	2.79	1.43	0.51	0.28	0.28	0.20
T. verrucosa	3.10	3.82	4.38	2.20	2.00	0.67	0.50
U. imbecillis				1.00			
All Taxa	1.7	2.19	1.46	0.82	0.42	1.11	0.85

Table 8. Female/male sex ratios, 1988-2004, Interstate and Hudson study areas (n≥10).

	Interstate				Hudson		
Taxon	**1988**	**1996**	**2000**	**2004**	**1988**	**2000**	**2004**
E. lineolata	2.14	1.07	0.96	0.71	1.20	1.00	0.3
E. triquetra	0.74	1.88	0.24	0.38			
L. cardium		0.33	0.63	0.67		0.50	
L. higginsi	0.50			1.33	1.00	1.08	0.69
L. recta							
L. siliquoidea					0.00	1.33	
T. verrucosa	0.90	1.69	1.20	0.68			

Table 9. First quartile of Length Distribution for taxa with n≥30.

	Interstate				Hudson		
Taxon	**1988**	**1996**	**2000**	**2004**	**1988**	**2000**	**2004**
A. l. carinata	54	30	63	56			
A. plicata	66	35	57	55	42	56	61
C. monodonta	50			81			
C. tuberculata	50	50	49	50			
E. dilatata	15	66	47	74	94	87	97
E. lineolata	40	48	45	57			
E. triquetra	19	16	34	26			
F. flava	35	36	45	47	37	40	38
L. cardium	40	41	62	81			
L. fragilis	46	28	16	34			
O. olivaria	47	50	43	48			
O. reflexa	32	37	41	33	37	38	42
P. alatus	64	72	59	93			
P. coccineum	45	40	55	52	42	44	67
Q. metanevra	38	42	67	71			
Q. pustulosa	47	38	42	48	52	53	55
S. ambigua	25						
T. donaciformis	20	23	18				
T. truncata	27	34	39	38			
T. verrucosa	51	71	85	101			

Figure 5. Total mussel density at Hudson, 1988-2004.

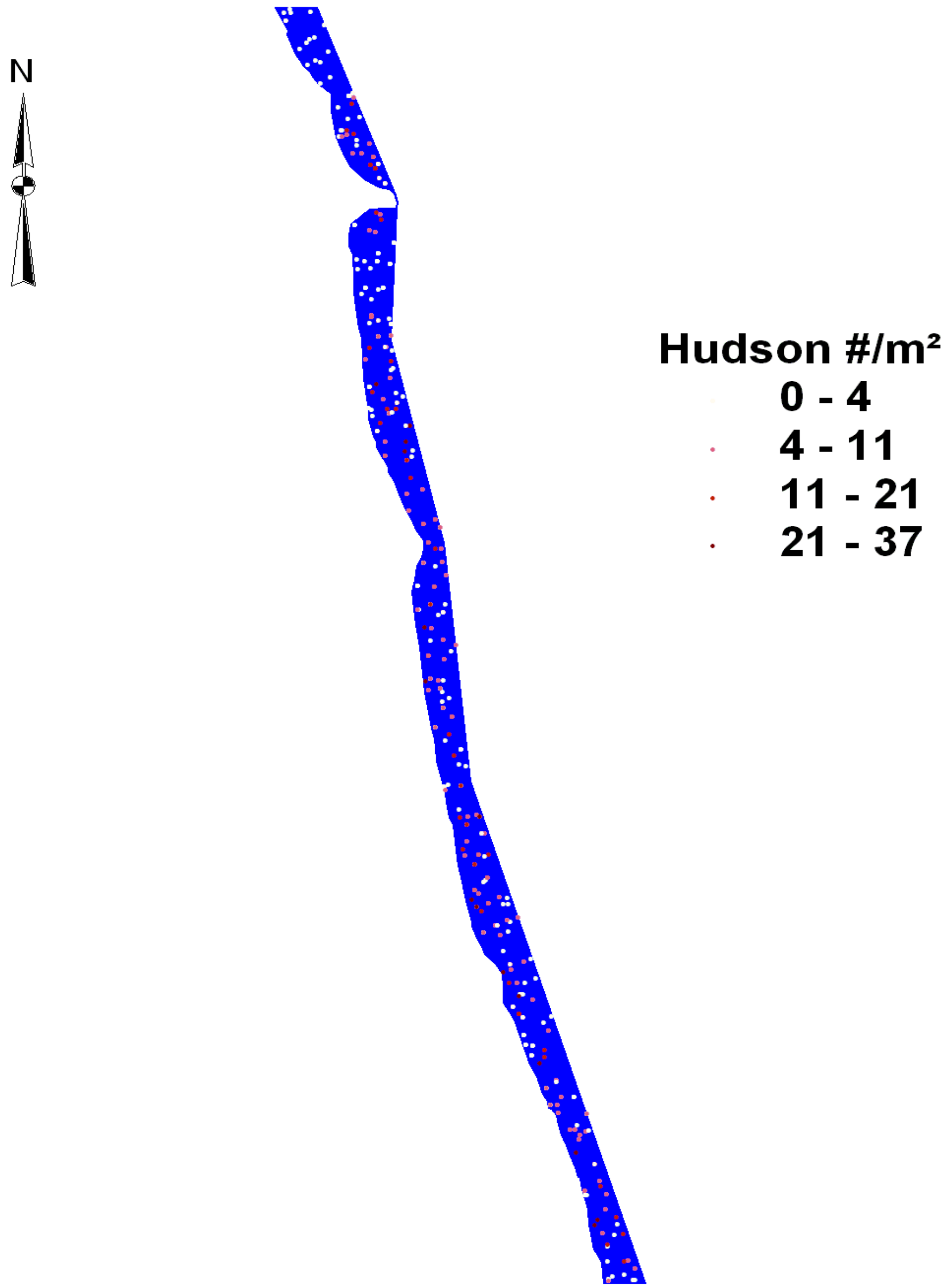

Figure 6. Total mussel density at Interstate, 1988-2004.

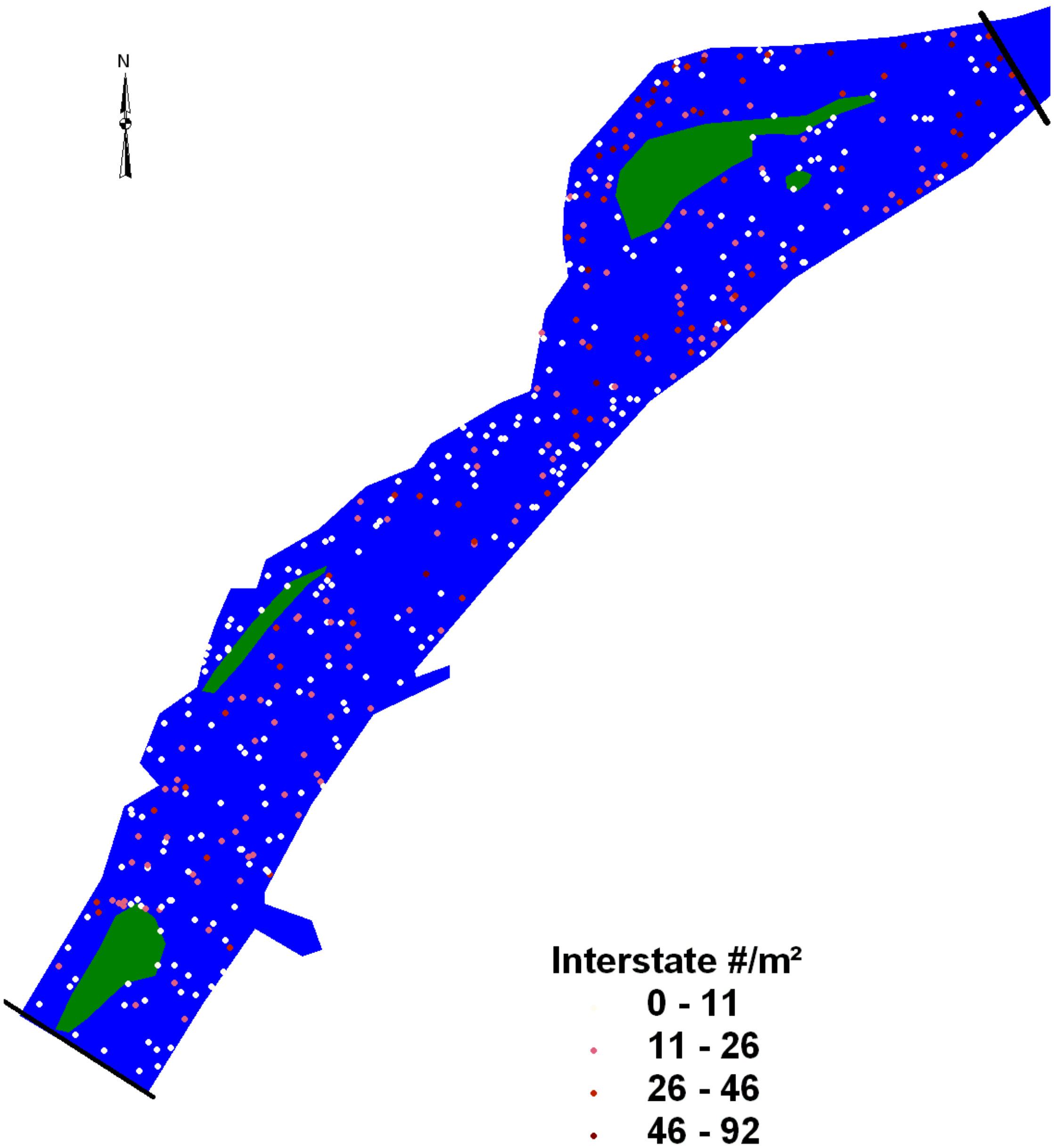

Table 10. General summaries of 2004 population and community measurements compared to previous years for the St. Croix River. “-” Indicates a reduction, “+” indicates an increase and “- +” indicates no change.

Parameter	Hudson	Interstate
Taxa Richness	-	+
Total Mussel Population Density	- +	-
"Sensitive" density	- +	-
"Indifferent" density	- +	-
"Exploitive" density	- +	- +
Q. fragosa abundance		-
L. higginsii abundance	+	- +
Total Mussel Living/Dead ratio	- +	-
Sex Ratios	- +	- +
Recruitment	-	-