LAKE CHAMPLAIN 2003
ZEBRA MUSSEL MONITORING PROGRAM

Final Report
April 2004

A Report Prepared for the
Lake Champlain Basin Program

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TABLE OF CONTENTS

LIST OF TABLES AND FIGURES i

EXECUTIVE SUMMARY ii

ACKNOWLEDGMENTS iii

INTRODUCTION 1

GOALS AND OBJECTIVES 1

FIELD SAMPLING METHODS 2

OPEN-WATER VELIGERS 2
NEARSHORE VELIGERS 4
NEARSHORE SETTLED JUVENILES 4
ADULT DISTRIBUTION 5
TRIBUTARY SAMPLING 5
INLAND LAKE SAMPLING 5

LABORATORY ANALYTICAL METHODS 5

VELIGERS 5
SETTLED JUVENILES 7
QUALITY ASSURANCE PROCEDURES 7

RESULTS AND DISCUSSION 7

VELIGERS 9
SETTLED JUVENILES 15
TRIBUTARIES AND INLAND LAKES 16
ADULT DISTRIBUTION 17
QUALITY ASSURANCE RESULTS 18

SUMMARY AND CONCLUSIONS 18

RECOMMENDATIONS 19

VELIGER SAMPLING 19
JUVENILE SAMPLING 19
ADULT SAMPLING 19

REFERENCES 20

APPENDIX A A-1

APPENDIX B B-1

LIST OF TABLES AND FIGURES

LIST OF TABLES:

Table 1. Mean veliger densities using plankton net and peristaltic pump sampling methods at selected stations in Lake Champlain during 2003……………………….…………..…15

Table 2. Mean relative percent difference for 2003 laboratory and field zebra mussel veliger and juvenile duplicate samples ……………………………………..…18

LIST OF FIGURES:

Figure 1. Open-water and nearshore sampling site location ………………………………3

Figure 2. Settling plate array……………………………………………………………4

Figure 3. Inland lake and tributary sampling sites………………………………………6

Figure 4. Annual changes in zebra mussel distribution since 1993………………………..8

Figure 5. Veliger densities at open-water stations during 2003…………….….……………10

Figure 6. Veliger densities at open-water stations during 2003……………..……………11

Figure 7. Veliger and settled juvenile densities at Northeast Lake nearshore stations during 2003…………………………………………………………………12

Figure 8. Seasonal weighted mean veliger densities from 1994-2003………………….…..13

Figure 9. Seasonal weighted mean veliger densities from 1994-2003……………..….…14

Figure 10. Seasonal weighted mean juvenile densities for selected nearshore stations from 1998-2003……………………………………..…………………...16

Figure 11. Season plate densities from 1998-2003 for selected nearshore stations……....17

EXECUTIVE SUMMARY

The Vermont Department of Environmental Conservation, in cooperation with the Lake Champlain Basin Program, has monitored zebra mussel (*Dreissena polymorpha*) densities in Lake Champlain since 1994. In 2003, 12 open-water lake stations and 4 nearshore stations were sampled for occurrence and density of veligers. Occurrence and density of settled juveniles were determined at 13 near shore sites using dark colored PVC settling plates. Mask and snorkel surveys were conducted to characterize adult zebra mussel densities. Twenty Vermont inland lakes with high boating activity or close proximity to Lake Champlain, and 15 Lake Champlain tributaries, were selected for veliger sampling.

Zebra mussels in Lake Champlain continued to reproduce and settle successfully during 2003, with veliger densities increasing at 12 of 16 stations compared to the previous year. Juvenile settlement increased or remained the same at 3 of 4 stations compared to densities found in 2002. Zebra mussel adults have been well established in the South, Central, and Northwest Lake since 1996. The expansion phase of the zebra mussel infestation may be over in these areas of the lake. None of the 2003 veliger densities in the South, Central, or Northwest Lake areas were as high as the peak densities from previous years. In contrast, the range expansion in the Northeast Lake is continuing, but at a relatively slow rate. As of 2003, known adult zebra mussel distribution in the Northeast Lake includes Malletts Bay and the Inland Sea. Although no adult zebra mussels have been confirmed in Missisquoi Bay, settled juvenile results from 2003 suggest that adults may be present.

Adult zebra mussels continue to be found in Lake Bomoseen. No other lakes in Vermont were found to have zebra mussels. Adult zebra mussels have been found in the lower reaches of Otter Creek, Little Otter Creek, Lewis Creek, LaPlatte River and the Winooski River in past years. No new tributaries into Lake Champlain were found to be harboring zebra mussels in 2003.

ACKNOWLEDGMENTS

This monitoring program benefited greatly from the contributions of the following individuals at the Vermont Department of Environmental Conservation: Mike Hauser for mapping assistance and distribution of periodic zebra mussel updates; Eric Smeltzer for expert report review and guidance; and Jim Kellogg for veteran quality assurance contributions. We also thank the marina operators who allowed us to deploy our settling plates at their facilities.

This report was funded and prepared under the authority of the Lake Champlain Special Designation Act of 1990, P.L. 101-596, through the U.S. Environmental Protection Agency (EPA Grant #EPA X 001840-01). Publication of this report does not signify that the contents necessarily reflect the views of the Lake Champlain Basin Program or the U.S. Environmental Protection Agency.

INTRODUCTION

The Vermont Department of Environmental Conservation (VTDEC), in cooperation with the Lake Champlain Basin Program, initiated the Lake Champlain Zebra Mussel Monitoring Program in 1994 to track zebra mussel distribution in the lake. Annual reports have been provided each year (Kamman 1994, Stickney 1996, Eliopoulos and Stangel 1997, 1998, 1999, 2000, 2001, and 2003). This report presents veliger, juvenile, and adult zebra mussel distributions during 2003 in comparison with previous years of monitoring.

GOALS AND OBJECTIVES

Zebra mussel monitoring included veliger (larvae), settled juvenile, and adult life stages at open-water and nearshore lake stations, lake tributaries, and inland lakes. Greater emphasis was placed on veliger monitoring, as it is in their pelagic stage that zebra mussels are most easily spread and sampled in Lake Champlain. The goals of the Lake Champlain Zebra Mussel Monitoring Program include the following monitoring and technical assistance aspects:

(1) Monitor the distribution and abundance of zebra mussel larvae, juveniles, and adults in Lake Champlain.

(2) Determine the occurrence of new zebra mussel colonization in Lake Champlain, its tributaries, and inland lakes with high boating activity and/or close proximity to Lake Champlain and incorporate this information into a database.

(3) Use the data to help determine the appropriate management response and assess the effectiveness of spread prevention or control measures.

(4) Inform the public, related water treatment facility operators, and marina managers of the presence of zebra mussels so that they may take appropriate spread prevention and control measures.

(5) Provide technical assistance to the groups listed above regarding the design and operation of zebra mussel monitoring programs.

(6) Document selected water quality parameters pertinent to zebra mussel survival at open-water sampling sites in Lake Champlain and its tributaries.

(7) Produce annual reports documenting the findings of the Lake Champlain Zebra Mussel Monitoring Program.

(8) Maintain the Lake Champlain Zebra Mussel Monitoring Program website.

FIELD SAMPLING METHODS

OPEN-WATER VELIGERS

Twelve open-water lake stations (Figure 1) were sampled for occurrence and density of veligers. These stations were co-located with stations of the Lake Champlain Long-Term Water Quality and Biological Monitoring Project (New York State Department of Environmental Conservation and Vermont Department of Environmental Conservation, 2003). Co-location of these stations allowed for relating zebra mussel monitoring results with other water quality and biological data in previous reports, and for improved overall sampling efficiency. As recommended by the Lake Champlain Zebra Mussel Workgroup, veliger sampling at nearshore stations in the South, Central and Northwest parts of the lake was discontinued in 2003.

Open-water veliger samples were collected twice monthly starting in late April or early May using vertical plankton net tows as described in the Vermont Department of Environmental Conservation Field Methods Manual (1989, method 4.2.1). A 13 cm aperture size Wisconsin style plankton net with a 63 Fm (micron) net mesh size was towed vertically to the lake surface from a depth of ten meters, or one meter from the lake bottom in areas where the bottom depth was less than ten meters, at a 0.5 m/sec retrieval rate for optimal veliger entrapment (Marsden, 1992, method 3.5). To calculate veliger densities, a net efficiency of 95% was assumed and the volume of water filtered was estimated based on the length of tow and net aperture. Veliger samples consisted of five composited net tows of equal length. Volume of water filtered for each sample ranged from 0.13 m^3 to 0.66 m^3 depending on depth of station sampled. Length of net tow, surface water temperature, and Secchi disk transparency were recorded for each sample. Once out of the water, the net contents were concentrated and transferred to a 50 ml plastic container and preserved with a 95% ethanol solution in a 1:1 ratio of sample to ethanol solution. After sampling, the net was rinsed vigorously three times in the lake. Sampling was discontinued in October.

Open-water veliger samples were collected at 4 stations twice monthly starting in June using a peristaltic sampling pump as described in the Vermont Department of Environmental Conservation Field Methods Manual (1989,method 2.2.4). The peristaltic pump was connected to a garden hose and lowered to a depth of 3 meters. The pump was allowed to run 60 seconds to flush any water that may have remained in the hose from previous sampling. Once flushed, 28 liters of lake water were filtered through a 13 cm aperture size Wisconsin style plankton net with a 63 Fm net mesh size. Sample preservation for the sample was the same as for open-water veligers. After sampling, the net was rinsed vigorously three times in the lake. Sampling was discontinued in September.

As described in Eliopoulos and Stangel (2000), plankton net efficiency is highly variable. Results obtained from plankton net sampling should be compared only within Lake Champlain and not with data from other monitoring programs using other techniques.

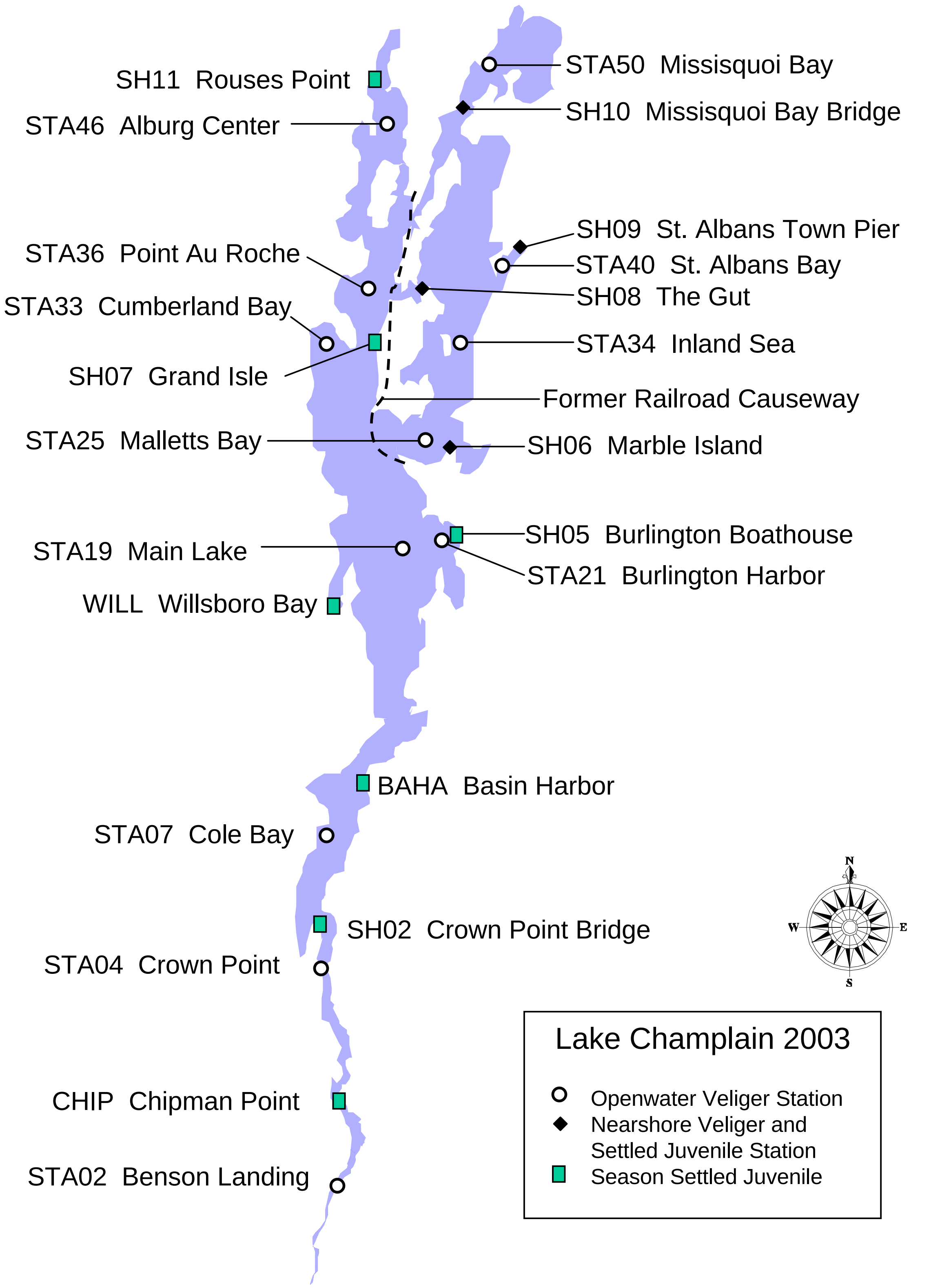


Figure 1. Open-water and nearshore sampling site locations for the Lake Champlain 2003 Zebra Mussel Monitoring Program.

NEARSHORE VELIGERS

Occurrence and density of veligers were determined at four nearshore lake stations (Figure 1) located in shallow water near marinas or in bays in the Northeast lake. Nearshore veliger samples were collected using horizontal plankton net tows twice a month beginning in late April or early May. The net was thrown from shore and slowly towed horizontally below the surface at a rate of 0.5 m/sec (Vermont Department of Environmental Conservation, 1989, method 4.2.2). Net tow samples and field duplicates were composites of five tows of equal length. Length of tow, surface water temperature, and Secchi disk transparency were recorded for each sample. Estimated volume of water filtered, net cleaning protocol, sample preservation, and storage were the same as for open-water veliger samples. Sampling was discontinued in October.

NEARSHORE SETTLED JUVENILES

Occurrence and density of settled juveniles were determined at four nearshore stations (Figure 1) beginning in early-May by deploying an array of three 15X15 cm gray colored polyvinyl chloride (PVC) settling plates. The plates were arranged horizontally (Figure 2), along a stainless steel threaded eyebolt and separated with nuts and washers by approximately 3 cm. The plate array was suspended in the water column by attaching a rope to the eyebolt and to a dock, bridge abutment, or float. The plate array was submerged so that the top plate was 2-3 m below the lake surface. The bottom of the plate array was attached to a rope with a weight resting on the lake bottom. The top plate remained in the water for the entire sampling season to estimate seasonal accumulation. The middle and bottom plates were collected and replaced alternately every two weeks. This allowed plates to be available for settled juveniles for a total of four weeks.

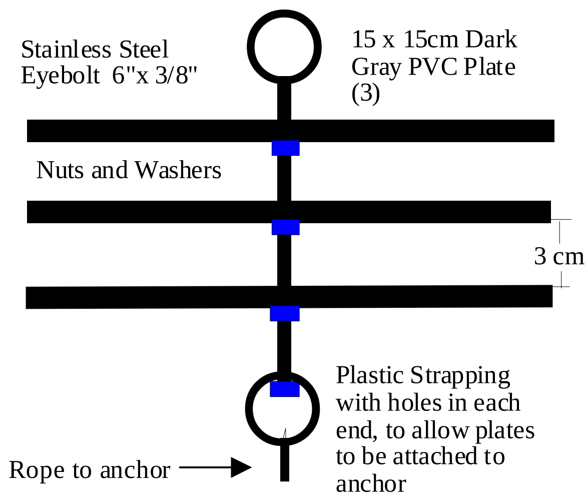


Figure 2. Settling plate array.

As recommended by the Lake Champlain Zebra Mussel Workgroup, settled juvenile sampling in the South, Central and Northwest parts of the lake was discontinued in 2003. Season settling plates were placed at seven nearshore stations (Figure 1) in areas of the lake where zebra mussel colonization has been established for many years. These plates were positioned in the water in May and retrieved in October.

Each retrieved settling plate was stored in an airtight plastic container and treated with a minimal amount of 95% ethanol. Drenching the plates with ethanol could cause the mussels to detach, and was avoided. The plates were transported to the laboratory where they were stored in a refrigerator at 4EC. Since newly settled zebra mussel shells are fragile, plates were handled carefully to avoid damage.

ADULT DISTRIBUTION

Information on the distribution of adult zebra mussels in Lake Champlain was compiled from a variety of sources including observations by VTDEC staff biologists working on this and other related projects, researchers from the University of Vermont, and confirmed citizens' sightings. Adult mussel densities have been characterized by relative abundance at selected areas during snorkel surveys from 1997-2003. Snorkel surveys were conducted by two people for approximately fifteen minutes at each site. This information was used to track the extension of the adult zebra mussel distribution in Lake Champlain.

TRIBUTARY SAMPLING

Fifteen Lake Champlain tributaries (Figure 3) were selected for sampling, including the Missisquoi River, Lamoille River, Winooski River, Castleton River, Otter Creek, Lewis Creek, Dead Creek and the Poultney River on the Vermont side of the lake, and the Great Chazy River, Little Chazy River, Saranac River, Salmon River, Little Ausable River, Ausable River, and the Bouquet River in New York. The net used for river sampling was not used in Lake Champlain. When traveling between sampling sites, the plankton net was stored in a 95% ethanol solution to kill any veligers remaining in the net. Net cleaning protocol and sample preservation were the same as for open-water veliger sampling.

INLAND LAKE SAMPLING

Twenty Vermont inland lakes with high boating activity or close proximity to Lake Champlain were selected for sampling. These lakes included Arrowhead Mt. Lake, Lake Bomoseen, Lake Carmi, Caspian Lake, Cedar Lake, Crystal Lake, Lake Dunmore, Fairfield Pond, Lake Fairlee, Glen Lake, Harvey's Lake, Lake Hortonia, Lake Iroquois, Island Pond, Lake Memphremagog, Lake Morey, Seymour Lake, Shelburne Pond, Lake Willoughby, and Lake St. Catherine (Figure 3). Horizontal plankton net tows were taken from the shore at public access areas or lake outlets during July and August. The net used in Lake Champlain was not used in inland lakes and was stored in 95% ethanol between sampling sites.

LABORATORY ANALYTICAL METHODS

VELIGERS

Analytical procedures and calibration followed methods detailed in Marsden (1992). A dissecting stereo-microscope at 30X magnification was used with a cross-polarization light technique (Johnson, 1995) to enhance veliger detection for counting purposes. Veliger identification was verified under a compound microscope with assistance of VTDEC Biomonitoring and Aquatic Studies Section taxonomists. For samples containing relatively few veligers (approximately #100 per sample), all veligers were counted. If veligers were too

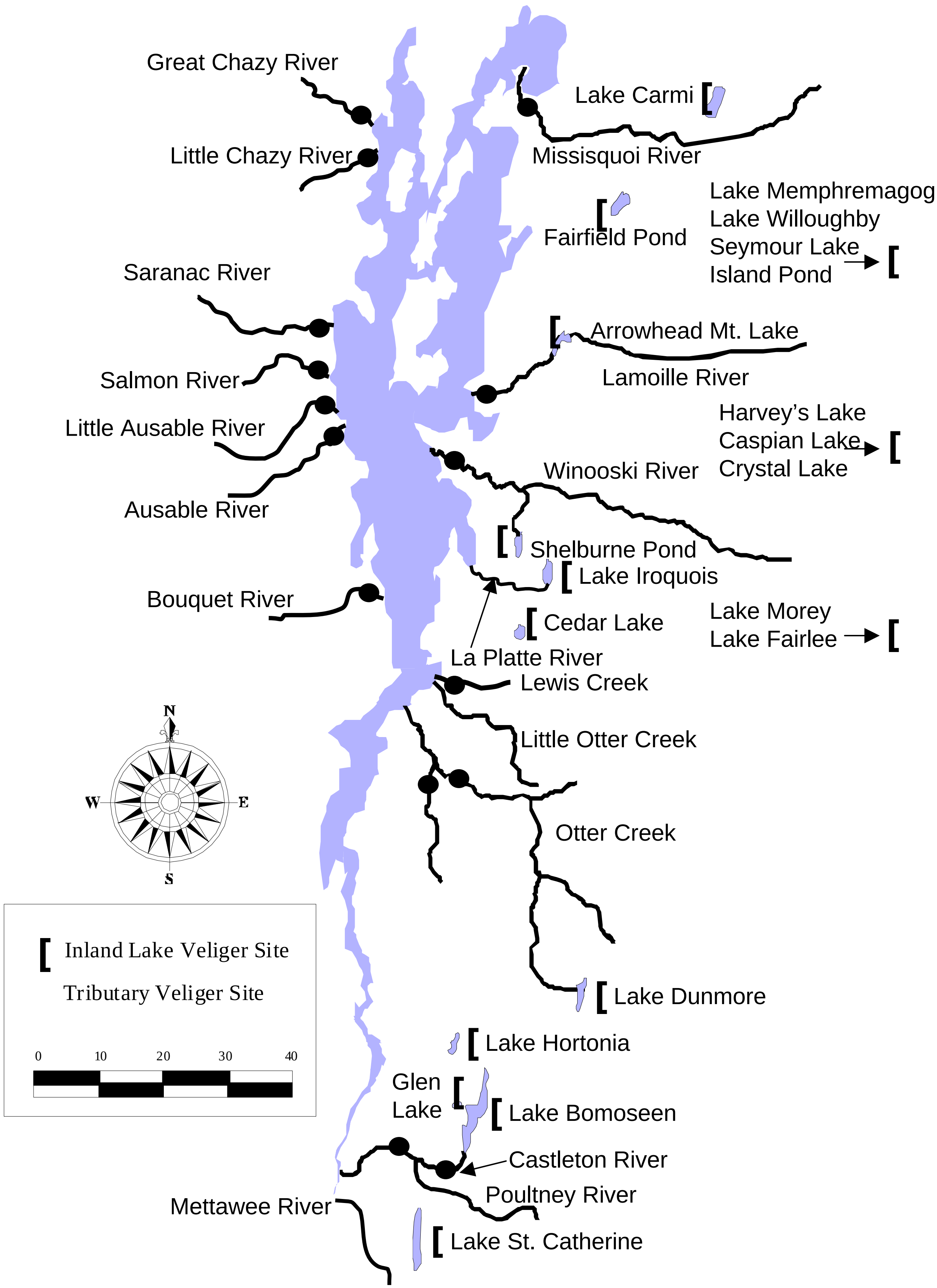


Figure 3. Inland lake and tributary sampling site locations for the Lake Champlain 2003 Zebra Mussel Monitoring Program.

abundant to count in full (approximately >100 per sample), the sample was diluted quantitatively as necessary and three 1.0 ml sub-samples were extracted into 1.0 ml Sedgewick-Rafter cells, and the sub-sample counts were used to estimate the density of the entire sample. Densities were reported as number of veligers/m^3.

SETTLED JUVENILES

The 15X15 cm (225 cm^2) settling plate was placed under a dissecting stereo-microscope at 30X magnification and all juveniles on the underside of the plate were counted. If settled juvenile densities were too abundant to count accurately, five 1.0 cm^2 replicates were counted using a 1.0 cm^2 counting cell randomly placed on the plate. Juveniles were counted in each 1.0 cm^2 block, and plate density was estimated as number of juveniles/m^2 (method modified from Marsden, 1992). On plates with extremely dense encrustations and uniform distribution of individuals, ¼ of the plate area was counted.

QUALITY ASSURANCE PROCEDURES

A complete description of project quality assurance procedures is provided in the Lake Champlain Zebra Mussel Monitoring Program Work/QA plan (Stangel, 2003). Data precision for 2003 was determined through field duplication of 7% of the veliger samples and 12% of juvenile settling plate samples. In addition, 9% of all veliger samples and 13% of juvenile sampling plates were reanalyzed as laboratory duplicates. The relative percent difference (RPD) for both field and laboratory duplicates was calculated as follows:

$$RPD= *(\text{count a} - \text{count b}) / (\text{count a} + \text{count b}) / 2* \times 100$$

Accuracy of veliger and settled juvenile identifications was accomplished by comparison with reference samples and through consultation with taxonomists in the Biomonitoring and Aquatic Studies Section of VTDEC. Data comparability was achieved by using standardized methods as defined in the Vermont Department of Environmental Conservation Field Methods Manual (1989) and in Marsden (1992).

RESULTS AND DISCUSSION

Zebra mussels in Lake Champlain continued to reproduce and settle successfully during 2003, with veliger densities increasing at 12 of 16 stations compared to the previous year. Figure 4 shows the annual changes in zebra mussel distribution since 1993, the year of their discovery in Lake Champlain. In 2003, settled juveniles were found on the Missisquoi Bay Bridge (SH10) plates, and a few adult zebra mussels were found attached to native mussels relocated for the construction of the Missisquoi Bay Bridge, (D. Mason, personal comm., 2004).

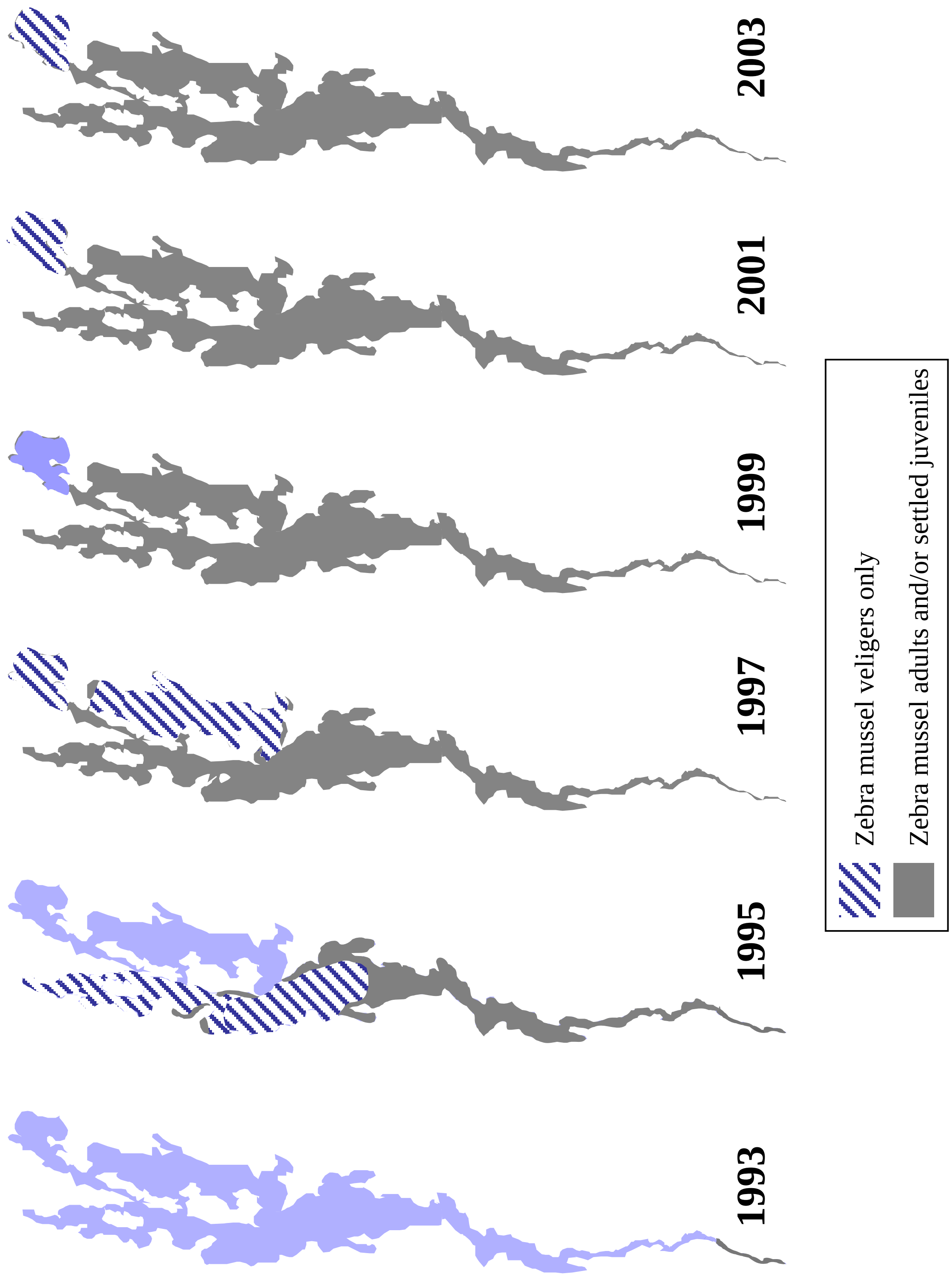


Figure 4. Annual changes in Lake Champlain zebra mussel distribution since 1993.

Comparisons of veliger and settled juvenile densities between lake stations and/or between years were based on seasonal time-weighted mean density estimates. Simpson's integral was used to calculate the area under the density vs. time plots for each year, and the areas were divided by the duration of the sampling season. Seasonal weighted mean estimates were based on equal sampling season lengths of 150 days starting and ending with zero density values at the beginning and end of the sampling seasons.

Seasonal weighted mean densities were considered more appropriate than geometric means, arithmetic means, or single peaks because of the extreme within-season variation in veliger and settled juvenile densities. Veliger production and juvenile settlement occur during discrete time periods, causing densities to increase from zero upwards over several orders of magnitude within a short time interval during a season at some stations. Mean values would therefore be too strongly biased by the number of samples obtained during non-reproductive periods. Seasonal time-weighted mean density values provide a better index of the overall larval and juvenile production at each site.

VELIGERS

Variations in veliger densities during the 2003 sampling seasons are described for all regions of the lake in Figures 5-7. Veliger densities with temperature and Secchi depths for 2003 are available in Appendix A. The 1994-2003 data are available on the Vermont DEC website at http://www.vtwaterquality.org/lakes/htm/lp_zebramon.htm .

Veligers were first detected in 2003 in the South Lake in mid-May as water temperatures rose to 18º C. The South Lake is shallow and narrow, and therefore the water tends to warm more quickly than other areas of the lake. Veligers were found two to four weeks later in the Central, Northeast, and Northwest lake regions. In 2003, the timing of peak densities throughout the lake regions was variable, ranging from June 16 to August 6, with the highest peak of 67,973 veligers/m^3 sampled at the Northwest Lake station Alburg Center, (STA46) on July 22. Veligers were reduced to very low densities throughout the lake by early October.

Peak densities in the Northeast Lake continued to be about two or three orders of magnitude lower in comparison to all other lake regions. Veligers were recorded at all lake stations during 2003. The highest veliger density recorded in the Northeast Lake was at St. Albans Bay (SH09), with a density of 810 veligers/m^3 on July 10.

Changes in seasonal weighted mean veliger densities at each lake station during the period of 1994-2003 are shown in Figures 8 and 9. In 2003, seasonal weighted mean veliger densities increased at 12 of 16 stations sampled for veligers, compared to densities found in 2002. The Northeast Lake sections had increases at 6 of 8 stations in 2003, although the changes were slight. Four of these stations recorded the highest densities since sampling began in 1994.

Mean veliger densities were compared for two different sampling methods (Table 2) at Crown Point (STA04), Main Lake (STA19), Burlington Bay (STA21) and STA46. The methods included a plankton net tow, which is based on an estimated volume of water to calculate veliger density, and a peristaltic pump to collect a known volume of water sampled.

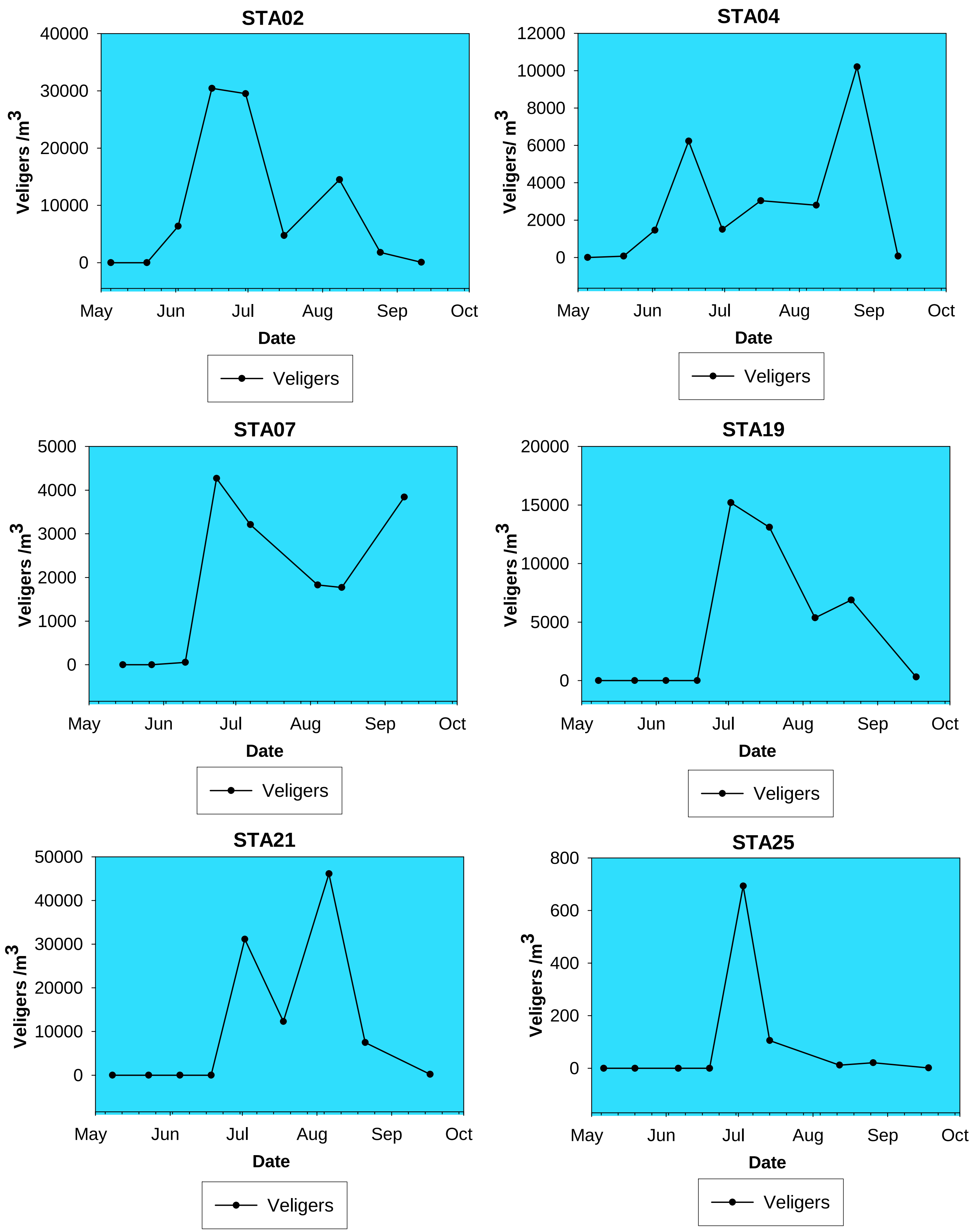


Figure 5. Veliger densities at openwater stations during 2003.

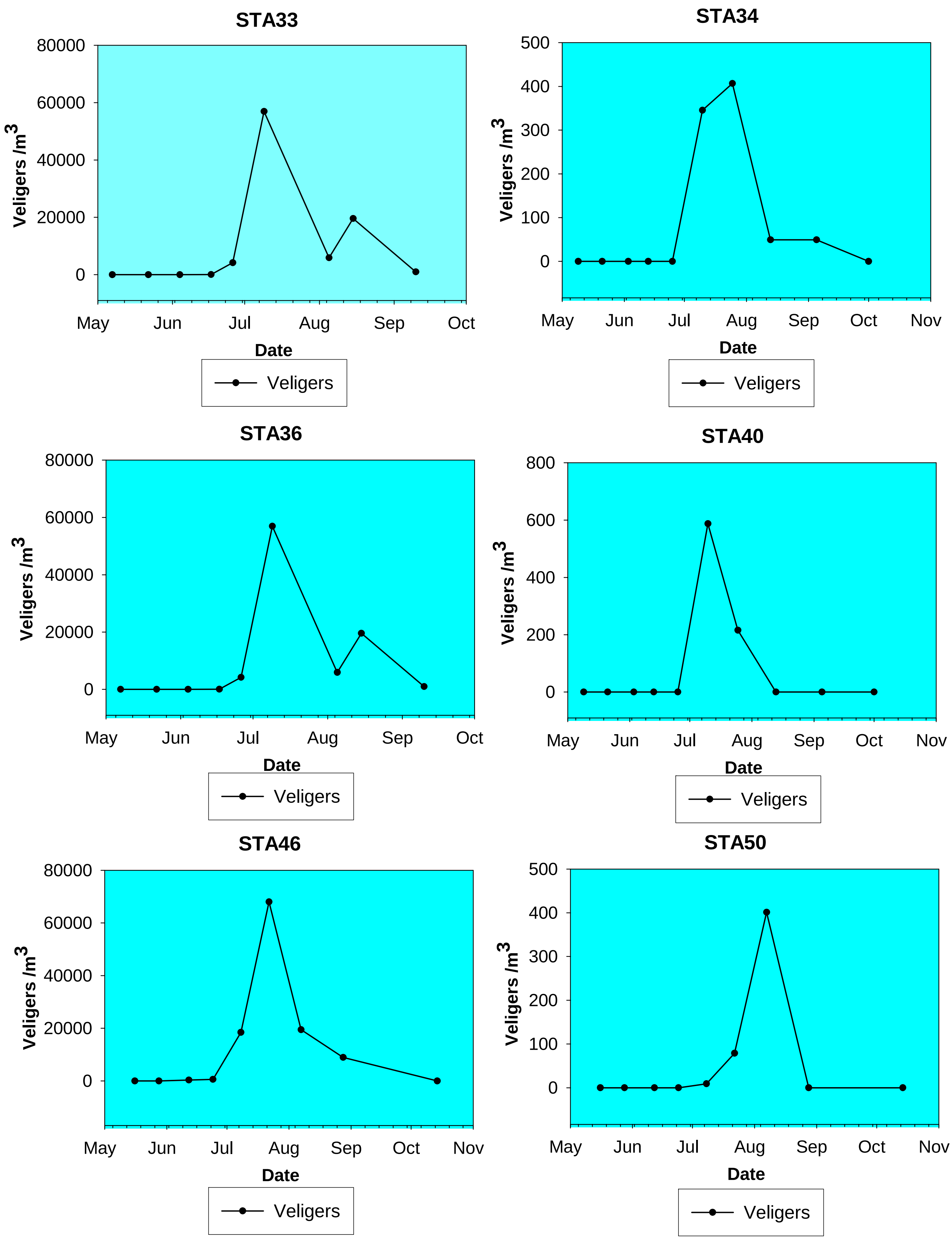


Figure 6. Veliger densities at openwater stations during 2003.

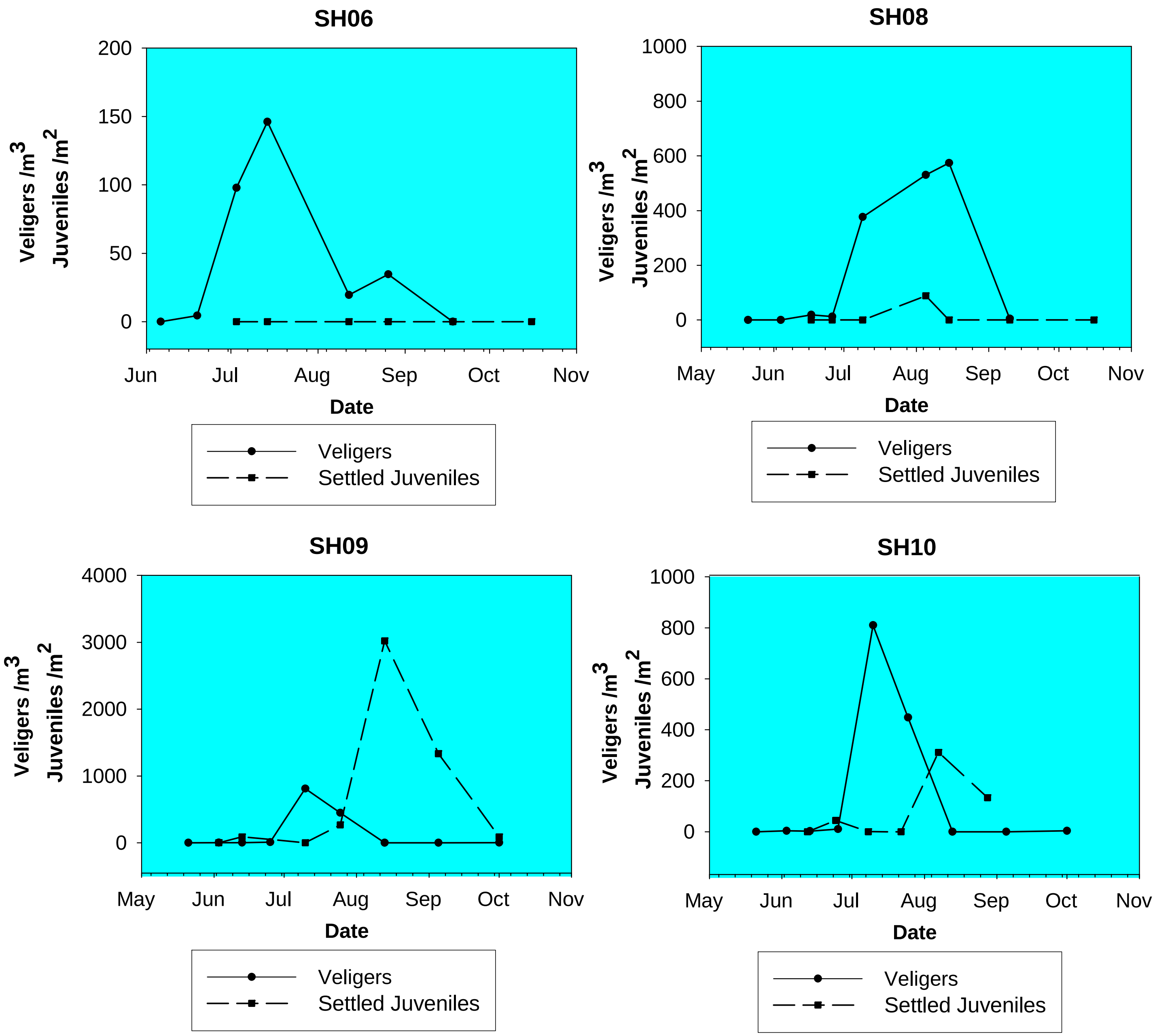
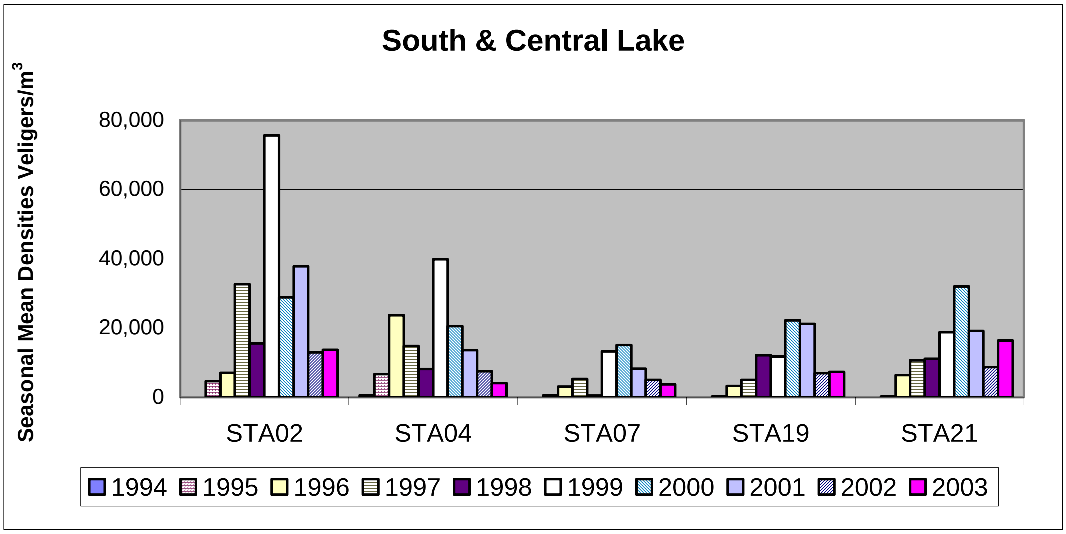


Figure 7. Veliger and settled juvenile densities at Northeast Lake nearshore stations during 2003.



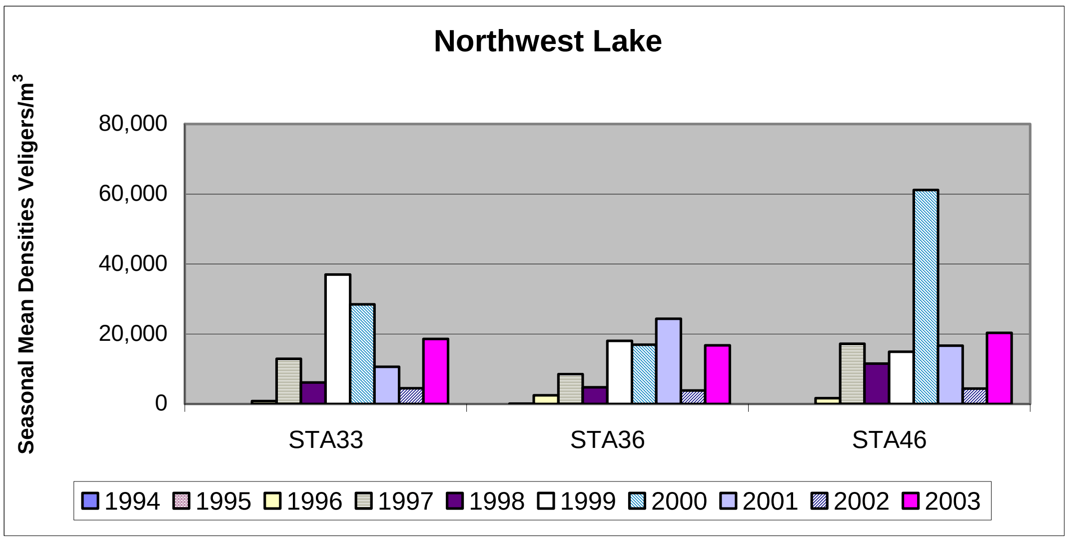
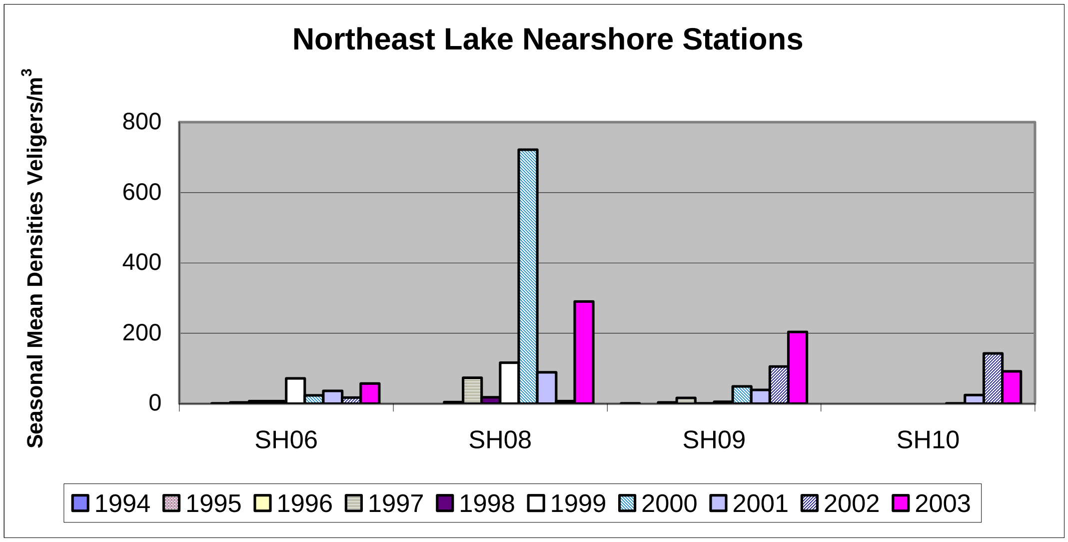


Figure 8. Seasonal weighted mean veliger densities for selected stations from 1994-2003.



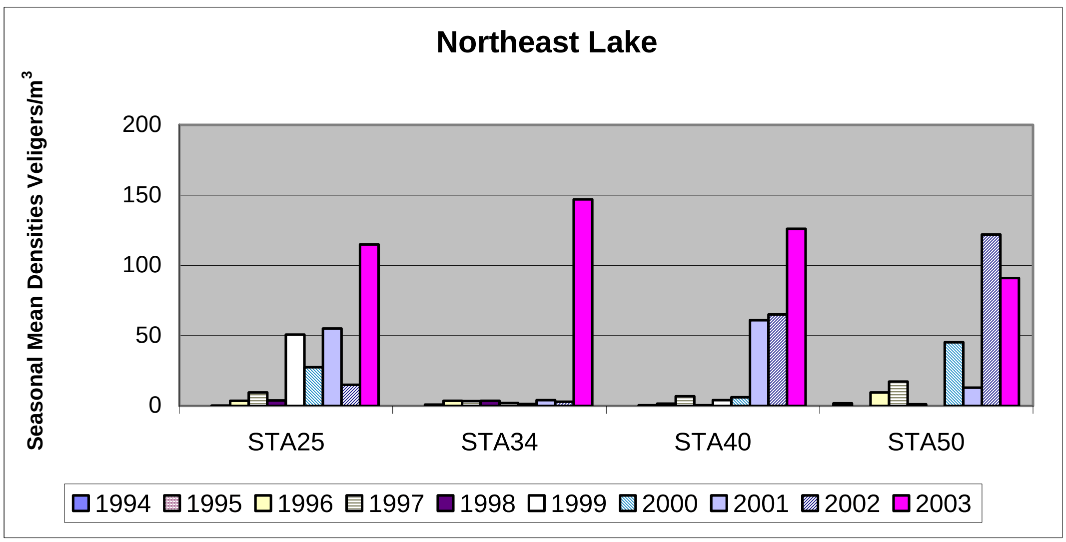


Figure 9. Seasonal weighted mean veliger densities for selected stations from 1994-2003.

The data shown in Table 1 indicate that the plankton net method yielded significantly lower mean densities compared to the pump method. Plankton net results ranged from 8-21% for all stations with a mean difference of 15%.

The lower densities collected by the plankton net are likely related to inefficient filtering which resulted in the over-estimation of the amount of water filtered through the net. Water flowing through the plankton net may have created a pressure wave in front of the net mouth, which pushed water and plankton away from the net mouth. The greater the pressure wave, the less accurate the sample (Wildlife Supply Company, 1999). This, coupled with net clogging from plankton, was likely responsible for the reduced filtering efficiency. Other factors may also have resulted in the lower densities for the plankton net results compared to the pump samples. The pump samples were taken from a depth of 3 m, while the net hauls were taken from 10 m to the surface, except at STA46 where the net haul was taken from 1 m off the bottom to the surface, generally 5-6 m. It is possible that veligers may tend to be concentrated at the 2-3 m layer and the longer net hauls may be sampling lower densities at deeper depths.

The advantage of known volume sampling at the 3 m depth at all stations is that one could compare veliger production from station to station throughout the lake. A disadvantage would be that the existing veliger sampling database could not be used for comparison with future data.

Table 1. Mean veliger densities (veligers/m^3) using plankton net and peristaltic pump sampling methods at selected stations in Lake Champlain during 2003.

Station	N	Pump Method Mean Veliger Density	Standard Error	N	Plankton Net Tow Mean Veliger Density	Standard Error	% of Pump Density
STA04	6	52,883	16,386	6	3,975	1,501	8
STA19	6	59,168	28,601	6	6,814	2,587	12
STA21	6	101,943	40,476	6	16,210	7,587	16
STA46	6	89,578	41,455	6	19,287	10,308	21

SETTLED JUVENILES

Variations in juvenile densities during the 2003 sampling season at Northeast Lake nearshore stations are described in Figure 7. Settled juvenile densities for 2003 in the Northeast Lake are available in Appendix B. The 1994-2003 data are available on the Vermont DEC website at http://www.vtwaterquality.org/lakes/htm/lp_zebramon.htm .

In 2003, settled juveniles were first detected in the Northeast Lake on June 13 at SH09. The 2003 peak settled juvenile density was 3022 juveniles/m^2 collected on August 13 at SH09. No settlement occurred at Marble Island (SH06) during 2003. In 2003, settlement occurred at SH10 for the first time since one juvenile was found in 1998. The settling plate array from SH10 was lost in October. The settling plate array from SH09 was lost in June and was replaced.

Differences among seasonal weighted mean juvenile densities from 1998-2003 for selected Northeast Lake nearshore stations are shown in Figure 10. Data from only 1998-2003 were used due to a lack of reliable data from some stations during previous years because of loss or vandalism of sampling plates.

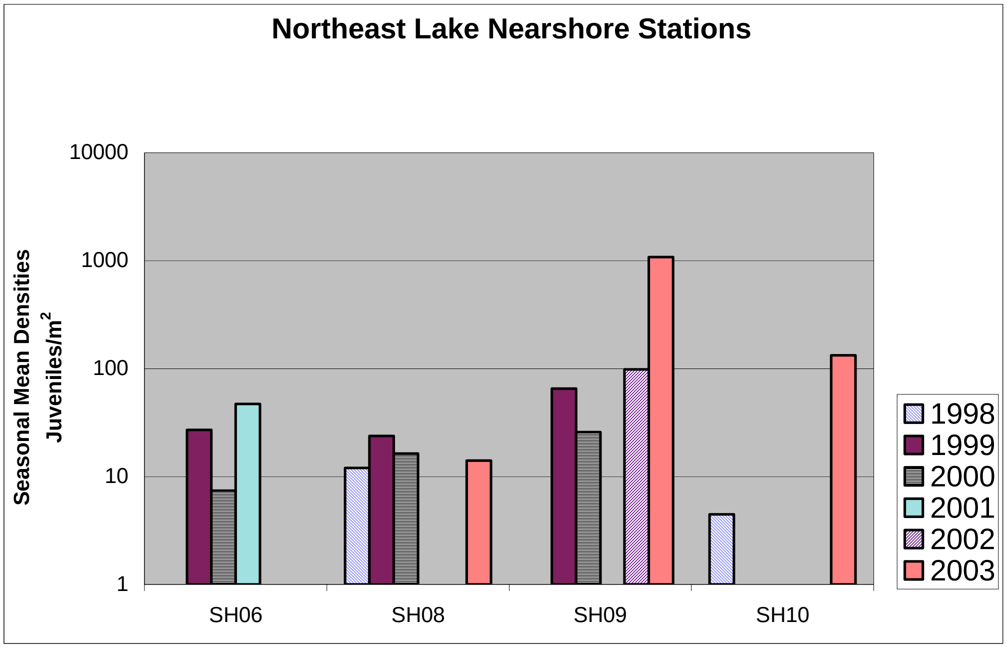


Figure 10. Seasonal weighted mean juvenile densities for selected nearshore stations in Northeast Lake Champlain from 1998-2003.

Season juvenile settling plate densities and average juvenile size for selected nearshore stations from 1998-2003 are shown in Figure 11. The greatest season plate density during the 2003 season was recorded at Burlington Boathouse (SH05), with 97,067 juveniles/m^2. Early settlers at Chipman Point Marina (CHIP) grew to approximately 15 mm by October. The season plate at Crown Point Bridge (SH02) was vandalized twice in 2003 therefore no result was recorded. The average size of settled juveniles on season plates at all other nearshore stations was variable, with sizes ranging from 4-9 mm. During 2000-2002, the settling plates at Grand Isle Ferry (SH07) were infested with the exotic snail, mud bythinia, (*Bythinia tentaculata),* which feed by grazing and filtering. The season plate at SH07 had no settlement until 2003, though the density was lower than what would be expected considering that veliger production at nearby open-water stations was high.

TRIBUTARIES AND INLAND LAKES

No veligers were found in any of the samples collected during 2003 in Arrowhead Mt. Lake, Lake Carmi, Caspian Lake, Cedar Lake, Crystal Lake, Lake Dunmore, Fairfield Pond, Lake Fairlee, Glen Lake, Harvey's Lake, Lake Hortonia, Lake Iroquois, Island Pond, Lake Memphremagog, Lake Morey, Seymour Lake, Shelburne Pond, Lake Willoughby, and Lake St. Catherine. Veligers were detected in all Lake Bomoseen samples collected in 2003. Snorkel surveys conducted by researchers from Castleton State College confirmed the presence of adult zebra mussels at numerous locations in Lake Bomoseen in 2000 (A. Hampton, personal comm., 2000).

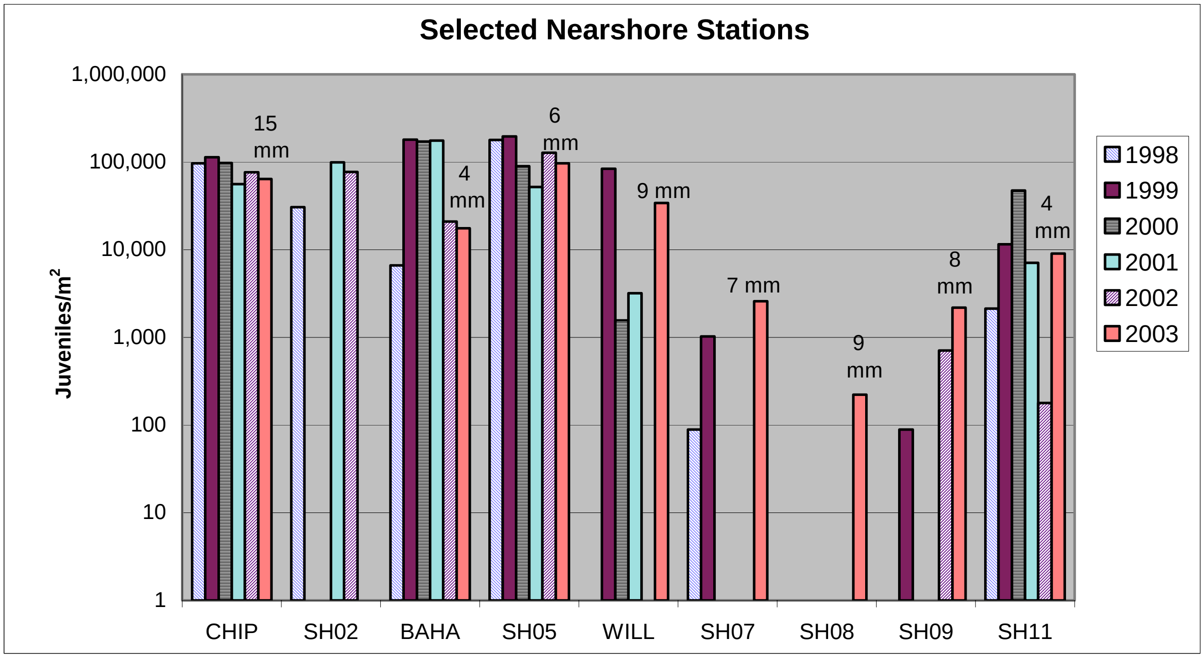


Figure 11. Season plate densities from 1998-2003. The 2003 average juvenile size (mm) is noted above the bars for selected nearshore stations in Lake Champlain. Stations with values of less than one indicate no settlement, or missing plates in the case of SH02.

No veligers were found in samples taken in 2003 from the Missisquoi River, Lamoille River, Winooski River, Castleton River, Otter Creek, Lewis Creek, Dead Creek and the Poultney River on the Vermont side of the lake, and the Great Chazy River, Little Chazy River, Saranac River, Salmon River, Little Ausable River, Ausable River, and the Bouquet River in New York. In 2002 and 2003, additional sampling was performed in the Castleton River downstream of the outlet of Lake Bomoseen to determine whether veligers from this lake have drifted. No veligers were found in these samples. Adult zebra mussels had been found in the LaPlatte River in 1997 and in Lewis Creek and Otter Creek in 1998. Veligers had been found in Little Otter Creek and the Winooski River in 1999. Researchers found two adult zebra mussels in samples from dismantled Sea Lamprey nests in Lewis Creek, upstream of the Route 7 Bridge (C. Martin, USFW, personal comm., 2003). In 2004, sampling will be increased in Lewis Creek, Cedar Lake and Lake Winona (which have outlets to Lewis Creek), to determine if a reproducing population exists.

ADULT DISTRIBUTION

Adult zebra mussels continue to be common to very abundant on most firm substrates in the South, Central, and Northwest regions of Lake Champlain. In contrast, comparatively few adults were found in the Northeast Lake (Malletts Bay, north to Missisquoi Bay) with the exception of St. Albans Bay, which has had more numerous recruitment in the past two to three years. The Northeast Lake is open to water exchange with the Central Lake only through five openings in the railroad causeway as shown in Figure 1. These restrictions may slow the drift of veligers into the Northeast region of the lake. Expansion of adult zebra mussel populations in the Northeast Lake after the initial appearance of veligers has occurred more slowly than in the South, Central, and Northwest regions (Figure 4).

QUALITY ASSURANCE RESULTS

Mean relative percent differences (RPD) of field and laboratory duplicates were calculated for open-water and nearshore veliger and settled juvenile samples for 2003 (Table 1). The RPD of field duplicates represents the combined field sampling and analytical variability, while the RPD of laboratory duplicates measures only the variability within the analytical procedure. The mean RPD values for all veliger and settled juvenile laboratory and field duplicate samples were within the acceptable data quality objective limits (Stangel, 2003).

Table 2. Mean relative percent differences for 2003 laboratory and field zebra mussel veliger and juvenile duplicate samples.

	Sample Type	Number Counted	Mean RPD	Number of Duplicate Pairs
Laboratory RPD's	Veligers	0 -100	2.8	4
		>100	2.9	10
	Juveniles	0 -100	1.7	3
		>100	4.0	2
Field RPD's	Veligers	0 -100	10.0	4
		>100	3.9	7
	Juveniles	0 -100	5.6	3
		>100	26.0	2

SUMMARY AND CONCLUSIONS

The results of the 2003 Zebra Mussel Monitoring Program indicate that veliger densities in Lake Champlain increased at 12 of 16 stations compared to densities found in 2002, although none of the 2003 veliger densities in the South, Central, or Northwest Lake areas were as high as the peak densities from previous years. In contrast, the range expansion in the Northeast Lake is continuing, where 4 of 8 stations recorded their highest peaks, but at a relatively slow rate compared to the rest of the lake. Juvenile settlement increased or remained the same at 3 of 4 stations compared to densities found in 2002. The Northeast Lake continued to have very little settled juvenile production.

Zebra mussel adults have been well established in the South, Central, and Northwest Lake since 1996. The expansion phase of the zebra mussel infestation may be over in these areas of the lake. In contrast, the range expansion in the Northeast Lake has been relatively slow. As of 2003, known adult zebra mussel distribution in the Northeast Lake includes Malletts Bay and the Inland Sea. Although no adult zebra mussels have been confirmed in Missisquoi Bay, settled juvenile results from 2003 suggest that adults may be present. The slower range expansion and the lack of large zebra mussel populations in the Northeast Lake may be due to the restricted water exchange with other lake regions, or the lower calcium levels found in this section of the lake. As previously reported (Eliopoulos and Stangel 1998, 1999, 2000), calcium is critical to zebra mussel growth, reproduction and survival.

Adult zebra mussels continue to be found in Lake Bomoseen. No other lakes in Vermont were found to have zebra mussels. Adult zebra mussels have been found in the lower reaches of Otter Creek, Little Otter Creek, Lewis Creek, LaPlatte River and the Winooski River in past years. No new tributaries into Lake Champlain were found to be harboring zebra mussels in 2003.

RECOMMENDATIONS

The efficient combination of the Zebra Mussel Monitoring Program with the Long-Term Water Quality and Biological Monitoring Program provides a nationally unique lake database. Information on veliger and juvenile densities monitored consistently since the initial colonization is obtained concurrently with comprehensive water quality data. This information is critical for determining the effects of zebra mussels on the Lake Champlain ecosystem and for assessing the risk and impact of zebra mussel colonization of other water bodies.

VELIGER SAMPLING

Zebra mussel colonization of Lake Champlain and other Vermont lakes and tributaries should continue to be documented by collecting plankton samples and analyzing them for veligers. If time allows, an effort should be made to survey for adult zebra mussels in lakes where veligers are found.

JUVENILE SAMPLING

The project should continue to monitor juvenile settlement in Lake Champlain to document the establishment of zebra mussels in the Northeast lake.

ADULT SAMPLING

The project should continue to track the distribution and abundance of adult zebra mussels in Lake Champlain. Adult density sampling techniques using an underwater camera and SCUBA diver assisted verification of densities should be researched and developed for possible use in Lake Champlain.

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Appendix A: Zebra mussel veliger density data, 2003

Station	Date	Temp (C)	Secchi (m)	Density (n/m3)
SH06	6/6/2003	16.5	5.2	0
SH06	6/19/2003	18.0	6.2	5
SH06	7/3/2003	23.6	4.3	98
SH06	7/14/2003	23.7	5.0	146
SH06	8/12/2003	25.6	5.6	20
SH06	8/26/2003	23.4	5.5	35
SH06	9/18/2003	21.7	6.0	0
SH08	5/21/2003	6.5	4.0	0
SH08	6/4/2003	14.1	3.9	0
SH08	6/17/2003	18.0	4.0	19
SH08	6/26/2003	19.6		12
SH08	7/9/2003	22.7		377
SH08	8/5/2003	23.8	3.6	530
SH08	8/15/2003	26.8		574
SH08	9/10/2003	20.6		5
SH09	5/21/2003	16.6	1.6	0
SH09	6/3/2003	14.3	2.2	3
SH09	6/13/2003	16.6	2.0	2
SH09	6/25/2003	25.5	2.4	10
SH09	7/10/2003	25.7	1.7	810
SH09	7/25/2003	24.2	1.4	448
SH09	8/13/2003	25.7	2.2	0
SH09	9/5/2003	20.2	1.5	0
SH09	10/1/2003	16.0	1.6	4
SH10	5/16/2003	14.7	2.3	0
SH10	5/28/2003	17.2	1.8	0
SH10	6/12/2003	19.3	1.9	0
SH10	6/24/2003	25.0	3.0	2
SH10	7/8/2003	25.8	2.3	0
SH10	7/22/2003	23.0	1.4	51
SH10	8/7/2003	25.1	1.5	433
SH10	8/28/2003	20.6	0.8	0
STA02	5/5/2003	11.0	0.8	0
STA02	5/20/2003	18.0	1.1	0
STA02	6/2/2003	18.0	0.9	6,374
STA02	6/16/2003	20.9	1.6	30,437
STA02	6/30/2003	24.1	1.7	29,508
STA02	7/16/2003	23.9	1.1	4,751
STA02	8/8/2003	25.5	0.9	14,497
STA02	8/25/2003	23.9	1.2	1,793
STA02	9/11/2003	20.9	0.9	80
STA04	5/5/2003	11.9	1.0	0
STA04	5/20/2003	18.0	1.3	71
STA04	6/2/2003	18.0	2.0	1,456
STA04	6/16/2003	19.6	3.3	6,228
STA04	6/30/2003	23.8	2.9	1,507
STA04	7/16/2003	22.4	1.7	3,039
STA04	8/8/2003	26.8	1.6	2,796
STA04	8/25/2003	23.9	1.2	10,212
STA04	9/11/2003	22.2	1.3	68
STA07	5/15/2003	10.8	3.5	0
STA07	5/27/2003	11.5	4.3	0
STA07	6/10/2003	12.0	3.9	56
STA07	6/23/2003	17.7	4.1	4,272
STA07	7/7/2003	23.1	5.4	3,212
STA07	8/4/2003	21.7	4.9	1,828
STA07	8/14/2003	25.4	8.5	1,770
STA07	9/9/2003	19.9	3.0	3,842
STA19	5/8/2003	9.0	8.5	0
STA19	5/23/2003	8.3	5.0	0
STA19	6/5/2003	12.5	7.9	0
STA19	6/18/2003	14.6	4.5	2
STA19	7/2/2003	20.9	6.3	15,203
STA19	7/18/2003	21.2	6.9	13,102
STA19	8/6/2003	22.5	5.5	5,374
STA19	8/21/2003	24.7	5.7	6,893
STA19	9/17/2003	20.2	6.6	309
STA21	5/8/2003	8.0	6.4	0
STA21	5/23/2003	10.4	4.1	0
STA21	6/5/2003	10.5	6.1	0
STA21	6/18/2003	15.5	4.1	5
STA21	7/2/2003	22.0	5.3	31,140
STA21	7/18/2003	22.9	6.1	12,299
STA21	8/6/2003	24.3	5.9	46,108
STA21	8/21/2003	24.9	5.5	7,498
STA21	9/17/2003	20.9	6.0	208
STA25	5/6/2003	6.0	2.4	0
STA25	5/19/2003	14.2	6.0	0
STA25	6/6/2003	15.3	5.3	0
STA25	6/19/2003	17.5	4.7	0
STA25	7/3/2003	23.1	4.4	693
STA25	7/14/2003	22.0	5.1	105
STA25	8/12/2003	25.0	6.8	12
STA25	8/26/2003	22.5	5.5	21
STA25	9/18/2003	21.0	7.5	2
STA33	5/7/2003	10.7	3.7	0
STA33	5/22/2003	10.0	6.0	0
STA33	6/4/2003	11.9	6.2	0
STA33	6/17/2003	16.1	3.4	51
STA33	6/26/2003	21.0	4.4	4,195
STA33	7/9/2003	23.2	7.2	56,957
STA33	8/5/2003	24.1	5.0	5,902
STA33	8/15/2003	25.3	5.3	19,588
STA33	9/10/2003	18.5	6.5	972
STA34	5/9/2003	6.9	3.4	0
STA34	5/21/2003	9.6	2.7	0
STA34	6/3/2003	13.5	4.1	0
STA34	6/13/2003	15.5	4.1	0

Appendix A: Zebra mussel veliger density data, 2003

Station	Date	Temp (C)	Secchi (m)	Density (n/m3)	Station	Date	Temp (C)	Secchi (m)	Density (n/m3)
STA34	6/25/2003	21.3	6.9	0					
STA34	7/10/2003	23.3	6.5	346					
STA34	7/25/2003	21.6	5.0	407					
STA34	8/13/2003	24.9	5.8	49					
STA34	9/5/2003	19.8	4.0	49					
STA34	10/1/2003	17.2	4.8	0					
STA36	5/7/2003	6.1	4.2	0					
STA36	5/22/2003	9.8	6.6	0					
STA36	6/4/2003	10.7	9.7	0					
STA36	6/17/2003	14.8	6.6	27					
STA36	6/26/2003	20.3	6.4	2,365					
STA36	7/9/2003	23.0	5.9	47,414					
STA36	8/5/2003	23.1	7.9	19,337					
STA36	8/15/2003	24.8	5.5	11,862					
STA36	9/10/2003	18.9	6.0	1,025					
STA40	5/9/2003	10.3	2.6	0					
STA40	5/21/2003	15.0	2.0	0					
STA40	6/3/2003	12.7	3.0	0					
STA40	6/13/2003	17.9	2.9	0					
STA40	6/25/2003	24.0	4.6	0					
STA40	7/10/2003	25.4	2.2	588					
STA40	7/25/2003	22.8	2.9	216					
STA40	8/13/2003	26.5	2.5	0					
STA40	9/5/2003	20.2	1.6	0					
STA40	10/1/2003	17.0	2.3	0					
STA46	5/16/2003	10.0	7.0	0					
STA46	5/28/2003	15.3	6.1	0					
STA46	6/12/2003	15.5	6.7	316					
STA46	6/24/2003	21.7	6.8	603					
STA46	7/8/2003	24.1	5.0	18,458					
STA46	7/22/2003	22.4	5.2	67,973					
STA46	8/7/2003	24.6	4.3	19,452					
STA46	8/28/2003	20.3	4.6	8,920					
STA46	10/14/2003	14.8	4.8	0					
STA50	5/16/2003	14.5	1.5	0					
STA50	5/28/2003	17.7	2.0	0					
STA50	6/12/2003	19.3	2.2	0					
STA50	6/24/2003	23.0	2.7	0					
STA50	7/8/2003	25.4	2.1	9					
STA50	7/22/2003	22.7	1.3	79					
STA50	8/7/2003	24.7	1.4	401					
STA50	8/28/2003	20.1	1.0	0					
STA50	10/14/2003	13.3	1.9	0					

Appendix B: Zebra mussel juvenile density data 2003

Station	Date	Days in Lake	Density (n/m2)
BAHA	10/20/2003	158	17,600
CHIP	10/23/2003	171	64,000
SH05	10/20/2003	165	97,067
SH06	7/3/2003	28	0
SH06	7/14/2003	26	0
SH06	8/12/2003	40	0
SH06	8/26/2003	43	0
SH06	9/18/2003	36	0
SH06	10/16/2003	132	0
SH06	10/16/2003	28	0
SH07	10/23/2003	169	2,578
SH08	6/17/2003	39	0
SH08	6/26/2003	37	0
SH08	7/9/2003	23	0
SH08	8/5/2003	41	89
SH08	8/15/2003	38	0
SH08	9/10/2003	37	0
SH08	10/16/2003	160	222
SH08	10/16/2003	60	0
SH09	6/3/2003	26	0
SH09	6/13/2003	24	89
SH09	7/10/2003	16	0
SH09	7/25/2003	30	267
SH09	8/13/2003	34	3,022
SH09	9/5/2003	42	1,333
SH09	10/1/2003	42	2,178
SH09	10/1/2003	98	89
SH10	6/12/2003	27	0
SH10	6/24/2003	28	44
SH10	7/8/2003	27	0
SH10	7/22/2003	29	0
SH10	8/7/2003	31	311
SH10	8/28/2003	36	133
SH11	10/14/2003	151	9,067
WILL	10/23/2003	153	34,133