LAKE CHAMPLAIN 2004
ZEBRA MUSSEL MONITORING PROGRAM

Final Report
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A Report Prepared for the
Lake Champlain Basin Program

Peter Stangel and Angela Shambaugh
Vermont Department of Environmental Conservation
103 So. Main St.
Building 10 North
Waterbury, Vermont 05671-0408
(802) 241-3777

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

LIST OF TABLES:

LIST OF FIGURES:

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 2004, 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 distribution in Missisquoi Bay. Twenty-one Vermont inland lakes with high boating activity or close proximity to Lake Champlain, and 16 Lake Champlain tributaries, were selected for veliger sampling.

Zebra mussels in Lake Champlain continued to reproduce and settle successfully during 2004, although veliger densities decreased at 9 of 16 stations compared to the previous year. None of the 2004 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. Juvenile settlement occurred at only 1 of the 4 stations in the Northeast Lake in 2004. 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. Season settling plates retrieved at nearshore stations in these areas in 2004 confirm continued reproductive success, and similar growth rates as in years past. In 2004, a single adult zebra mussel was confirmed in Missisquoi Bay.

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 mussel adults in 2004, although veligers were found in the Castleton River approximately 2.5 miles downstream from the population of zebra mussels in Lake Bomoseen.

A general consensus of the Lake Champlain Zebra Mussel Workgroup in 2003 was that the lack of data about adult zebra mussel densities in the lake should be addressed. The effects of zebra mussels filter feeding lake water may create changes in water chemistry and in phytoplankton and zooplankton populations, which in turn could have negative effects on fish populations. Zebra mussels settle on native mussels, causing their extirpation. Increased clarity due to filtering can increase macrophyte growth. A review of recent literature found that there have been few attempts to assess adult zebra mussel densities on a large scale, e.g. lakewide. These studies, primarily in Lake Erie, use an integrated approach to evaluate mussel densities with diver-collected samples, underwater videography and/or sonar. By incorporating large scale, but less detailed, video or sonar surveys with the detailed, but costly, information provided by analysis of a limited set of diver-collected materials, a quantitative estimate of adult mussel densities is possible at a reasonable cost. Further discussion of how this project should best be implemented on Lake Champlain is also warranted. In particular, the ability of the current mussel monitoring program to undertake this study should be evaluated.

ACKNOWLEDGMENTS

This monitoring program benefited greatly from the contributions of the following individuals at the Vermont Department of Environmental Conservation: Mike Hauser for assistance and distribution of webpage 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.

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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, Stangel 2004). This report presents veliger, juvenile and adult zebra mussel distributions during 2004 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, 2004). 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 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.

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.

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 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.

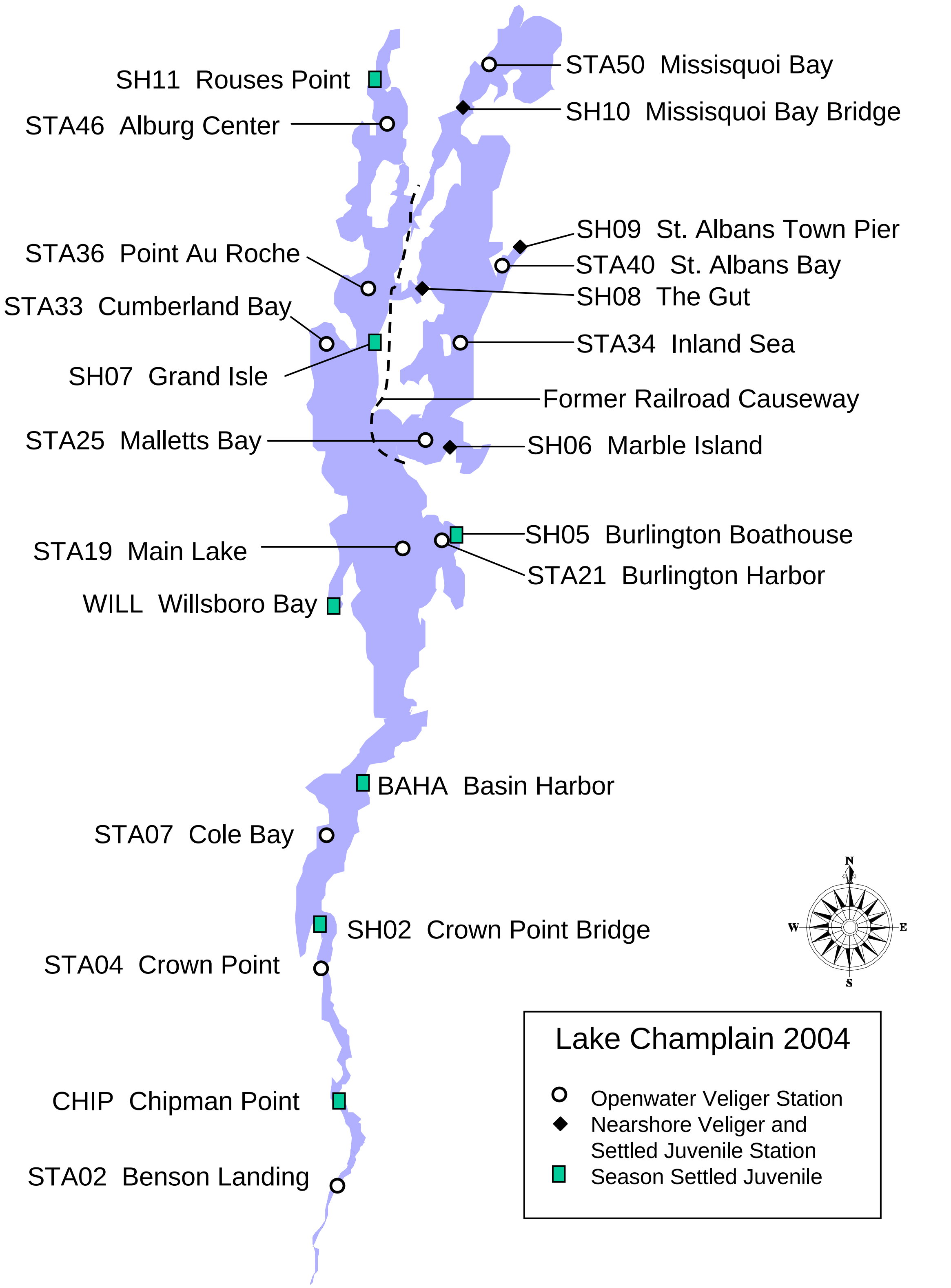

Figure 1. Open-water and nearshore sampling site locations for the Lake Champlain 2004 Zebra Mussel Monitoring Program.

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 or bridge abutment. 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.

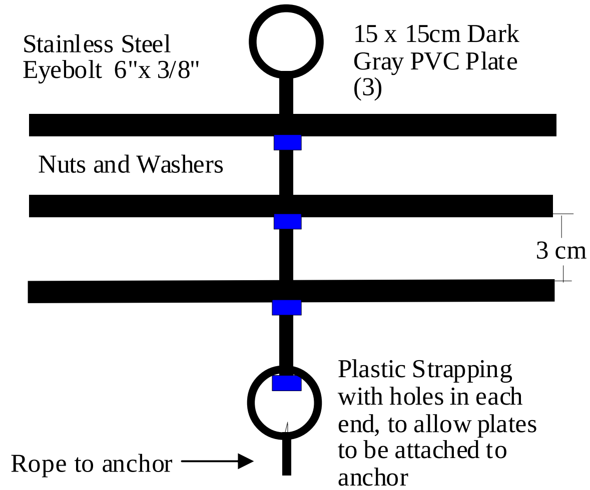

Figure 2. Settling plate array.

As recommended by the Lake Champlain Zebra Mussel Workgroup, the two-week interval 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 1997-2004. 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

Sixteen Lake Champlain tributaries (Figure 3) were selected for sampling, including the Castleton River, Lamoille River, Lewis Creek, Missisquoi River, Otter Creek, Poultney River, and the Winooski River on the Vermont side of the lake, and the Ausable River, Bouquet River, Great Chazy River, Little Ausable River, Little Chazy River, Mettawee River, Putnam Creek Salmon River, and the Saranac River in New York. The Connecticut River in North Thetford was also sampled. The net used in Lake Champlain was not used for river sampling. 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-one 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, Joes Pond, Lake Memphremagog, Lake Morey, Seymour Lake, Shelburne Pond, Lake St. Catherine and Lake Willoughby (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 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

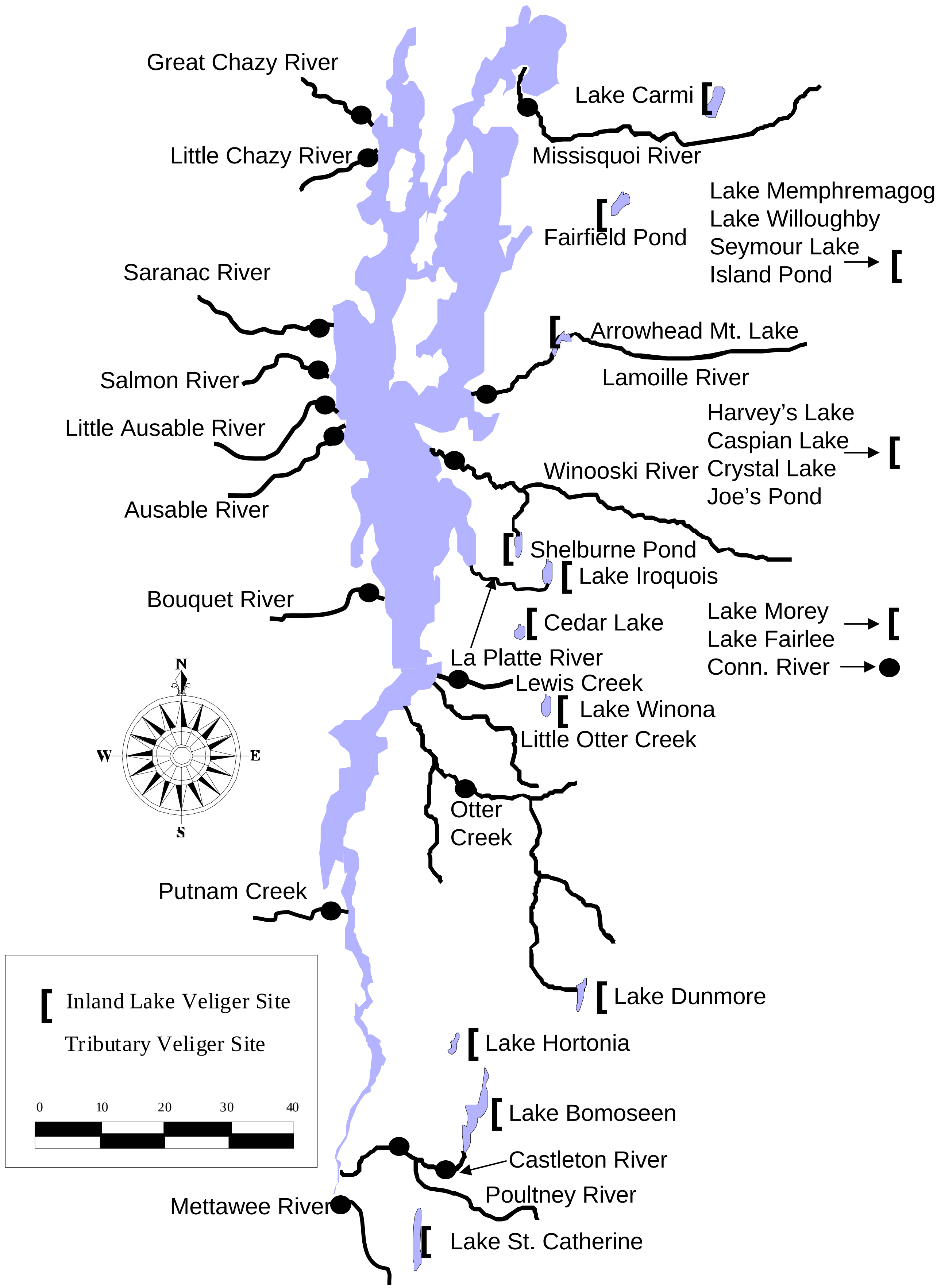

Figure 3. Inland lake and tributary sampling site locations for the Lake Champlain 2004 Zebra Mussel Monitoring Program.

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, 2004). Data precision for 2004 was determined through field duplication of 9% of the veliger samples and 19% of juvenile settling plate samples. In addition, 9% of all veliger samples and 30% 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= *(count a - count b) / (count a + count b) / 2* x 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 2004, although veliger densities decreased at 9 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 2004, during a snorkel survey a single adult zebra mussel (33.5 mm long) was found in Missisquoi Bay, approximately 2.5 miles north of the Missisquoi Bay Bridge. This is the first reported sighting of zebra mussels in the bay.

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.

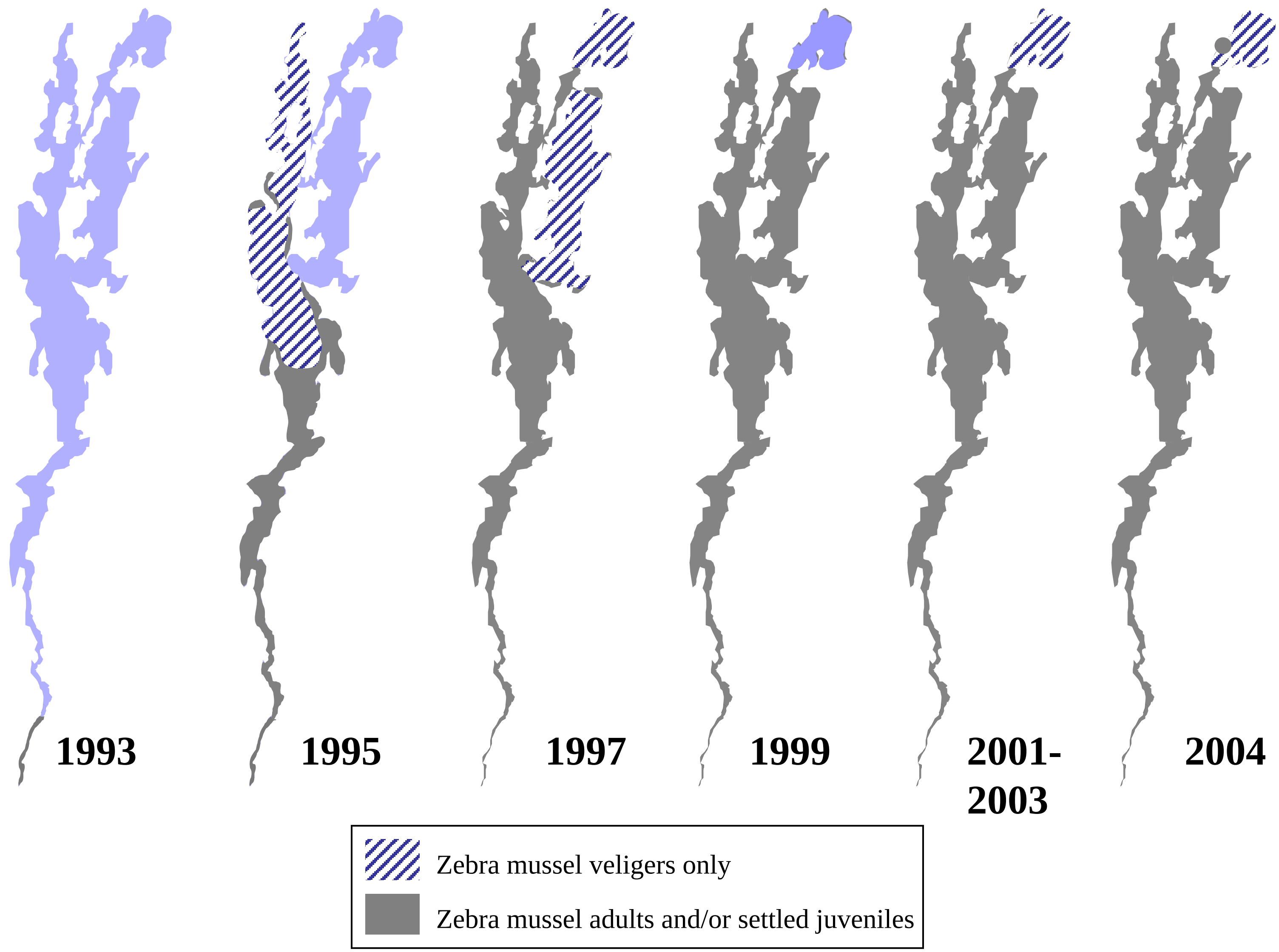

Figure 4. Annual changes in Lake Champlain zebra mussel distribution since 1993.

VELIGERS

Variations in veliger densities during the 2004 sampling season are described for all regions of the lake in Figures 5-7. Veliger densities with temperature and Secchi depths for 2004 are available in Appendix A. The 1994-2004 data are available on the Vermont DEC website at http://www.vtwaterquality.org/lakes/htm/lp_zebramon.htm .

Veligers were first detected in 2004 in the South Lake in mid-May as water temperatures rose to 17º 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 three to four weeks later in the Central, Northeast, and Northwest lake regions. In 2004, the timing of peak densities throughout the lake regions was concentrated during the time of warmest water temperature, ranging from July 6 to August 17, with the highest peak of 187,512 veligers/m^3 sampled at the South Lake station Benson Landing, (STA02) on July 13. 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 2004. The highest veliger density recorded in the Northeast Lake was at St. Albans Bay (STA40), with a density of 1,423 veligers/m^3 on August 10.

Changes in seasonal weighted mean veliger densities at each lake station during the period of 1994-2004 are shown in Figures 8 and 9. In 2004, seasonal weighted mean veliger densities decreased at 9 of 16 stations sampled for veligers, compared to densities found in 2003. The Northeast Lake sections had increases at 3 of 8 stations in 2004. Stations in St. Albans Bay, (STA40 and St. Albans Town Pier (SH09)) had increases approximately 3 to 6 times above 2003 levels. These St. Albans Bay stations recorded the highest densities since sampling began in 1994.

SETTLED JUVENILES

Variations in juvenile densities during the 2004 sampling season at Northeast Lake nearshore stations are described in Figure 7. Settled juvenile densities for 2004 in the Northeast Lake are available in Appendix B. The 1994-2004 data are available on the Vermont DEC website at http://www.vtwaterquality.org/lakes/htm/lp_zebramon.htm .

In 2004, settled juveniles were first detected in the Northeast Lake on July 19 at SH09. The 2004 peak settled juvenile density was 1,556 juveniles/m^2 collected on the same day at SH09. No settlement occurred at Marble Island (SH06), The Gut (SH08) or Missisquoi Bay Bridge (SH10) during 2004.

Differences among seasonal weighted mean juvenile densities from 1998-2004 for selected Northeast Lake nearshore stations are shown in Figure 10. Data from only 1998-2004 were used due to a lack of reliable data from some stations during previous years because of loss or vandalism of sampling plates.

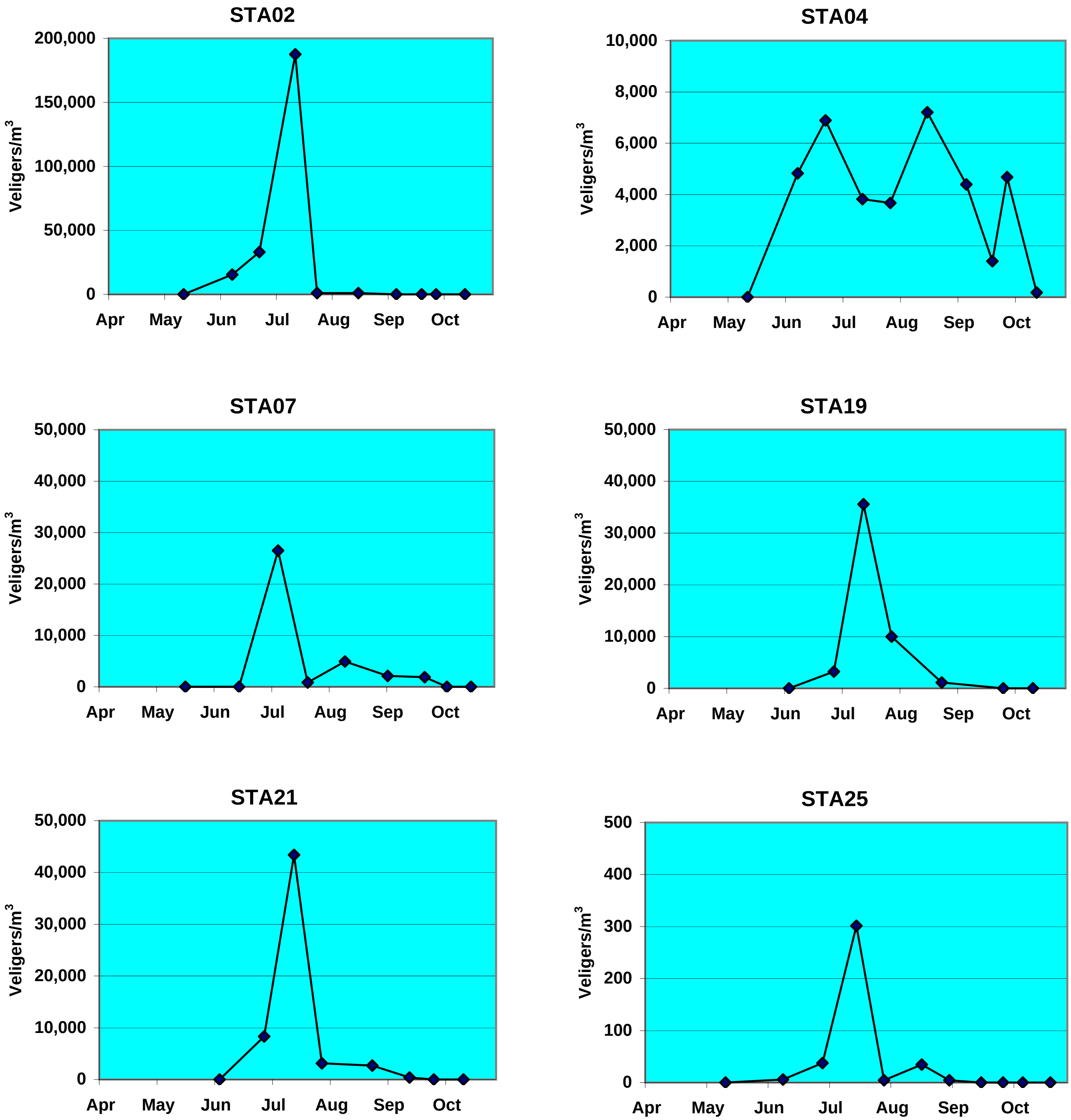

Figure 5. Veliger densities at open-water stations during 2004.

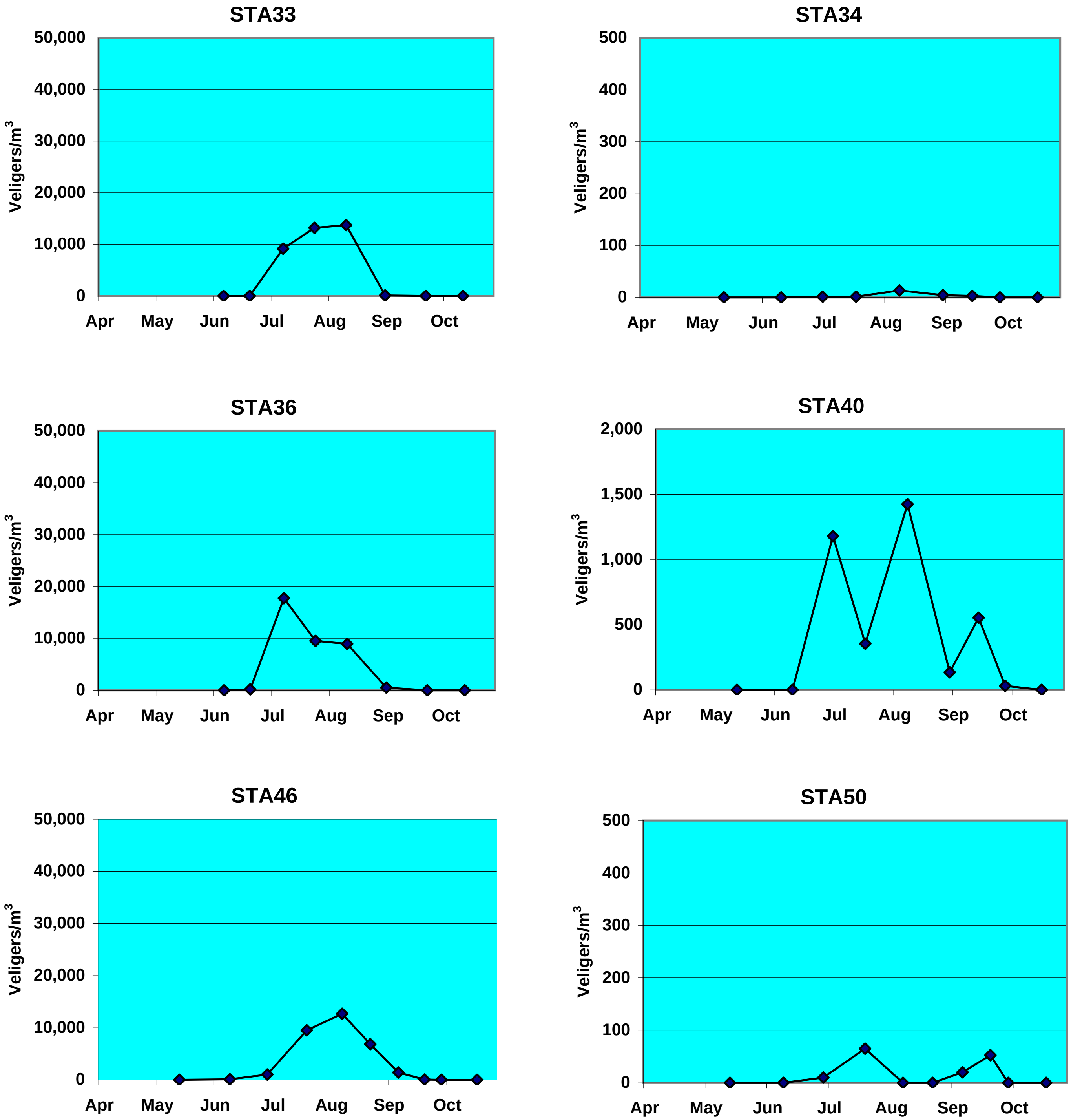

Figure 6. Veliger densities at open-water stations during 2004.

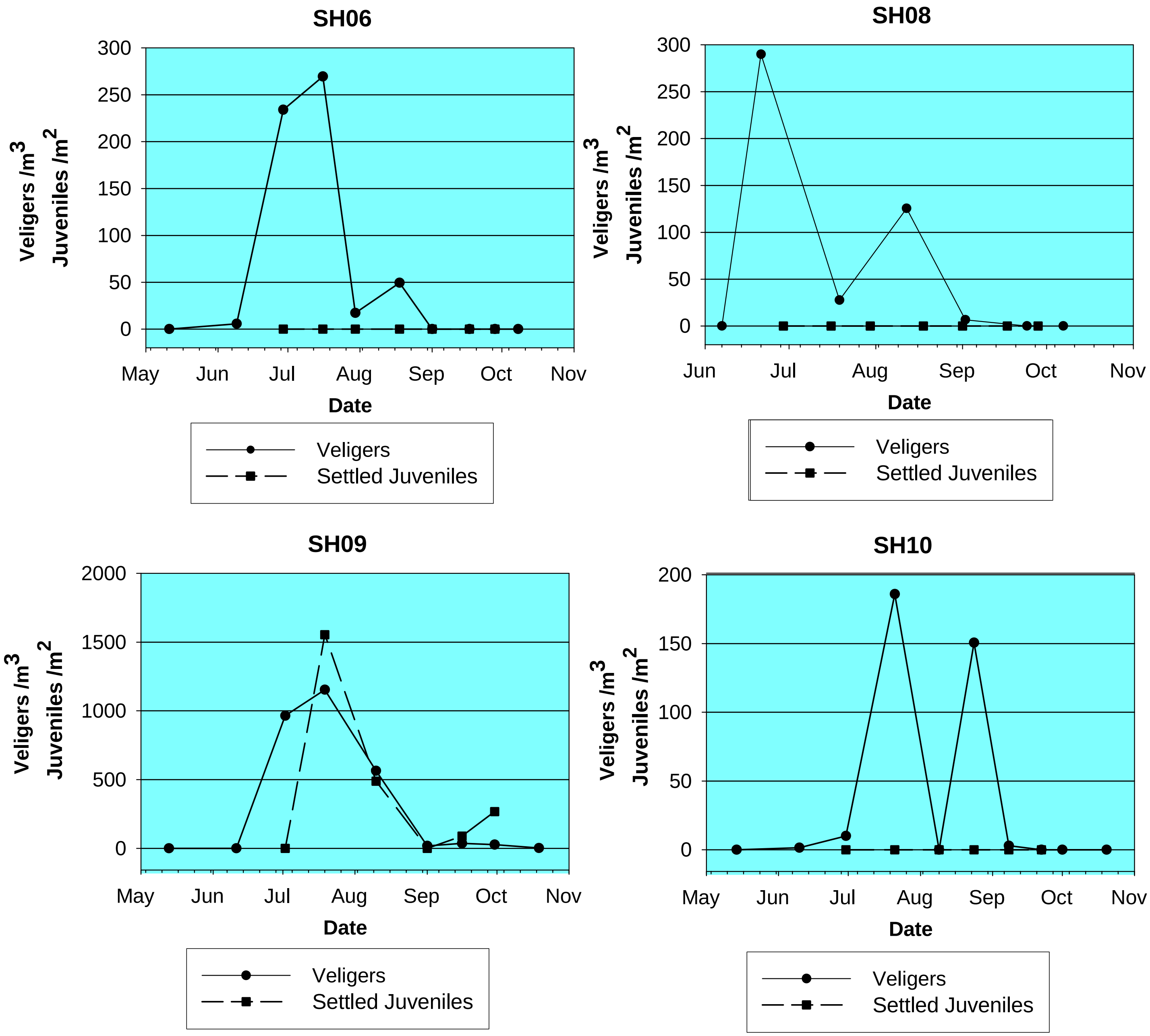

Figure 7. Veliger and settled juvenile densities at Northeast Lake nearshore stations during 2004.

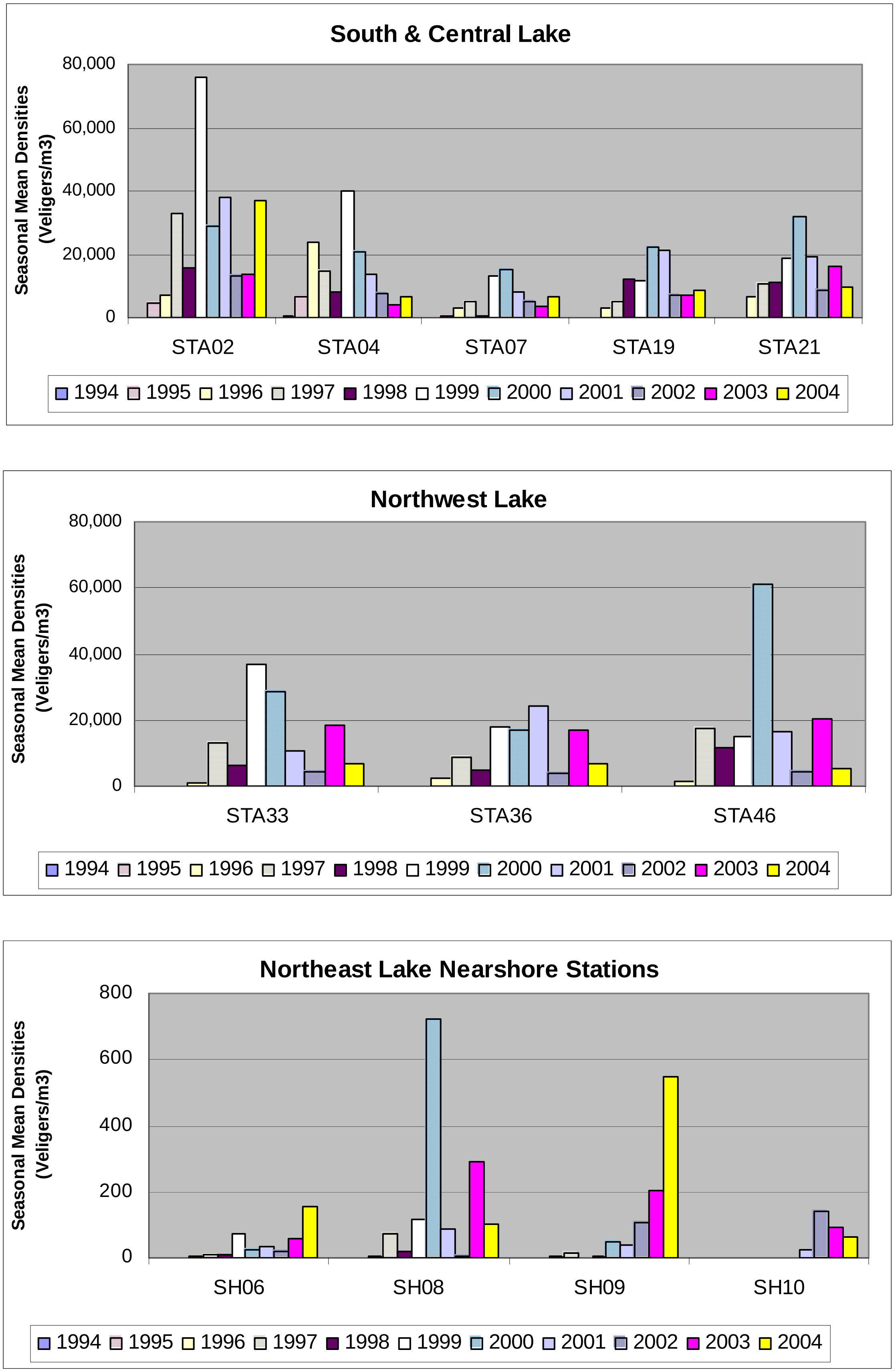

Figure 8. Seasonal weighted mean veliger densities for selected stations from 1994-2004.

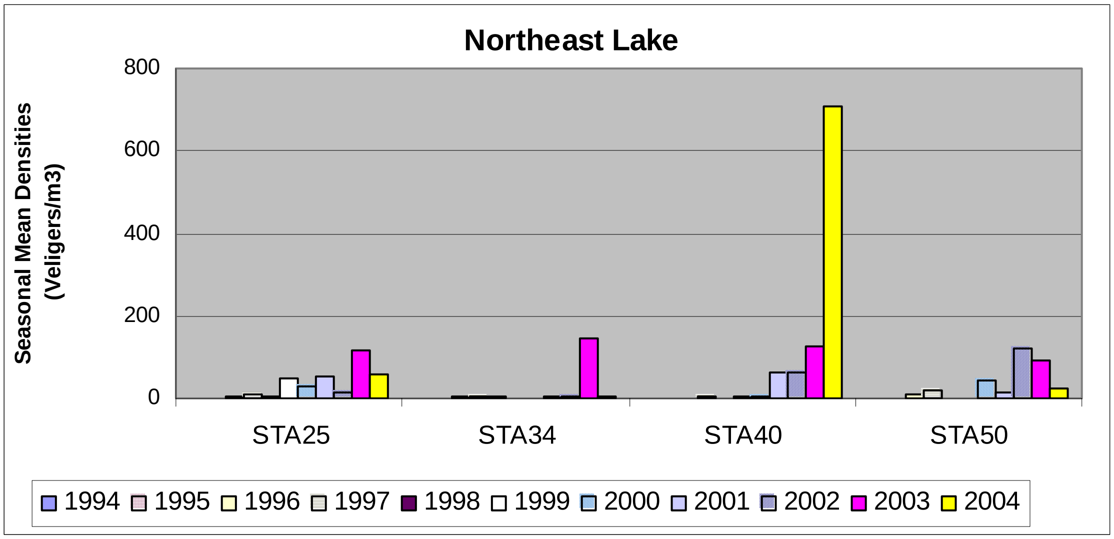

Figure 9. Seasonal weighted mean veliger densities for selected stations from 1994-2004.

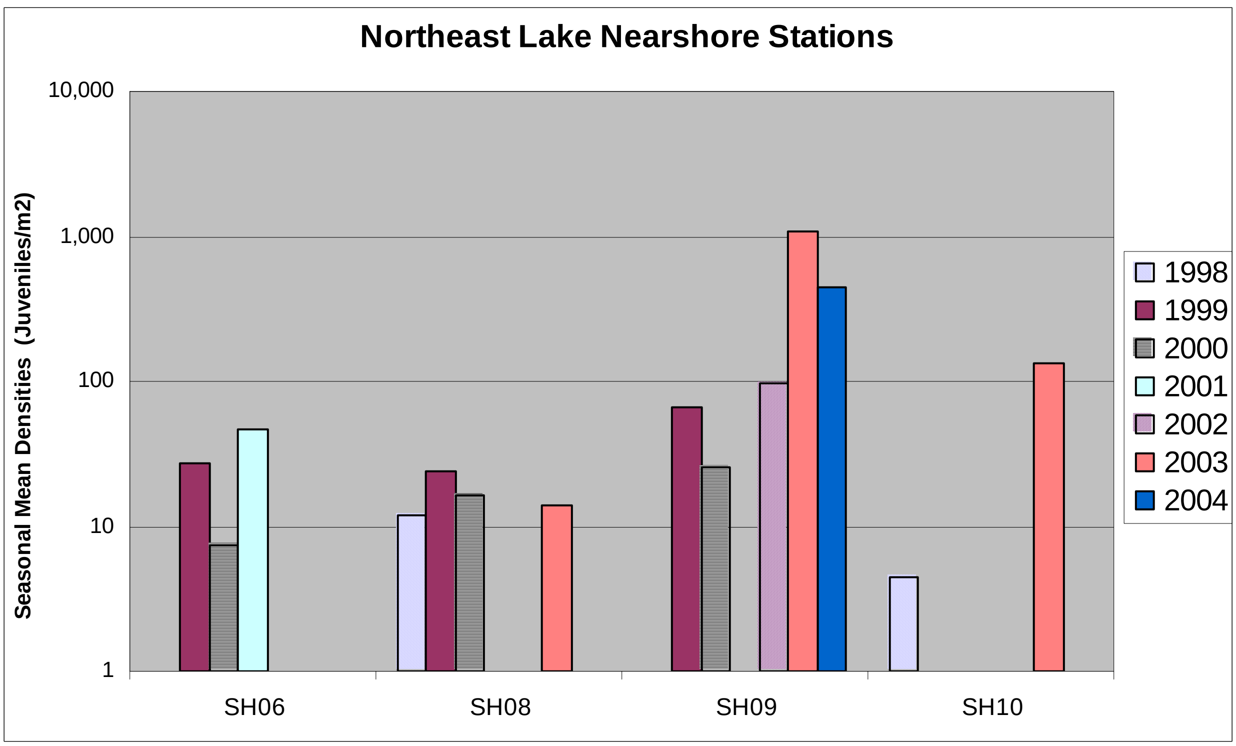

Figure 10. Seasonal weighted mean juvenile densities for selected nearshore stations in Northeast Lake Champlain from 1998-2004.

Juvenile season settling plate densities and average juvenile size for selected nearshore stations from 1998-2004 are shown in Figures 11 and 12. The greatest season plate density during the 2004 season was recorded at Rouses Point (SH11), with and estimated density of 116,000 juveniles/m^2, although the average size of individuals was 3 mm, the smallest average from all the season plates. Early settlers at Chipman Point Marina (CHIP) grew to approximately 16 mm by October and the estimated density which included a second cohort of settlers was 107,378 juveniles/m^2. The size of the second cohort averaged 6 mm.

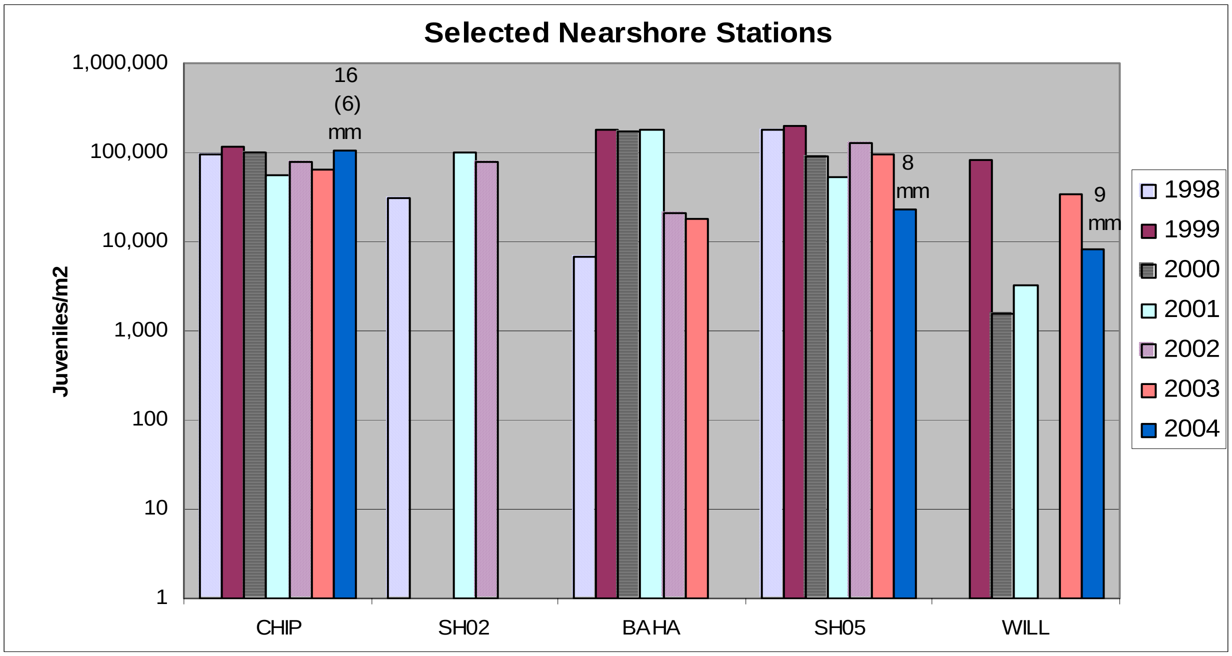

Figure 11. Season plate densities from 1998-2004. The 2004 average juvenile size (mm) is noted above the bars for selected nearshore stations in Lake Champlain. The second cohort average size at CHIP is in parentheses. Stations with values of less than one indicate no settlement, or missing plates in the case of BAHA in 2004 and SH02 in 1999, 2000, 2003 and 2004.

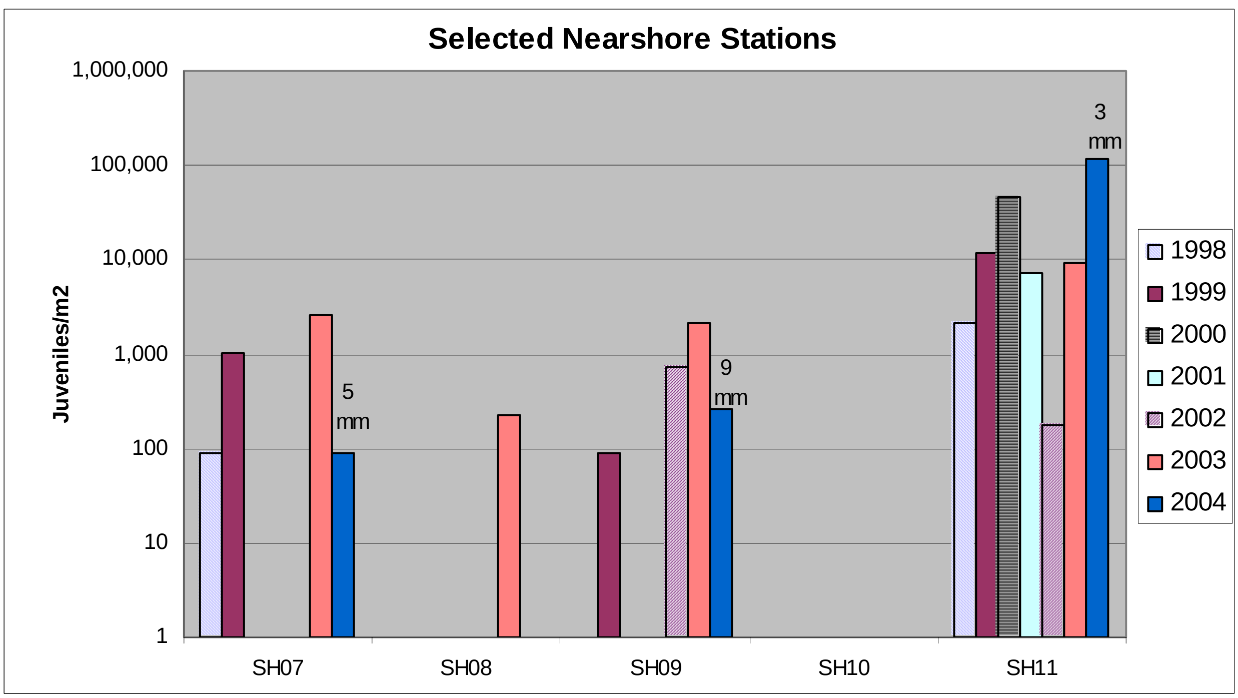

Figure 12. Season plate densities from 1998-2004. The 2004 average juvenile size (mm) noted above the bars for selected nearshore stations in Lake Champlain. Stations with values of less than one indicate no settlement, or missing plates in the case of SH09 in 2001. Marble Island (SH06) has never had seasonal settlement, although there are zebra mussels located nearby.

The season plates at Crown Point Bridge (SH02) and Basin Harbor (BAHA) were vandalized in 2004, so no results were recorded. The average size of settled juveniles on season plates at all other nearshore stations was variable, with sizes ranging from 5-9 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 openwater stations was high. In 2004, only two setters were found on the plate at SH07, along with many mud bythinia.

INLAND LAKES AND TRIBUTARIES

Selected tributaries and inland lakes sampled for veligers and/or adult zebra mussels from 1998-2004 are shown in Table 1. No veligers were found in any of the samples collected during 2004 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, Joes Pond, Lake Memphremagog, Lake Morey, Seymour Lake, Shelburne Pond, Lake St. Catherine, Lake Willoughby and Lake Winona. Veligers were detected in both Lake Bomoseen samples collected in 2004. 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).

No veligers were found in samples taken in 2004 from the Connecticut River in North Thetford, Lamoille River, Lewis Creek, Missisquoi River, Otter Creek, Poultney River, and the Winooski River on the Vermont side of the lake, or the Ausable River, Bouquet River, Great Chazy River, Little Ausable River, Little Chazy River, Mettawee River, Putnam Creek, Salmon River, and the Saranac River in New York. In 2004, as in the previous two years, additional sampling was performed in the Castleton River downstream of the outlet of Lake Bomoseen to determine whether veligers from this lake have drifted downstream. Veligers were found in a sample taken in 2004 in Fair Haven. 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. In 2002, 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 was increased in Lewis Creek, Cedar Lake and Lake Winona (which have outlets to Lewis Creek) to determine if a reproducing population exists. No veligers were found in these samples, and physical surveys of the streams produced no zebra mussels.

Table 1. Selected tributaries and inland lakes sampled for veligers and/or adults from 1998-2004.

Site	Veligers		Adults	
Lake	**2004**	**Previous years**	**2004**	**Previous years**
Arrowhead Mt. Lake	Absent	Absent	Not assessed	Not assessed
Lake Bomoseen	Present	Present since 1998	Present	Present since 1999
Lake Carmi	Absent	Absent	Not assessed	Not assessed
Caspian Lake	Absent	Absent	Not assessed	Not assessed
Cedar Lake	Absent	Absent	Not assessed	Not assessed
Lake Dunmore	Absent	Present in 1999	Not assessed	Absent in 1999
Fairfield Pond	Absent	Absent	Not assessed	Not assessed
Lake Fairlee	Absent	Absent	Not assessed	Not assessed
Glen Lake	Absent	Absent	Absent	Absent
Harvey's Lake	Absent	Absent	Not assessed	Not assessed
Lake Hortonia	Absent	Present in 1999	Not assessed	Absent in 1999
Lake Iroquois	Absent	Absent	Not assessed	Not assessed
Island Pond	Absent	Absent	Not assessed	Not assessed
Joes Pond	Absent	Absent	Not assessed	Not assessed
Lake Memphremagog	Absent	Absent	Not assessed	Not assessed
Lake Morey	Absent	Absent	Not assessed	Not assessed
Seymour Lake	Absent	Absent	Not assessed	Not assessed
Shelburne Pond	Absent	Absent	Not assessed	Not assessed
Lake St. Catherine	Absent	Absent	Not assessed	Not assessed
Lake Willoughby	Absent	Absent	Not assessed	Absent in 2003
Lake Winona	Absent	Not assessed	Not assessed	Not assessed
Tributaries-VT				
Castleton River	Present	Absent	Not assessed	Not assessed
Connecticut River	Absent	Absent	Not assessed	Absent in 1999
Lamoille River	Absent	Absent	Not assessed	Not assessed
LaPlatte River	Absent	Absent	Not assessed	Present in 1997
Lewis Creek	Absent	Absent	Absent E. of Rt. 7 Bridge	Present in 1998 at boat access
Little Otter Creek	Not assessed	Present in 1999	Not assessed	Present in 1999
Missisquoi River	Absent	Absent	Not assessed	Not assessed
Otter Creek	Absent	Absent	Not assessed	Present in 1998
Poultney River	Absent	Absent	Not assessed	Absent in 2003
Winooski River	Absent	Present in 1999	Not assessed	Present in 1999
Tributaries-NY				
Ausable River	Absent	Absent	Not assessed	Not assessed
Bouquet River	Absent	Absent	Not assessed	Not assessed
Great Chazy River	Absent	Absent	Not assessed	Not assessed
Little Ausable River	Absent	Absent	Not assessed	Not assessed
Little Chazy River	Absent	Absent	Not assessed	Not assessed
Mettawee River	Absent	Absent	Not assessed	Not assessed
Putnam Creek	Absent	Absent	Not assessed	Not assessed
Salmon River	Absent	Absent	Not assessed	Not assessed
Saranac River	Absent	Absent	Not assessed	Not assessed

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 four 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 2004 (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, 2004).

Table 2. Mean relative percent differences for 2004 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	20.0	5
		>100	1.8	7
	Juveniles	0 -100	0.0	5
		>100	0.7	1
Field RPD's	Veligers	0 -100	21.4	5
		>100	7.6	7
	Juveniles	0 -100	0.0	5
		>100	9.8	2

EVALUATION OF METHODOLOGY TO ASSESS ADULT ZEBRA MUSSEL DENSITY IN LAKE CHAMPLAIN

INTRODUCTION

The current Lake Champlain Zebra Mussel Monitoring Program has focused primarily on documenting the expansion of zebra mussels and reproductive success throughout the lake using artificial substrates to collect settled juveniles, and a plankton net to capture drifting veligers. These data show that zebra mussels are well established in many parts of Lake Champlain and veliger densities appear to be leveling off in the areas where mature populations of mussels exist. This long-term database, in conjunction with the long-term water quality database, is an invaluable resource for exploring historical changes in Lake Champlain water quality.

In recent years, however, there has been a decline in potential users of these data and recognition that areas of the program could be revised and improved. A general consensus of the Lake Champlain Zebra Mussel Workgroup in 2003 was that the lack of data about adult zebra mussels in the lake should be addressed. This document presents an overview of methods recently cited in the literature to evaluate adult mussel densities and suggests a possible monitoring program for Lake Champlain.

AVAILABLE METHODOLOGY TO TRACK ADULT MUSSEL DENSITIES

Traditional methods of evaluating adult mussel densities include ponar dredge, benthic sled and hand-sampling via SCUBA, snorkel or wading (Marsden 1992, Nalepa *et al.* 1995, Dermott and Munawar 1993, Mellina and Rasmussen 1994). Choice of collection method is usually driven by the type of substrate to be sampled. Ponar dredges and benthic sledges function best in soft sediments and small rocks or cobble. Hand-sampling is employed when hard and/or large substrates are present. Although zebra mussels were initially believed to prefer solely hard, fixed substrates, numerous studies have documented the occurrence of adult mussels on soft shifting substrates (Berkman 2004, Dermott and Munawar 1993). In a typical lake environment, the bottom topography represents a mix of hard and soft substrate and potentially requires a combination of sampling methods to accurately assess adult mussel density.

Recent attempts to evaluate adult zebra mussel densities and their potential impact on lake water quality and biota have utilized SCUBA, sidescan sonar and underwater videography. Ioannou *et al.* (1996) used a video camera to obtain information on adult mussel densities in Lake Erie. Video footage collected along a transect was separated into still frames and a subsample of frames from each transect was evaluated. Data gathered from each frame included a count of “live” (dark) vs. “dead” (bleached or broken) mussels, an estimate of percent coverage by mussels, and an estimate of the area counted in each frame that was evaluated. Resulting densities (mussels/m^2) provided an estimate of minimum lake floor coverage and were “difficult to compare” to quadrat sample counts. Drawbacks included the lack of information about the depth of the zebra mussel mat, difficulty in accurately discerning an average mussel length, and difficulty in establishing the true distance of the camera from the substrate (which influences the area photographed at any point along the transect). The authors concluded that there was a fairly uniform distribution of mussels through the area filmed, with surface densities ranging from 1,000-2,000 mussels/m^2 on soft sediments to 5,000/m^2 on hard rock.

Coakley *et al.* (1997) incorporated the use of sidescan sonar, still and video photography, and diver surveys to assess Lake Erie mussel densities. Sidescan sonar provided information on bottom topography and the extent of zebra mussel beds. Resolution of this data was not high enough to be able to accurately count individual mussels. Instead, divers equipped with underwater cameras were used to ground-truth the sonar data. Camera frames were evaluated following the method of Ioannou *et al.* (1996) discussed above. Divers collected bottom samples along the camera transects using randomly selected quadrats. All mussels in the quadrat were removed and brought to the lab for analysis. Divers also took short core samples which allowed for grain size analysis of underlying sediment and an estimate of mussel mat thickness. From these collections, the authors estimated densities of up to 20,000 live mussels/m^2 on soft sediments. When mussel densities on different substrate types were integrated with areal data on available habitat, an overall lake population of 10^{13} molluscs larger than 0.84 mm was estimated.

Berkman *et al* (1998, 2004) used sidescan sonar to evaluate available substrate along a 200 mile swath in Lake Erie. SCUBA, ROV and towed video cameras were used to verify the presence of zebra mussels in randomly selected locations. From this data, zebra mussels were estimated to have covered about 2,000 km^2 of soft sediment in Lake Erie by 1995.

Haltuch *et al* (2000) used GIS technology to create an integrated map of bathymetry, substrate, and sidescan sonar data of Lake Erie. Incorporating the data collected by Berkman *et al*, ROV data from the 1990s and additional sidescan sonar, a model was developed to describe the extent of zebra mussel coverage on the lake bottom, and predict future expansion. Predictions made for 1997 and 1998 correlated well with observed coverage. The model estimated that zebra mussels on soft sediments have been spreading an average of 1,000 km^2 annually since 1994 and presently occupy 5,500 km^2 of the roughly 26,000 km^2 of available sedimentary bottom.

Idrisi *et al* (2001) utilized observations of substrate types gathered through previous sonar studies to estimate available substrate for adult mussels. SCUBA collections of randomly selected quadrats were then made on the different types of substrate and used to infer lake-wide mussel densities. In conjunction with available data series on nutrients, plankton and young-of-the-year fish, the authors investigated the response of the food web in Oneida Lake, NY, to zebra mussel grazing.

Lozano *et al* (2004) proposed an integrated approach to evaluate dreissenid population abundance. They will utilize sediment maps of Lake Erie generated in 2002, mussel biomass estimates from ponar grabs made at 45 sites in 2002 and 2003, and video and acoustic data collected during 2004 at the same 45 sites. Estimates of mussel densities and biomass will be made. Bioenergetic and filtering models will then be developed from these data, and used to investigate the impact of zebra mussels on Lake Erie. This study is still underway and no data are available.

PROPOSED ADULT MUSSEL SAMPLING METHODS FOR LAKE CHAMPLAIN

No single method is ideal for assessing mussel densities. Grab samples collected by dredge will not accurately assess mussel populations on hard and/or vertical substrates, yet preferred mussel attachment is often to hard substrates. Extensive diver surveys to evaluate available substrate and collect mussels are cost-prohibitive. Sidescan sonar is also expensive and not readily available. Underwater photography does not allow assessment of the threedimensionality of zebra mussel beds, especially those on soft substrates. Photographic surveys often counted bleached individuals as dead, but in Lake Champlain most living adult mussels show evidence of bleaching. In-lab analysis of photographs and zebra mussel samples is lengthy and labor-intensive.

Given the drawbacks of any one method, the best approach appears to be an integration of several methods similar to that used by Coakley *et al.* (1997). This approach would use underwater photography to document selected areas of lake bottom with respect to substrate type and/or mussel coverage followed by the use of SCUBA divers to ground-truth a portion of each transect. In addition to assessing adult mussel densities, diver-collected samples would allow determination of age, size, and volume. The availability of historical sidescan sonar data from the Lake Champlain Maritime Museum's shipwreck surveys and ROV data from the zebra mussel shipwreck project potentially allows adult densities to be estimated for those areas, using an approach similar to that proposed by Haltuch *et al.* (2000) and Lozano *et al.* (2004). A proposed method for implementing an adult zebra mussel sampling program on Lake Champlain is described below.

Adult site selection

Shoreline transect locations would be selected near each of the original 12 Long-term Monitoring stations. These correspond to the available long-term historical water quality, biological and veliger data. The monitoring stations were chosen to characterize the diverse water quality found in different lake segments, which may potentially influence adult mussel densities. The ideal transects will traverse a number of different substrates (submersed macrophytes, rocks and soft sediment) and depths (from 3 to 15 m).

Adult sampling frequency

Many video-only transects could be surveyed in a single season, with a limited number of transects sampled by diver to ground-truth the visual data. Twelve transects seems like a reasonable number to be completed by divers in less than a month, limiting the expense of this portion of the project. Video-only surveys could be completed with the divers on the same day if time allowed, or completed from a small boat on another date. Repeating the process every 2-3 years would allow assessment of changes in the adult population

Adult sampling protocol

Fifty-meter transects would be identified, perpendicular to shore. Beginning and end points would be documented by GPS, and a tape measure would be placed between the two points. Three transects would be made at each location, including two video-only surveys and one sampling survey. Video-only transects would provide additional substrate data to support that collected by the divers.

An underwater digital video camera would be used to film the transects. The camera would be equipped with a known area grid at a fixed distance from the lens to allow calculation of area observed. Video images would be made for the entire length of the transect.

Divers would use a quadrat frame (0.25 m^2) to sample sites along the transect (Marsden 1992). Sites should be selected within each visually different habitat along the transect (e.g., soft sediment, macrophytes, cobble and bedrock/boulder) to accurately assess the mussel population. Sites will be matched with the video footage using the markings on the tape measure. Mussels within the quadrat would be bagged, rinsed in a 1mm sieve in the boat, placed on ice and frozen upon return to the lab for later analysis. Five quadrats along the transect would be sampled by divers. A core would be collected from each transect to provide an estimate of mussel mat thickness (Marsden 1992).

Since accurate estimation of area sampled in each video frame is dependent upon a good image and stable angle of view, camera surveys taken from a boat would have to be done on calm days. Diver surveys would not have to occur on the same day, but should be in a similar time frame. Alternately, video transects could be made through the ice during winter months, increasing the stability of the photography and improving accuracy. Divers would then sample in spring or early summer before new recruitment occurs.

Adult analysis

Video footage would be assessed following the procedure of Ioannou *et al.* (1996), enumerating mussels and estimating areal coverage for each different habitat observed. The number of frames analyzed would be dependent upon the number of habitats visible along an individual transect, but at least 5 frames along each transect would be evaluated. Video frame data would be compared to mussel counts from the quadrats and used to assess the accuracy of the densities made from video footage.

Bagged samples would be analyzed from each diver transect. Samples with fewer than 200 individuals would be analyzed in their entirety. Samples with a large number of individuals will be subsampled. Two hundred mussels per sample would be measured, evaluated for health (e.g., live, dead, bleached), and used to make volume estimates. Volume of adult mussels would be estimated using displacement (Marsden 1992). Total mussel density would be calculated for each quadrat.

Products after year 1

1. Adult mussel densities would be estimated quantitatively at the long-term monitoring sites. Data would be available on age/size distribution, density/m^2, volume/m^2, and "health" of mussel populations.
2. There would be video documentation of habitat types at the long-term monitoring sites, with estimates of adult mussel densities corresponding to each habitat type.
3. An assessment would be made of the effectiveness of underwater photography to quantify adult zebra mussel densities.

Data usage in future years

1. By repeating the surveys at intervals and including new locations, it would be possible to assess changing adult mussel populations over a variety of substrate types and document expansion into new areas of the lake.
2. The integration of historical sonar and ROV data with new surveys would provide a historical perspective on zebra mussel expansion and estimation of available habitat that is yet uncolonized. (See Berkman, Coakley and Haltuch)
3. Assessment of long-term water quality data and adult densities may provide information on the factors influencing mussel expansion in Lake Champlain.
4. A quantitative assessment of adult mussel densities at the transect locations and the extent of lake bottom coverage by zebra mussels will provide some of the data necessary to begin investigating the impact of zebra mussels on the lake's food web and water quality. (See Idrisi and Lozano)

Equipment needed

Sampling: 2 divers with boat and gear, 1-2 support crew
- Underwater Digital Video Camera with TV, battery and digital video recorder (DVR)
- Quadrat/corer
- Bags for collecting mussels
- 1 mm sieve
- Coolers and ice
- Scrapers for removing mussels from hard substrates

Analysis: TV with DVR
- Dissecting microscopes
- Calipers
- Large known-volume containers

Total cost of equipment: $1,600±

Estimation of effort

Sampling by 2 divers: 12 locations at 2 locations per day = 6 days in the water

Video transects: 12 locations with 3 transects per location at 2 locations per day = 6 days film time with 36 transects filmed. Ideally, diver days and video transect days will be the same, otherwise diver, video transect, and overall effort estimates will have to be re-assessed.

Video analysis: 36 transects x 5 frames/transect = 180 frames x 0.5 hrs/frame = 90 hrs (11 days)

Habitat assessment from video footage: 36 transects x 0.5 hrs/transect = 18 hrs (2.25 days)

Zebra mussel counts: 12 transects x 5 frames = 60 frames x 3.0 hrs/frame = 180 hrs (22.5 days)

Data entry for roughly 300 frames/counts: 0.25 hrs/frame = 75 hrs (9.4 days)

Field effort: 2 divers and support team for 6 days
Analytical effort: 45 days

SUMMARY AND CONCLUSIONS

The results of the 2004 Zebra Mussel Monitoring Program indicate that veliger densities in Lake Champlain decreased at 9 of 16 stations compared to densities found in 2003, and none of the 2004 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 3 of 8 stations recorded their highest peaks, but the expansion is occurring at a relatively slow rate compared to the rest of the lake. Juvenile settlement occurred at only one of the four stations located in the Northeast Lake at St. Albans Bay. Season plate settlement at stations in the South, Central, or Northwest Lake was variable, with Chipman Point Marina (CHIP) having the largest sized settlers, consistent with past years results.

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 included Malletts Bay and the Inland Sea. In 2004, a single adult zebra mussel was found in Missisquoi Bay. 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 discussed (Eliopoulos and Stangel 1998), 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. The Castleton River, a tributary to the Poultney River had veligers when sampled in 2004. No veligers or adults were found in any of the rivers on the New York side of Lake Champlain.

A review of recent literature found that there have been few attempts to assess adult zebra mussel densities on a large scale, e.g. lakewide. These studies, primarily in Lake Erie, use an integrated approach to evaluate mussel densities with diver-collected samples, underwater videography and/or sonar. By incorporating large scale, but less detailed, video or sonar surveys with the detailed, but costly, information provided by analysis of a limited set of diver-collected materials, a quantitative estimate of adult mussel densities is possible at a reasonable cost. While there are limitations to the type of data that can be gathered implementing this approach in Lake Champlain, the resulting database will allow for a first assessment of total lake bottom affected by zebra mussels, adult mussel habitat preferences, and an estimate of mussel densities in different lake segments. Purchase of an underwater camera would be necessary. Further discussion of how this project should best be implemented is also warranted. In particular, the ability of the current mussel monitoring program to undertake this study should be evaluated.

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. Veliger sampling remains an effective way to document the presence of adult mussels. Planktonic veligers are more easily detected than their sedentary parents, especially when there may be only a few adults reproducing in a lake or pond. 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. While expansion of mussel populations appears to be stabilizing in many areas of the lake, particularly in the southern portions, other areas of the lake have not stabilized. Monitoring of juvenile settlement should continue to document the establishment of zebra mussels in the Northeast lake.

ADULT SAMPLING

The establishment of large populations of adult mussels in the Lake Champlain has profound implications for the lake's food web. Assessment of adult populations may provide insight to changes water quality, water clarity and biota. 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 considered for use in Lake Champlain.

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Appendix A: Zebra mussel veliger density data 2004

Station	Date	Temp (C)	Secchi (m)	Secchi to bottom?	Density (N/m3)	Station	Date	Temp (C)	Secchi (m)	Secchi to bottom?	Density (N/m3)
SH06	5/11/2004	11.2	3.4	No	0	STA02	8/17/2004	20	0.2	No	964
SH06	6/9/2004	18.8	4.5	No	6	STA02	9/7/2004	21.3	1.2	No	45
SH06	6/29/2004	19.7	5	No	234	STA02	9/21/2004	16.6	0.7	No	33
SH06	7/16/2004	22.4	4	No	270	STA02	9/29/2004	17.7	1.2	No	10
SH06	7/30/2004	23.8	4.3	No	17	STA02	10/15/2004	13.4	1.7	No	0
SH06	8/18/2004	22.8	4.1	No	50	STA04	5/12/2004	16.7	1.5	No	0
SH06	9/1/2004	21.5	2.6	No	0	STA04	6/8/2004	19.5	1.2	No	4,832
SH06	9/17/2004	20	3.6	No	0	STA04	6/23/2004	21.8	2.1	No	6,890
SH06	9/28/2004	18.7	4.8	No	0	STA04	7/13/2004	23.4	1.8	No	3,817
SH06	10/8/2004	16.6	4.9	No	0	STA04	7/28/2004	22.7	1.9	No	3,674
SH08	6/7/2004	12.8	4.1	No	0	STA04	8/17/2004	23.5	1.6	No	7,209
SH08	6/21/2004	16.1		Yes	290	STA04	9/7/2004	21.6	1.1	No	4,395
SH08	7/19/2004	24.6		Yes	28	STA04	9/21/2004	19.8	1.5	No	1,406
SH08	8/12/2004	21.8		Yes	126	STA04	9/29/2004	18.6	2	No	4,679
SH08	9/2/2004	21.4	3	No	7	STA04	10/15/2004	13.8	2.4	No	179
SH08	9/24/2004	19.4		Yes	0	STA07	5/17/2004	13	3.1	No	0
SH08	10/7/2004	16.3		Yes	0	STA07	6/15/2004	14.8	5.2	No	6
SH09	5/13/2004	14.2	2.8	No	0	STA07	7/6/2004	19.4	3	No	26,520
SH09	6/11/2004	18	2.8	No	0	STA07	7/22/2004	21.6	3.7	No	859
SH09	7/2/2004	22.5	2.5	No	964	STA07	8/11/2004	21.3	5.3	No	4,922
SH09	7/19/2004	25.2		Yes	1,153	STA07	9/3/2004	19.8	4	No	2,101
SH09	8/10/2004	23.1	0.9	No	564	STA07	9/23/2004	18	3.8	No	1,878
SH09	9/1/2004	21.8	1.1	No	18	STA07	10/5/2004	16.1	6	No	17
SH09	9/16/2004	20.3	1.6	No	36	STA07	10/18/2004	13.4	6	No	0
SH09	9/30/2004	19.8	2.6	No	28	STA19	6/4/2004	12	5.6	No	0
SH09	10/19/2004	11.8	2.2	No	2	STA19	6/28/2004	16.4	5.6	No	3,249
SH10	5/14/2004	15.8	1.5	No	0	STA19	7/14/2004	20.4	5.6	No	35,560
SH10	6/10/2004	19.1	2	No	2	STA19	7/29/2004	21.3	8.5	No	9,999
SH10	6/30/2004	20.6	2	No	10	STA19	8/25/2004	20.4	6	No	1,107
SH10	7/21/2004	27.5	1.4	No	186	STA19	9/27/2004	17.8	6.7	No	2
SH10	8/9/2004	21.9	0.3	No	0	STA19	10/13/2004	14.8	8.1	No	0
SH10	8/24/2004	21.2	0.6	No	151	STA21	6/4/2004	13.2	4.7	No	2
SH10	9/8/2004	19.9	0.7	No	3	STA21	6/28/2004	18.1	5	No	8,332
SH10	9/22/2004	19.2	1	No	0	STA21	7/14/2004	21.1	4.7	No	43,396
SH10	10/1/2004	18.7	1.1	No	0	STA21	7/29/2004	22.3	7.9	No	3,147
SH10	10/20/2004	10.7	0.5	No	0	STA21	8/25/2004	20.5	5.6	No	2,683
STA02	5/12/2004	17.4	1.7	No	68	STA21	9/14/2004	17.5	4.9	No	370
STA02	6/8/2004	19.9	1.1	No	15,396	STA21	9/27/2004	18.5	6.4	No	0
STA02	6/23/2004	21.8	0.7	No	32,955	STA21	10/13/2004	14.7	8.7	No	0
STA02	7/13/2004	24.1	1.4	No	187,512	STA25	5/11/2004	10.7	4.1	No	0
STA02	7/25/2004	20.8	0.4	No	939	STA25	6/9/2004	17.3	4	No	6

Appendix A: Zebra mussel veliger density data 2004

Station	Date	Temp (C)	Secchi (m)	Secchi to bottom?	Density (N/m3)
STA25	6/29/2004	19.2	5.7	No	38
STA25	7/16/2004	22.2	5.2	No	301
STA25	7/30/2004	23.3	5.5	No	5
STA25	8/18/2004	22.2	5	No	35
STA25	9/1/2004	21.9	3.3	No	5
STA25	9/17/2004	19.5	3.2	No	0
STA25	9/28/2004	18.4	4.5	No	0
STA25	10/8/2004	16.1	4.1	No	0
STA25	10/22/2004	13.5	4	No	0
STA33	6/7/2004	14.9	3	No	0
STA33	6/21/2004	14.6	5.7	No	9
STA33	7/9/2004	20.3	5.1	No	9,176
STA33	7/26/2004	22.6	6.3	No	13,184
STA33	8/12/2004	22.1	4.6	No	13,715
STA33	9/2/2004	20.4	5.5	No	116
STA33	9/24/2004	18.3	3.5	No	12
STA33	10/14/2004	14.6	8.1	No	0
STA34	5/13/2004	9.9	4.1	No	0
STA34	6/11/2004	14.9	5.6	No	0
STA34	7/2/2004	19	5.9	No	2
STA34	7/19/2004	23.2	4.5	No	2
STA34	8/10/2004	22.2	4	No	14
STA34	9/1/2004	21.3	4.5	No	5
STA34	9/16/2004	19.6	4	No	3
STA34	9/30/2004	18.2	4.9	No	0
STA34	10/19/2004	14.7	3.3	No	0
STA36	6/7/2004	13	4.5	No	0
STA36	6/21/2004	15.8	4.7	No	203
STA36	7/9/2004	20.3	6.2	No	17,760
STA36	7/26/2004	23.4	6.7	No	9,525
STA36	8/12/2004	21.7	6	No	8,940
STA36	9/2/2004	20.9	3	No	552
STA36	9/24/2004	18.1	5.7	No	3
STA36	10/14/2004	14.7	9.1	No	0
STA40	5/13/2004	14.7	3.2	No	0
STA40	6/11/2004	18.4	4	No	0
STA40	7/2/2004	20.1	3.7	No	1,178
STA40	7/19/2004	25.3	3.2	No	354
STA40	8/10/2004	22.1	2.3	No	1,423
STA40	9/1/2004	21.9	4.5	No	136
STA40	9/16/2004	20.1	2	No	552
STA40	9/30/2004	18.2	2.7	No	30
STA40	10/19/2004	13.5	3.5	No	0
STA46	5/14/2004	11.8	5	No	0
STA46	6/10/2004	15.4	6	No	100
STA46	6/30/2004	18.2		Yes	1,017
STA46	7/21/2004	24.9	5	No	9,493
STA46	8/9/2004	21.2		Yes	12,671
STA46	8/24/2004	20.8	2.7	No	6,856
STA46	9/8/2004	20.2	4	No	1,386
STA46	9/22/2004	17.6	4	No	58
STA46	10/1/2004	17.4		Yes	0
STA46	10/20/2004	11.9		Yes	0
STA50	5/14/2004	15.8	2.5	No	0
STA50	6/10/2004	18.1	1.8	No	0
STA50	6/30/2004	20.6	2.1	No	10
STA50	7/21/2004	25.1	1.2	No	65
STA50	8/9/2004	21.6	0.8	No	0
STA50	8/24/2004	19.2	0.7	No	0
STA50	9/8/2004	19.8	1	No	20
STA50	9/22/2004	18.1	1	No	53
STA50	10/1/2004	17.2	1.1	No	0
STA50	10/20/2004	10.3	1.6	No	0

Appendix B: Zebra mussel juvenile density data 2004

Station	Date	Days in Lake	Density (N/m2)
CHIP	10/15/2004	157	107,378
SH05	10/13/2004	133	23,378
SH06	6/29/2004	50	0
SH06	7/16/2004	37	0
SH06	7/30/2004	50	0
SH06	8/18/2004	32	0
SH06	9/1/2004	32	0
SH06	9/17/2004	30	0
SH06	9/28/2004	27	0
SH06	10/8/2004	150	0
SH07	10/14/2004	136	89
SH08	6/21/2004	19	0
SH08	7/19/2004	41	0
SH08	8/12/2004	53	0
SH08	9/2/2004	43	0
SH08	9/24/2004	40	0
SH08	10/7/2004	35	0
SH08	10/14/2004	136	0
SH08	10/14/2004	42	0
SH09	7/2/2004	51	0
SH09	7/19/2004	38	1,556
SH09	8/10/2004	38	489
SH09	9/1/2004	40	0
SH09	9/16/2004	37	89
SH09	9/30/2004	29	267
SH09	10/19/2004	158	267
SH10	6/30/2004	51	0
SH10	7/21/2004	41	0
SH10	8/9/2004	40	0
SH10	8/24/2004	33	0
SH10	9/8/2004	30	0
SH10	9/22/2004	28	0
SH10	10/20/2004	158	0
SH11	10/20/2004	132	116,000
WILL	10/13/2004	131	8,133