COUNTY OF ONONDAGA
DEPARTMENT OF DRAINAGE
AND SANITATION

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1999 Seneca River Dreissenid Mussel Assessment Program Distribution of Zebra Mussels Along a Selected Reach of the Seneca River

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EXECUTIVE SUMMARY

In August 1999, the County of Onondaga Department of Drainage and Sanitation (County) retained Beak Consultants Incorporated (Beak) to conduct an assessment of the dreissenid mussel population on the Seneca River system as a part of the County's Ambient Monitoring Program (AMP). The objective of the study was to determine the distribution and abundance of zebra mussels (*Dreissena spp*) along an approximately 30 mile reach of the Seneca and Oneida Rivers from just east of Cross Lake eastward to near Schroeppel Island about four miles east of the confluence of the Seneca, Oswego and Oneida Rivers. The initial task of the study was to map the habitat of the river as it related to potential colonization by zebra mussels (i.e., habitat assessment). Based on the results of that task, reaches of the river that contained comparable contiguous habitat were mapped. These zones were referred to as zebra mussel habitat zones. Within each habitat zone, standardized techniques using SCUBA were employed to collect samples of the substrate and zebra mussels present. Subsequently, analyses were performed to determine the density, size distribution and biomass of the zebra mussel populations that were present in each habitat zone as well as in each substrate type. The results of this investigation will be used in conjunction with two laboratory investigations also performed by Beak to develop information on aspects of the Seneca River mussel physiology (e.g., oxygen uptake, ammonia excretion, phosphorus and nitrogen mobilization). These results will be used to update the kinetic framework of the County's Seneca River model.

Two principle methodologies were used to perform the habitat assessment; (1) a sonar survey to profile the bottom contour and general substrate type (i.e., hard or soft); and, (2) a semiquantitative assessment of substrate composition and zebra mussel presence/abundance along transects set at regular intervals throughout the study reach using a Petite Ponar dredge. Water quality sampling for selected parameters was performed in conjunction with the Ponar sampling.

Following the determination of available habitat in the study reach, Beak scientists met with County personnel and Dr. Ray Canale (developer of existing Seneca River model) to review the

results of the assessment and reach a consensus on sampling locations and level of effort for the quantitative measurements of the dreissenid population in the study reach.

SCUBA techniques were employed to sample dreissenid densities along transects set within each habitat zone. Within each habitat zone, a minimum of three transects were sampled. In habitat zones that had a more complex substrate mix or were much longer than average, five transects were sampled. At each transect, three samples were collected; one about mid-channel and one about midway between each marker buoy and the corresponding shore.

At each sampling location, the diver carefully placed a 10-inch diameter (0.051 m^2) open center ring on a random location on the bottom. All substrate, including zebra mussels within the ring, was carefully removed from the ring and placed into a macroinvertebrate wash bucket fitted with a 583-micron mesh bottom which was attached to a line and buoy. All zebra mussels were placed into labeled plastic bags. The plastic bags were carefully placed into coolers with ice and transported to Beak's Lancaster, New York, Biological Laboratory for further processing.

The sonar recorded large differences in bottom depth, bottom regularity and substrate type. It was found that the Petite Ponar sampling provided a much better measure of habitat so the sonar data was used only to verify habitat breaks (i.e.: where significant changes in habitat occurred).

A total of 19 habitat zones was present in the 31.67 mile study area. The habitat zones ranged in length from 0.48 miles to 4.5 miles and occupied a mean area of between 0.018 and 0.220 square miles. A total of 189 samples was collected within the project area to assess the population characteristics of the dreissenids in the portions of the Seneca and Oneida Rivers of concern to the County. Dreissenids were present in 93 (49.2 percent) of the samples analyzed. All of the dreissenids collected were zebra mussels (*Dreissena polymorpha*); no quagga mussels (*D. bugensis*) were present.

The overall mean density of mussels present in the project area was 1,945 individuals/m^2. The mean density of zebra mussels ranged from 9 mussels/m^2 in Zone I to 12,977 mussels/m^2 in Zone

III. The highest density of mussels in any individual sample was 43,937/m^2 which occurred in Zone III that includes the State Ditch Cut.

The overall mean weight of zebra mussels per unit area in the project area was 1,356 g/m^2. The mean weight of mussels ranged from 0.7 g/m^2 in Zone I to 3,511 g/m^2 in Zone V. The greatest weight of zebra mussels in any sample was 23,957 g/m^2 (approximately 52.8 lb) in a sample collected in Zone V.

There were three different community structures evident from an examination of the length frequency data. One community type was dominated by zebra mussels that were 10 mm or less in total length. The second community type was a community dominated by large individuals (i.e., 20 mm and greater). The third community type had a more balanced size structure which included a mix of mussels of different sizes.

The striking differences in the length frequency distributions of the zebra mussel populations present among habitat zones in this relatively short river reach were unexpected. The most interesting distributions were found in Zones I, II and HI, where the population was almost exclusively made up of individuals less than 10 mm long. Individuals less than 10 mm generally are young-of-year mussels, which for this study were mussels that settled during 1999.

The lack of live mussels that would have settled prior to 1999 in Zones I, II and III suggests that some catastrophic event occurred in this reach which killed or displaced the existing population of mussels. Since the majority of successful zebra mussel settlement in temperate fresh water occurs between June and October, the unimodal distribution of young-of-year mussels indicates that the catastrophic event occurred after the 1998 year class had settled (i.e., fall 1998), but had ended some time prior to the occurrence of appreciable settlement in 1999. The existence of multiple year classes of mussels in Zone IV located just downstream of the Cut, indicated that whatever contributed to the die-off in the State Ditch Cut did not impact the population of mussels in Zone IV. A similar die off was reported to have occurred in the Cut in 1994. The presence of large

numbers of byssusses from adult mussels found in the Cut and the rafts of adult shells downstream indicates that the catastrophic die-offs in the Cut are not annual events.

A similar event also likely occurred in the Outlet of Onondaga Lake (Zone XIV). Over 87 percent of the mussels in Zone XIV were less than 10 mm and only 7.6 percent were larger than 20 mm. A notable observation made by the field personnel was that cobbles and other hard substrate in the Outlet lacked the carpet of byssusses from detached adults. This would suggest that there is an annual low survivorship of adults in the Outlet.

The results of this study strongly suggest that there are appreciable changes in the population of mussels in portions of the study area that could greatly impact the population's influence on water quality since many impacts on water quality caused by a zebra mussel population (e.g., oxygen depletion, ammonia excretion) are dependent on both the numbers of mussels and their size. This would indicate that periodic evaluation of the status of the zebra mussel populations in the Seneca River may be warranted to determine their impact to the water quality model.

TABLE OF CONTENTS

		Page
1.0	Introduction	1
2.0	Methods	4
	2.1 Habitat Assessment/Habitat Zone Determination	4
	2.2 Dreissenid Mussel Population Measurements	7
3.0	Results	11
	3.1 Habitat Assessment/Habitat Zone Determination	11
	3.2 Dreissenid Mussel Population Measurements	16
4.0	Discussion	20
5.0	References	31
APPENDIX		

LIST OF FIGURES

Figure 1 Map of Sampling Area, Seneca River Dreissenid Mussel Assessment, 1999.

Figure 2 Location of Study Zones and Ponar Sampling Transects, 1999 Seneca River Zebra Mussel Program, Habitat Assessment Survey.

Figure 3 Results of Habitat Assessment Survey - Habitat Type-Seneca River - 1999.

Figure 4 Results of Habitat Assessment Survey - Zebra Mussel Densities - 1999.

Figure 5 Location of Zebra Mussel Habitat Zones, 1999 Seneca River Zebra Mussel Program, Habitat Assessment Survey.

Figure 6 Length Frequency Distribution (5 mm Increments) of Zebra Mussels by Habitat Zone.

Figure 7 Length Frequency Distribution of Zebra Mussels by Length Increments Corresponding to Laboratory Studies.

Figure 8 Mean Density and Mean Weight Along the Seneca River Study Area, Dreissenid Mussel Sampling, 1999.

LIST OF TABLES

Table 1 Length, Mean Width and Estimated Area of Habitat Zones. Seneca River Dreissenid Mussel Assessment, 1999.

Table 2 Seneca River Zebra Mussel Habitat Assessment, Water Quality Results, 1999.

Table 3 Density, Weight and Phi Values by Sample and Habitat Zone, Seneca River Dreissenid Assessment Program, 1999.

Table 4 Relative Frequency of Total Lengths of Zebra Mussels in Habitat Zones I - XIX, Seneca River Dreissenid Program, 1999.

Table 5 Estimate of Number and Total Weight of Zebra Mussel by Habitat Zone.

Table 6 Relative Mean Density of Zebra Mussels by Length Category, 1999 Dreissenid Mussel Program.

1999 Seneca River Dreissenid Mussel Assessment Program - Distribution of Zebra Mussels Along a Selected Reach of the Seneca River

1.0 INTRODUCTION

In August 1999, the County of Onondaga Department of Drainage and Sanitation (County) retained Beak Consultants Incorporated (Beak) to conduct an assessment of the dreissenid mussel population on the Seneca River system as a part of the County's Ambient Monitoring Program (AMP). The primary objective of the mussel program was to provide data required to update a mathematical water quality model that will assist the County in making future management decisions concerning the discharge of treated wastewater into Onondaga Lake and the Seneca River system. The secondary objective was to provide baseline information to determine changes in the mussel population over time. The assessment was developed to document and identify the distribution of optimum dreissenid mussel habitat, dreissenid mussel communities, and population densities to enhance understanding of the processes and activities of the dreissenid mussels in the Seneca River system.

The zebra mussel (*Dreissena polymorpha*) is a fresh-water macrofouling species that is native to eastern Europe. The zebra mussel was first described from samples collected in the Ural River and Caspian Sea in 1769 (Stanczykowska 1977). The zebra mussel was first documented in the Laurentian Great Lakes of North America in 1988 (Hebert et al. 1989). Specimens were first collected from Lake St. Clair in June 1988. Based on the size and other characteristics of the collected mussels, they were probably introduced sometime in 1985 or 1986. They quickly extended their range and entered the inland waters of New York State by June 1990 (Empire State Electric Energy Research Corporation 1991). Zebra mussels were first detected in the Seneca River at Baldwinsville, New York in May 1991 (ESEERCO 1992). By 1993, a

population density of approximately 49,000 zebra mussels per square meter was reported in portions of the Seneca River (Effler and Siegfried 1994).

A closely related species of freshwater mussel, *Dreissena bugensis*, (commonly called the quagga mussel) was first reported from the Great Lakes in August 1991 (May and Marsden 1992). Although reported to be present in the New York State Barge Canal and the outlet of Onondaga Lake in 1991, it comprised less than one percent of the dreissenid population (May and Marsden 1992). It has not been reported in the Seneca River since that date (O'Neill 1999).

Zebra mussels are small (less than 5 cm total length) bivalve mollusks with elongated shells that are usually marked with light and dark alternating bands (O'Neill & MacNeill 1990). Utilizing a byssus, zebra mussels can potentially colonize any hard, non-toxic surface. The byssus is a network of strong, proteinaceous strands that the mussel uses to firmly attach itself to hard surfaces. The tensile strength of byssal thread protein is second only to silk among materials produced by animals (Baier 1991). Colonies of mussels can be comprised of many individuals. Densities of greater than 700,000 zebra mussels per square meter of surface have been reported at a power station on western Lake Erie (Kovalak et al. 1990). Densities of zebra mussels on natural shoals in western Lake Erie have averaged 147,000 mussels per square meter (Fitzsimons et al. 1991). Recent investigations have documented that extensive colonies of zebra mussels can also be established and persist on soft substrates (Coakley et al. 1997; Berkman et al. 1996).

Zebra mussels have the capability of affecting the nitrogen and phosphorus dynamics of a water body. Stancykowska (1984) estimated that zebra mussels in the Polish lakes that she studied contained and processed nitrogen and phosphorus comparable to the existing macrophytes. Zebra mussels (20 mm in length) can effectively filter over 280 ml of water per hour (Kryger and Riisgard 1988), and remove all seston between 1-micron and the size of their inhalant siphon (approximately 250-microns) (Jorgensen et al. 1984). The particles are packaged in mucus and expelled from the mussels either as feces or pseudofeces (Reeders and Bij de Vaate 1990). The size and mass of the pseudofeces limit their resuspension into the pelagic zone (Lange and Wittmeyer 1997). Investigators have documented changes to the nitrogen and phosphorus

budgets in lakes and rivers after zebra mussel invasions that can be directly attributed to filtration by the zebra mussels (Arnott and Vanni 1996; James et al. 1997; Johengen et al. 1995; Heath et al. 1995; Effler et al. 1997).

This report provides the results of a study conducted by Beak and County personnel during the fall of 1999 to determine the distribution and abundance of zebra mussels (*Dreissena* spp.) along an approximately 30-mile reach of the Seneca and Oneida Rivers from just east of Cross Lake eastward to near Schroeppel Island about 4 miles east of the confluence of the Seneca, Oswego and Oneida Rivers (Figure 1). The initial task of the study was to map the habitat of the river as it related to potential colonization by zebra mussels. Based on the results of that task, reaches of the river that contained comparable contiguous habitat were mapped. These zones were referred to as zebra mussel habitat zones. Within each habitat zone, standardized techniques using SCUBA were employed to collect samples of the substrate and zebra mussels present. Subsequently, analyses were performed to determine the density, size distribution and biomass of the zebra mussel populations present in each habitat zone as well as in each substrate type. Sampling procedures utilized to collect the information were based on techniques previously employed by Effler et al. (1997) on the Seneca River and Mellina and Rasmussen (1994) on the St. Lawrence River. The sampling effort for the present study, however, was much more intensive than for the previous Seneca River investigation. The results of this investigation will be used in conjunction with the results from two laboratory investigations (also performed by Beak) to develop information on aspects of the Seneca River mussel physiology (e.g., oxygen uptake, ammonia excretion, phosphorus and nitrogen mobilization) and to update the kinetic framework of the County's Seneca River model.

2.0 METHODS

2.1 Habitat Assessment/Habitat Zone Determination

Initially, a field study was conducted to determine the extent and quality of habitat that would support zebra mussel (dreissenid) colonies in the study area. The study area extended from Navigation Buoy R"412" located on the Seneca River just east of Cross Lake eastward to Navigation Buoy R"178" located on the Oneida River just east of Schroeppel Island (Figure 1). Recreation Charts of the New York State Barge Canal (NOAA 1998) were used as an expeditious means of determining location within the study reach. References to buoys in this report conform to the conventions used on the Recreation Charts.

Two principle methodologies were used to perform the habitat assessment; (1) a sonar survey to profile the bottom contour and general substrate type (i.e., hard or soft); and, (2) a semiquantitative assessment of substrate composition and zebra mussel presence/abundance along transects set at regular intervals throughout the study reach using a Petite Ponar dredge. Water quality sampling for selected parameters was performed in conjunction with the Ponar sampling.

The sonar survey for the study reach from Buoy R"412" to R"222A" was performed on September 27-29, 1999. At the request of the County, the study reach was extended from Buoy R"222A" eastward to Buoy R"178." The sonar survey of the additional reach was performed on November 5, 1999. A Lowrance Model X-16 Sonar that included a strip chart recorder was used. The transducer was placed at the stern of the boat to avoid interference with the boat's depth recorder. The accuracy of the system's depth measurement was verified just prior to the study. The unit was adjusted so secondary echoes would be recorded in the soft bottom areas. The study was conducted with a boat speed between 5 and 8 knots. Three transects parallel to shore were traversed; one along the centerline of the channel and one near each shore. The shore transects were generally located by positioning the boat midway between the shoreward navigation buoy (the red buoy for the right shore and the green buoy for the left shore when travelling westward) and the shore, unless extremely shallow water or other potential hazards

were encountered. For future reference, locations were recorded by noting buoy numbers on the strip charts.

The second component of the habitat assessment was performed on September 28-29 and November 5, 1999. Initially, the study reach was divided into approximately half-mile study zones using the Recreation Charts to determine and record their locations. Within each study zone, Petite Ponar dredge samples were collected along two transects. The transects were generally associated with buoy markers to expedite locating the area. To the extent possible, the transects selected were spaced at regular intervals (i.e. approximately one per quarter mile). Along each transect, three ponar grab samples were collected; one in midchannel, one midway between the red buoy line and shore, and one midway between the green buoy line and shore.

The substrate type collected in each grab sample was determined. The modified Wentworth scale used by the New York State Department of Environmental Conservation (NYSDEC) Stream Biomonitoring Unit (Bode et al. 1990) was used to determine the composition of the substrate. Substrate type was determined by visual estimation of the percentage of each particle type (nearest 10 percent) using the following:

Type	Particle Size
Bedrock/Ledge	-
Boulder	>256 mm (10 in)
Cobble	64 mm - 256 mm (2.5 in - 10 in)
Gravel	2 mm - 64 mm (.08 in - 2.5 in)
Sand	0.06 mm - 2.0 mm
Silt/Muck	0.004 mm - 0.06 mm
Clay	<0.004 mm

Throughout the study, substrate composition was determined by the same field scientist and periodically verified by a senior scientist to minimize biases in this somewhat subjective determination.

Relative mussel densities (e.g., few, some, many) and population status (e.g., multiple year classes, adults only, young-of-year only) were also noted. The presence of zebra mussel shell fragments and empty shells was recorded. Also, any mussels present on the submerged aquatic vegetation were documented.

Randomly within each study zone, water quality data were collected at one transect location at the midchannel station. The water temperature (°C), specific conductance (mmhos), and dissolved oxygen (ppm) at 1.0 m from the bottom were determined using the County's Hydrolab meter. Current velocity was determined using the County's Sigma Water Velocity meter. Water transparency (Secchi disk) was also measured.

Sonar data were reviewed to determine where major differences in bottom depth, bottom regularity and substrate type occurred. This information was used to supplement the Petite Ponar dredge results which provided a much better measure of habitat. The Petite Ponar dredge results for substrates were graphed as a diagram that stylistically represented the river reach studied. Each sample was represented by a block referenced by buoy number and side of the river channel. Recorded in each block was a description of the characteristics of the dominant substrate: soft bottom/muck, sand/gravel or hard substrate. These broad descriptors represented substrate particle size ranges that significantly influence the abundance of zebra mussels (Mellina and Rasmussen 1993). The relative abundance of zebra mussels collected in the Petite Ponar samples were categorized qualitatively as none, few, some, or many. These descriptors were also graphed as a stylized representation of the study zone. These diagrams were used to visually assess recognizable breaks in substrate types. Water quality data were assessed to determine any changes that could affect the occurrence or density of zebra mussel assemblages. Based on breaks in habitat (substrate and water quality), discrete habitat zones were developed.

2.2 Dreissenid Mussel Population Measurements

Following the determination of available habitat in the study reach, Beak scientists met with County personnel and Dr. Ray Canale (developer of the existing Seneca River model) to review

the results of the assessment and to reach a consensus on sampling locations and level of effort for the quantitative measurements of the dreissenid population in the study reach.

SCUBA techniques were employed to sample dreissenid densities along transects set within each habitat zone. Sampling was performed by a three-person dive crew from Finger Lakes Enterprises who have performed other zebra mussel related diving tasks in Central New York State. The dive master, Mr. John Long, has previously assisted Beak scientists on scientific studies and heads a company that performs zebra mussel fouling assessments and the installation of zebra mussel controls in the Finger Lakes. Beak scientists assisted the dive crew throughout the study.

Sampling for mussels took place from October 26 to November 8, 1999. Within each habitat zone, a minimum of three transects were sampled. In habitat zones that had a more complex substrate mix or were much longer than average, five transects were sampled. At each transect, three samples were collected; one about mid-channel and one about midway between each marker buoy and the corresponding shore. Transects were preselected and were located at existing buoys to expedite future reference. The transects were distributed throughout each habitat zone.

At each sampling location, the diver carefully placed a 10-inch diameter (0.051 m^2) open center ring on a random location on the bottom. All substrate within the ring, including zebra mussels was carefully removed from the ring and placed into a macroinvertebrate wash bucket fitted with a 583-micron mesh bottom, which was attached to a line and buoy. After the diver was clear of the collection site, the crew in the sample processing boat retrieved the wash bucket.

The particle size distribution was visually determined as described in Section 2.1. A phi value that numerically described each sample was assigned (Bode 1990) to each sample as follows:

Type	Phi Scale
Ledge	-9.97
Boulder	-8.00

Cobble	-6.50
Gravel	-3.00
Sand	2.00
Silt	6.50
Clay	9.00

The phi value is determined by transforming the mean particle size of the substrate type to the negative log base 2 of the particle size in millimeters (Hakanson and Jansson 1993). The percentage of each substrate type (nearest 10 percent) was visually determined. The mean particle size was calculated by multiplying each phi value by the percentage present and summing all resultive values. Ledge was assigned a value of -9.97 to represent a 100 percent coverage by a single 1000-m particle (Mellina and Rasmussen 1994). Empty zebra mussel shells were considered to function as gravel and a phi value of -3.00 was assigned.

Fine sediment was then rinsed through the wash bucket. For each sample, all zebra mussels in the remaining material were placed into labeled plastic bags. If attached to large size substrates (e.g., large cobble), the mussels were carefully removed from the substrate with a dry wall seamer before being placed into the bags. The plastic bags were carefully placed into coolers with ice and transported to Beak's Lancaster, New York Biological Laboratory for further processing. Cold water limited the time that the divers could spend in the water, so only nine to 11 transects could be completed per day.

At each transect that had a soft bottom, a Petite Ponar grab sample was collected near mid-channel. All grab samples within a habitat zone were composited, thoroughly mixed and placed into labeled glass jars for particle size distribution analysis and sediment chemical analysis by the County's contract laboratory. Also, at one randomly selected transect within each habitat zone, water quality sampling was conducted as described in Section 2.1, except that water velocities were not measured, since they were found to be well within the limits required for zebra mussel establishment during the habitat assessment survey.

When received by the biological laboratory, all samples were checked in and refrigerated until processed. To process, initially all mussels were carefully separated from the substrate material. The mussels were then blotted dry with paper towels and the first 100 randomly selected mussels, if available, were measured (nearest 1 mm). All measured mussels were placed onto a triple beam balance and a batch weight was measured (nearest 0.1 gram). All remaining mussels were added to the measured group and a total batch weight (nearest 0.1 gram) was measured. Samples were processed as soon after collection as practical. In most cases, mussels were still alive when processed.

The total number of mussels per sample was estimated by multiplying the number of mussels counted by the total weight of mussels in the sample divided by the weight of the subsample of mussels measured. The estimated total number of mussels in each sample was converted to number of mussels per square meter of bottom. A simple mean density of mussels (no./m^2) was calculated for each habitat zone. The mean total weight of mussels per square meter for each habitat zone was also calculated.

Length frequency histograms were developed for each habitat zone to illustrate the relative frequency of occurrence of different sizes of mussels in each zone. Histograms were first developed by-5 mm increments. Histograms were also developed for use with subsequent laboratory studies according to the following size ranges: less than 10 mm, mussels 10 mm - 20 mm, and mussels greater than 20 mm.

The New York State Department of Transportation was contacted to determine whether data on distances between navigation buoys or other comparable information were available to obtain measurements of the area of each habitat zone. However, such information does not exist, so the area of each habitat zone was estimated by planimeter using the Recreation Charts. Areas were independently estimated by two scientists and the average was used. Based on the calculated areas, the total number and total weight of zebra mussels in each habitat zone were estimated.

3.0 RESULTS

3.1 Habitat Assessment/Habitat Zone Determination

The sonar recorded large differences in bottom depth, bottom regularity and substrate type. It was found that the Petite Ponar sampling provided a much better measure of habitat, so the sonar data were used only to verify habitat breaks (i.e., where significant changes in habitat occurred).

A total of 50 study zones was sampled by Petite Ponar (Figure 2). Forty-seven (47) of the study zones were located along the Seneca and Oneida Rivers proper; two were located within the Onondaga Lake Outlet, and one was located along the natural river bed associated with the State Ditch Cut. The Petite Ponar sampling results for the substrate determination are presented in Figure 3 as a stylized river reach. Transect numbers and buoy references were provided to assist in relating specific samples to the Recreation Charts (Figure 2). The results of the zebra mussel information are presented in comparable form in Figure 4.

Habitat, as indicated by substrate type, varied throughout the study reach. Included were well defined areas of hard substrates or soft substrates interspersed with areas of substrate mixes. In general, the presence of zebra mussels was related to the substrate type. That is, zebra mussels were most prevalent where hard substrates were present and were usually not abundant where soft, mucky bottoms dominated. Of note was the presence of many zebra mussel young-of-year (i.e., settled during 1999) on the submerged aquatic vegetation. Also of note, no quagga mussels (*Dreissena bugensis*) were collected.

A total of 19 habitat zones were present in the 31.67-mile study area (Figure 5). The habitat zones ranged in length from 0.48 miles (Zone II) to 4.5 miles (Zone XIX) and occupied a mean area of between 0.018 (Zone XIV) and 0.220 square miles (Zone XIII) (Table 1).

Zone I was the natural river bed that was largely bypassed by the State Ditch Cut. This zone generally had a soft/mucky bottom. No zebra mussels were collected in this zone during the

habitat assessment survey. The zone was 2.70 miles long, had a mean width of 0.066 miles and occupied an estimated area of 0.178 square miles (461,536 m^2).

Zone II was the reach upstream of the State Ditch Cut from Buoy G"411" to the cut. This reach was generally a mix of mucky and gravelly/sandy substrates with zebra mussel shell fragments present. No zebra mussels were collected in this zone during the habitat assessment survey. The zone was the shortest zone (0.48 miles) but among the widest (0.090 miles) and occupied an area of 0.043 square miles (111,888 m^2).

Zone III included the State Ditch Cut (the Cut) and consisted of a hard (shale) bottom overlain in parts with gravels and cobbles. Only young-of-year mussels were collected in the Cut during the habitat assessment survey. Byssal thread from large adult mussels completely covered all of the cobbles retrieved by the Petite Ponar dredge. Large rafts of adult mussel shells were found in the gravel shoals just downstream of the Cut. This suggests that a catastrophic die-off of the mussels in this zone occurred previous to the 1999 settlement period. Live mussels were collected in all 15 Ponar grab samples collected in this zone. The habitat zone that comprised the Cut was 1.18 miles long but was narrow compared to other zones (0.026 miles wide) and occupied an area of 0.030 square miles (78,477 m^2).

Zone IV extended from the State Ditch Cut downstream to about midway between Navigation Buoy G"379" and G"377." This zone contained a mix of substrates including hard, gravel/sand and soft muck. Large numbers of adult zebra mussel shells were also collected. Live zebra mussels were present in all substrate types, although they were generally more prevalent on the hard substrates. Both young-of-year and adult mussels were collected. Zone IV was the third longest habitat zone (3.25 miles), had an average width (0.050 miles) and occupied an area of 0.163 square miles (420,873 m^2).

Zone V was a relatively short reach of hard substrate that extended from the downstream end of Zone IV to midway between Navigation Buoy R"376" and R"374." Many zebra mussels of

multiple year classes were collected during the habitat assessment survey. The zone was 0.50 miles long by 0.050 miles wide, and occupied an area of 0.025 square miles (64,750 m^2).

Zone VI extended from the downstream end of Zone V to Navigation Buoy R"359." The habitat in the zone was typified by hard substrate on the north side of the channel (shoreward of the red buoy), soft sediments on the south side (shoreward of the green buoy), and a mix of substrates in mid-channel. High densities of zebra mussels were collected from the hard substrates on the north side of the channel and intermittently in aggregates elsewhere. The zone was moderately long (1.34 miles) and had an average width (0.050 miles). It occupied an area of 0.067 square miles (173,529 m^2).

Zone VII extended from the downstream end of Zone VI to the Maloney Island Cut. Its substrates predominately consisted of a soft/muck and a gravel/sand mix. Mussels were collected in only one of the 12 Petite Ponar grabs taken in this zone. Many young-of-year mussels were, however, noted to be attached to the stems and leaves of the submerged aquatic vegetation that was abundant in this zone at the time of the habitat assessment survey. The zone was approximately one mile long, 0.040 miles wide and occupied 0.037 square miles (96,348 m^2).

Zone VIII was a rather short reach that comprised the Maloney Island Cut. The substrate was predominately hard shale overlain by cobbles and gravel. High densities of multiple year classes of mussels were found during the habitat assessment survey. The zone was 0.62 miles long and 0.030 miles wide, so occupied a relatively small area of 0.019 square miles (48,172 m^2).

Zone IX extended from the downstream end of the Maloney Island Cut to just downstream of Cooper's Marine Incorporated (between Navigation Buoy G"337" and G"335"). This zone had a predominately soft, mucky bottom. Zebra mussels were infrequently collected except on the submerged vegetation, where they were prevalent. The zone was 1.10 miles long, comparatively wide (0.062 miles), and occupied 0.068 square miles (176,637 m^2). This was the most eastward zone that was entirely upstream of New York State Barge Canal Lock 24, which is located in Baldwinsville.

Zone X included an area of predominately hard substrate upstream of Lock 24, the lock proper, and downstream to near Navigation Buoy G"325." Relatively high densities of zebra mussels were collected in this zone. Although not sampled, the walls of the lock chamber were also heavily colonized below the low water line. Zone X was approximately one mile long and relatively narrow (0.024 miles wide). It had the third lowest area of the habitat zone at 0.023 square miles (58,534 m^2).

Downstream of Zone X to midway between Navigation Buoys W"303" and R"302" was Zone XI. This zone had a predominately soft, mucky bottom. Zebra mussels were sporadically collected in low densities on the bottom in this habitat zone. Young-of-year mussels were, however, prevalent on the submerged aquatic vegetation examined in this habitat zone. Zone XI was relatively long (3.20 miles), moderately wide (0.042 miles), and occupied 0.134 square miles (348,094 m^2).

Zone XII extended from the downstream end of Zone XI to midway between Navigation Buoys R"298" and R"296." The downstream end of this habitat zone was defined by a break found between two separate water quality regimens influenced by inflow from Onondaga Lake. Upstream, the specific conductance of the water was much lower and the dissolved oxygen (DO) much higher than downstream (Table 2). Both specific conductance (an indirect measure of salinity) and DO can impact zebra mussel populations (Setzler-Hamilton et al. 1997; McMahon and Alexander 1991; Karatayev 1995). So, although comparable substrate existed downstream, a habitat break was placed at this point.

Habitat Zone XIII extended from the water quality break to midway between Navigation Buoys W"261" and W"259." The zone also included the waters that surrounded Klein Island (Figure 5). Both Zones XII and XIII had a mix of muck, gravel and hard substrates. Zebra mussels were collected at densities ranging from few to high and were collected intermittently throughout both zones. Zone XII was 1.23 miles long and had a mean width of 0.050 miles. It occupied an area of 0.062 square miles (159,284 m^2). Zone XIII was much longer (4.40 miles) but had a mean

width comparable to Zone XII (0.050 miles). Zone XIII was the largest zone in terms of area and occupied 0.220 square miles (569,797 m^2).

Zone XIV was the relatively short reach between Onondaga Lake and where the outlet bifurcates around Klein Island. This reach was predominately hard substrate and gravel over a hard substrate. High densities of young-of-year mussels were found in this zone during the habitat assessment survey. The zone was 0.60 miles long, 0.030 miles wide, so occupied an area of 0.018 square miles (46,620 m^2) and was the smallest zone in the area.

Zone XV extended from the downstream end of Zone XIII to midway between Navigation Buoys R"256" and R"254." Only soft/muck substrates were collected in this zone. Zebra mussels were, however, present in two of the nine Petite Ponar samples taken during the habitat assessment survey. Zone XV was 0.80 miles long, 0.050 miles wide and occupied an area of 0.040 square miles (103,600 m^2).

Zone XVI extended from Zone XV to midway between navigation Buoys R"246" and G"243." The substrate was comprised of a relatively equal mix of soft and hard substrates. Low to moderate densities of multiple year classes of zebra mussels were collected throughout this reach. Zone XVI was moderately long (1.40 miles) and had a mean width of 0.040 miles. It occupied an area of 0.056 square miles (145,039 m^2).

Zone XVII extended from Zone XVI downstream to midway between Navigation Buoys R"232" and R"230." The zone had a substrate that was predominately a mix of hard substrates and gravel shoals, although a few areas of soft/mucky substrates were also present. Moderate densities of mussels were collected within this reach. Zone XVII was 1.60 miles long, 0.030 miles wide and occupied an area of 0.48 square miles (124,319 m^2).

Zone XVIII was a relatively short reach that had among the highest densities of zebra mussels encountered during the habitat assessment survey. Both young-of-year and adult mussels were collected. The bottom of this zone was typified by hard substrates in mid-channel with gravel on

both shores. This zone extended from the downstream end of Zone XVII to midway between Navigation Buoys G"221" and W"219" just upstream the confluence of the Seneca River and Oswego River. Zone XVIII was 0.90 miles long and 0.030 miles wide, and occupied an area of 0.027 square miles (69,930 m^2).

Zone XIX extended from the downstream end of Zone XVIII to Navigation Buoy R"178" located just east of Schroeppel Island (Figure 5). This zone included the Oneida River navigational channel including the Big Bend Cut, but did not extend into the Big Bend or the Oswego River. The entire reach was generally soft bottomed along each shore. Although there were some areas of harder substrates along the middle channel, most of the mid-channel was also generally soft. Zebra mussels were only collected in two of the 42 samples taken in this zone during the habitat assessment survey. Zone XIX was the longest habitat zone at 4.50 miles, had a mean width of 0.40 miles and occupied an area of 0.180 square miles (466,198 m^2).

3.2 Dreissenid Mussel Population Measurements

A total of 189 samples was collected within the project area to assess the population characteristics of the dreissenids in the portions of the Seneca and Oneida Rivers of concern to the County. Nine samples (three samples along each of three transects) were collected using SCUBA techniques within each habitat zone except Zones IV, XIII and XIX, where 15 discrete samples (three samples along each of five transects) were collected. All collected samples were successfully analyzed, and no problems that could affect the validity of the results or interpretation of the data occurred. Dreissenids were present in 93 (49.2 percent) of the samples analyzed. All of the dreissenids collected were zebra mussels (*Dreissena polymorpha*); no quagga mussels (*D. bugensis*) were present.

The overall mean density of mussels in the project area was 1,945 individuals/m^2 (Standard Deviation [S.D.] = 4,548). The mean density of mussels significantly differed among the habitat zones ($F = 3.51$; d.f. = 18; $p<0.00005$). The mean density of zebra mussels ranged from 9 mussels/m^2 (S.D. = 26.4) in Zone I to 12,977 mussels/m^2 (S.D. = 15,920) in Zone III (Table 3).

The mean density of mussels exceeded 1,000 individual/m^2 in 11 of the 19 zones (57.9 percent) and exceeded 400 individuals/m^2 in all zones except Zone 1. The highest density of mussels in any individual sample was 43,937/m^2 which occurred in Zone III, which includes the State Ditch Cut. Habitat Zone III was also the only zone in which all samples contained zebra mussels. Mussels were present in 75 percent or more of the samples collected in five of the habitat zones (Zones III, VI, VII, XVII and XVIII). Mussels were present in less than 25 percent of the samples collected in five habitat zones (Zones I, X, XIII and XV).

The overall mean weight of zebra mussels per unit area in the project area was 1,356 g/m^2 (S.D. = 2,862). The mean weight of mussels per unit area significantly differed among habitat zones ($F = 3.04$; d.f. = 18, $p = 0.0001$). The mean weight of mussels ranged from 0.7 g/m^2 (S.D. = 2.0) in Zone I to 3,511 g/m^2 (S.D. = 8,010) in Zone V (Table 3). Mean weight exceeded 1,000 g/m^2 (approximately 2.2 lb) in 10 of the 19 habitat zones (52.6 percent). The greatest weight of zebra mussels in any sample was 23,957 g/m^2 (approximately 52.8 lb) in a sample collected in Zone V.

The mean particle size of the substrate within a habitat zone ranged from a phi value of -7.22 in Zone III to a value of 5.45 in Zone XIII. Only Zone III had a mean phi value of less than -4.75, which represents predominately large particle size substrates (i.e., hard substrates). Three habitat zones (Zones I, XIII and XV) had mean phi values greater than 4.25, which represent small particle size substrates (i.e., fine or soft substrates). The other 15 habitat zones had intermediate phi values (i.e., between -4.75 and 4.25) which correspond to particle sizes in the range of sand and gravel or to mixtures of large and small size substrates. Overall, 70 individual samples (37.0 percent) had phi values greater than 4.25 (i.e., small size particles), and 29 samples (15.3 percent) had values less than -4.75 (i.e., large size particles). The other 90 samples (47.6 percent) had intermediate phi values.

The mean density of zebra mussels significantly differed among substrate types (i.e., particle size) ($F = 85.92$; d.f. = 2, $p<0.00005$). The mean density of mussels present in samples with small particle size substrate (i.e., phi values >4.25) was 44.1 individuals/m^2 (S.D. = 355). The mean density of mussels present in samples with large particle size substrates (i.e., phi value < -4.75)

was 6,952.0 individual/m^2 (S.D. = 10,960). The mean density of mussels in samples with intermediate phi values was 1,809 individuals/m^2 (S.D. = 2,305).

There was also a significant difference in the mean weight of individual mussels among substrate types ($F = 4.08$; d.f. = 2; $p = 0.0198$). The mean weight of mussels in samples with phi values greater than 4.25, corresponding to smaller-sized particles, was 2.65 g/individual. On average these individuals were heavier than mussels collected in areas with large size substrates (1.14 g/individual) and areas with intermediate phi values (1.11 g/individual).

Length frequency distributions illustrated obvious differences in the community structure of the zebra mussels among habitat zones (Table 4 and Figures 6-7). Figure 6 summarizes the length data in 5-mm increments and provides sufficient definition of the data to separate out some of the probable age groups. Figure 7 provides the same data with less definition. However, the length increments in Figure 7 represent the test sizes of zebra mussels that will be used for the laboratory studies conducted by Beak to develop information on the Seneca River mussel physiology which is to be used in the County's Seneca River model. Results of these tests are reported elsewhere.

There were three different community structures evident from an examination of the length frequency data. One community type was dominated by zebra mussels that were 10 mm or less in total length. The second community type was a community dominated by large individuals (i.e., 20 mm and greater). The third community type had a more balanced size structure which included a mix of mussels of different sizes.

Zones I, II, III, IX and XIV were dominated by zebra mussels that were 10 mm or less in length. Zone I had no mussels larger than 10 mm, but the overall density of mussels was low. Only 7.4 percent of the mussels in Zone II and 8.8 percent in Zone III (the State Ditch Cut) were greater than 10 mm. In Zone IX, located just upstream of the Baldwinsville Lock (Lock 24), 62.5 percent of the zebra mussels were 10 mm or less in length. The distribution in this zone is somewhat different than Zones I through III since larger mussels are represented, but at low levels. In Zone XIV, which is the outlet of Onondaga Lake, only 12.9 percent of the mussels

were greater than 10 mm in length. Mussels that are less than 10 mm long in late fall 1999 were likely recruited as veligers during 1999.

Zones XVI through XVIII had a disproportionate number of larger individuals (i.e., greater than 20 mm). In Zone XVI, 64.7 percent of the mussels were longer than 20 mm; in Zone XVII, 69.6 percent were longer than 20 mm; and in Zone XVIII, 70.1 percent exceeded 20 mm in length. Mussels longer than 20 mm likely included mussels that were in their third year and older (i.e., settled in or prior to 1998 for this study).

The length frequency distribution in the other 11 zones consisted of a relatively more even distribution of individuals among length increments. The samples collected in these zones included mussels that had settled in 1999 attached to the shells of larger mussels. Mussels that likely settled in 1998 were also common and attached to even longer mussels. These more size balanced communities existed in habitat zones that were adjacent to zones where the community structures were dominated by either large or small mussels.

4.0 DISCUSSION

The density and distribution of the zebra mussels in the studied reach of the Seneca River were best described as patchy and uneven. This was evidenced by the high standard deviations for the mussel mean density data both within a habitat zone as well as within a substrate type. Similar patterns of distribution were present in other river system studies. Unfortunately, although many studies on zebra mussel distribution have been conducted on lakes (Stanczykowska and Lewendowski 1993; Dorgelo 1993; Custer and Custer 1997), relatively little information exists on their distribution in river systems (Martel 1995).

An uneven distribution of zebra mussel abundance was observed in the Daugava River, a controlled river system located in the Baltic Basin (Kachalova and Sloka 1964). No mussels were collected over certain reaches of the river, but were present in relatively high densities (1,633/m^2) in other areas. Densities of 23 to 1,633/m^2 were present on identical substrates within the same reach of river. Differences in the size structure of the population in different areas of the river were also noted.

In the Rideau Canal, Ontario, Martel (1995) found some reaches where zebra mussels were rare or absent and others where densities greater than 3,500 individuals/m^2 existed. He observed that the highest densities of mussels occurred in the reach of the canal system where a long low-flow area occurred.

On the south shore of the St. Lawrence River, Mellina and Rasmussen (1993) found a mean density of 2,444 individual zebra mussels/m^2 (S.E. = 925) with a range of no mussels collected to 26,833 individuals/m^2. They also found a mean density of 5,091 mussels/m^2 (S.E. = 3,440) in the Hudson River. The density of mussels collected in the Hudson River samples ranged from none to 37,500 individuals/m^2. Mellina and Rassmussen were able to explain between 38 and 91 percent of the variability in the zebra mussel density in their study by substrate type. In a review of published literature, the substrate size explained 75 percent of the variability in density for lakes but only 29 percent of the variability in density in the river systems.

In the Seneca River, there was a significant relationship between substrate size and the density of zebra mussels. On average, the larger the substrate particle size, the greater the density of zebra mussels present.

The highest densities of mussels existed on the hard substrate which was expected based on the zebra mussels' epiphylic behavior. A mean density of 6,952 mussels/m^2 was found in areas with phi values that describe predominately cobble, boulder and ledge bottoms. However, high variability in zebra mussel density was observed even on these preferred substrates. Densities of mussels on substrates that were cobble size and larger ranged from zero to 43,937 individuals/m^2.

A somewhat lower mean density of zebra mussels (1,809/m^2) was present on substrates with intermediate phi values that describe gravels, sands and mixes of large and small size particles. The influence of the composition of the mixes could not be determined. However, field personnel did not observe live mussels on the true sand substrates but did observe them on gravels. The majority of mussels collected in areas with intermediate phi values were collected on cobbles or unionid shells found in a matrix of finer material, usually silt.

A mean density of 44.1 mussels/m^2 was present on small size particles (i.e., phi values >4.25). The density of mussels found on small size particles ranged from zero to 10,249/m^2. The small size particles were predominately soft, loosely consolidated silt. In many cases, the silt was highly organic and could be classified as muck. Generally, when collected in the silt or muck, the zebra mussels were aggregated in a "druse" or clump of mussels attached to each other by their byssal threads. The druse collected on the soft sediments during this study generally ranged from 7.5 cm to 20.0 cm in diameter and were usually dominated by larger individuals. Frequently, the innermost mussels were dead (i.e., empty shells).

These aggregates of mussels (druse) could have formed through any one of a number of processes. Detached adult mussels colonies from upstream could have been carried by a high flow event and deposited onto the soft sediments. If the colony had sufficient surface area, it

could have remained on the top of the soft substrate and established itself. Alternatively, opportunistic post-veligers could have settled on some piece of available hard substrate such as a small branch, zebra mussel shell, snail shell or unionid (native bivalve) that was present on the silt. As these pioneering individuals grew, subsequent settlement could occur on their shells, and eventually a zebra mussel reef could be formed in the soft substrate. This occurrence has been documented in western Lake Erie (Coakley and Brown 1996; Berkman et al. 1994).

A third mechanism for zebra mussel colonization of soft substrate habitats would involve the submerged aquatic vegetation (SAV) or macrophytes prevalent in the Seneca River. Zebra mussels were frequently observed on the SAV examined during the September habitat assessment survey. By November, the majority of the vegetation had died back, an annual occurrence in temperate fresh waters. As the plants died back, the stems colonized by the zebra mussels would fall to the bottom and ultimately act as a hard substrate that can support the attached individuals. Surviving mussels could then be colonized in subsequent years by post-veliger settlement and form reefs of mussels on the soft substrate. Submerged aquatic vegetation has been reported as a preferred substrate for settling mussels. In the majority of Mazurian Lakes studied by Stanczykowska and Lewandowski (1993) plant-dwelling zebra mussels represented over 85 percent of the population. Lewandowski (1982) found greater than 100,000 zebra mussels per 100 g of biomass of vegetation on species of *Elodea*, *Ceratophyllum*, *Fontinalis* and *Potamogeton* in certain Polish lakes. Although the population on the plants was predominately young-of-year, older individuals were also present. Grigorovich and Babko (1997) reported colonization of aquatic plants by zebra mussels in river systems. In the Dnieper and Dniester Rivers of the Ukraine, zebra mussels colonized a variety of aquatic vegetation species. They colonized 66 percent of the *Phragmites* and 41 percent of the *Potamogeton* and *Ceratophyllum* examined. Higher densities of mussels occurred on plants that were in areas with a detectable current.

The annual die-back of the exposed portions of much of the SAV in November prevented a determination of the abundance and distribution of mussel on this substrate in the Seneca River during the 1999 study. High densities of mussels, however, were observed on SAV during the

September habitat assessment survey. Stands of vegetation existed over a large portion of the Seneca River during the September assessment.

The mussels on the vegetation could seasonally (e.g., July through September) comprise a large, undetermined component of the overall population of zebra mussels in the river from the time when settlement occurred through the annual die-off of the vegetation. If significant numbers of individuals existed on the vegetation, the density of mussels in the study area would be underestimated in this study, especially for the habitat zones which were characterized by silt and mucky substrates. This underestimation could impact subsequent estimates important to the Seneca River model, especially during July through September. The occurrence of mussels on the SAV would be higher in the water column rather than confined to the bottom. This may provide them the opportunity to impact the upper portions of the water columns to a greater degree than the mussels residing on the bottom. This could be problematic to the model for this river system that is depth stratified (Canale et al. 1995).

To gain an appreciation for the size of the zebra mussel population that resided in the Seneca River study area during the study which can affect the ecological processes in the reach, the total number and biomass of mussels per habitat zone were estimated (Table 5). These estimates were derived by multiplying the mean density and biomass of zebra mussels present in each habitat zone by the estimated area of that zone. Biomass estimates were comparably developed.

An estimated 4.59×10^9 zebra mussels were present in the study reach of the Seneca River in October/November 1999. On average, 1.45×10^8 mussels existed per river mile. Over 22 percent (1.02×10^9 individuals) of the mussels resided in the State Ditch Cut (Habitat Zone III). An additional 14.6 percent of the mussels resided in Zone IV, which was adjacent to the downstream end of Zone III. A total of 2.1×10^8 mussels was also present in the Onondaga Lake Outlet (Zone XIV). Only Zone I, the natural channel around the State Ditch Cut, had less than 10×10^6 mussels present.

An estimated total biomass (wet weight) of 3.92×10^6 kg (4,325 ton) of mussels was present in the study reach (Table 5). The greatest biomass of mussels existed in Zones IV (8.52×10^5 kg) and XIII (6.99×10^5 kg). These two zones contributed to 39.5 percent of the total biomass of mussels in the study reach. Although the mussels in Zone III represented over 22 percent of all mussels, because they were almost exclusively young-of-year mussels, they contributed to less than two percent of the total biomass.

The striking differences in the length frequency distributions of the zebra mussel populations among habitat zones in this relatively short river reach were unexpected. The most interesting distributions were found in Zones I, II and III, where the population was almost exclusively made up of individuals less than 10 mm long. Only 8.5 percent of the mussels in Zone II, 8.8 percent in Zone III and none in Zone I were greater than 10 mm long. No individuals greater than 20 mm were present in Zones I or II. Only one percent of the individuals in Zone III were longer than 20 mm. Individuals less than 10 mm generally are young-of-year mussels (Chase and Bailey 1999; Dorgelo and Gorter 1984; Morton 1969) which for this study were mussels that settled during 1999. The length distribution of the mussels in Zone IV adjacent to the downstream end of Zone III was fairly uniform. About 33 percent of the individuals were less than 10 mm; 21 percent were between 10 mm and 20 mm; and about 46 percent were greater than 20 mm. The length distribution in Zone IV represented the presence of multiple year classes of adults, with a large number of young-of-year mussels recruited to the population.

The lack of live mussels that would have settled prior to 1999 in Zones I, II and III suggests that some catastrophic event occurred in this reach which killed or displaced the existing population of mussels. Since most successful settlement in temperate fresh water occurs between June and October (Sprung 1993), the unimodal distribution of young-of-year mussels indicates that the catastrophic event occurred after the 1998 year class had settled (i.e., fall 1998), but had ended prior to the occurrence of appreciable settlement in 1999. High densities of young-of-year mussels were collected from Zone III on September 29, 1999, during the habitat assessment survey. Along with the small live mussels (less than 5 mm), the cobbles retrieved were entirely covered with the byssusses of adult mussels. The size of the byssusses indicated that the mussels

that produced them had been attached for a considerable period, probably for longer than one year based on published information (Eckroat et al. 1993; Clarke and McMahon 1995) and personal observations (Lange unpublished data). A large number of empty shells from adult zebra mussels were collected in Zone IV by Ponar dredge sampling during the habitat assessment survey. These rafts of empty shells were collected in depositional areas as evidenced by the silty sediments also collected. The majority of the shells were greater than 20 mm long which indicated that the mussels were at least two years old when they died. No soft tissues were observed in the shells, but there was no indication of calcium leaching from the shells (i.e., the shells were not soft and porous) which indicated that they were from fairly recently killed mussels. The existence of multiple year classes of mussels in Zone IV indicated that whatever contributed to the die off in the State Ditch Cut did not impact the population of mussels in Zone IV.

Effler et al. (1997) reported a similar occurrence in the State Ditch Cut in 1994. In June/July 1994, they estimated that 40,000 individuals/m^2 existed in the Cut, and that about 50 percent of the individuals were 20 mm and greater in length. The biomass of the mussels in the Cut averaged 930 g/m^2 (dry weight) in June/July. In September/October 1994, Effler et al. resampled the Cut. The density of mussels collected was reduced to 18,000 individuals/m^2. Approximately 75 percent of the mussels present were less than 10 mm. Although fewer than during June/July 1994, and unlike 1999, larger adult mussels persisted in the Cut in September/October 1994.

Effler et al. (1997) attributed the reduction of adult mussels in the Cut to a high flow event in August that dislodged the existing multiple year classes of mussels from the substrate and washed them downstream. The discharge (measured downstream at Gage #0437500 at Baldwinsville, NY) was about 4,500 cfs (USGS datum). They attributed the presence of druse downstream to translocated adults from this washout event. Effler et al. suggested that other chronic stresses such as high summertime temperatures, low dissolved oxygen concentrations or increased suspended solids could have made the population more susceptible to dislodgment. Based on observations made during 1999 and other available information, it is doubtful that the high flow event described would in itself almost completely remove all existing mussels from the Cut.

A force of up to 49.7 Pa (1.04 lbs/ft^2) was required to separate individual mussels from substrates during a lab test (Akerman et al. 1993). These tests probably underestimate the force required to remove established populations of mussels, since byssal formation is ongoing while the mussels for Akerman's laboratory test were allowed to attach to the test plates for less than one month. Even though a high flow event may scour some of the mussels from the substrate, the zebra mussel's rugophyllic behavior suggests that at least some of the adult population would persist in refugia in the Cut protected from the high flows (e.g., cracks and crevices in the shale, on the lee side of boulders). The divers during the 1999 study specifically looked for adult mussel colonies in the Cut but could not find any. The presence of large numbers of byssusses on small hard substrates (e.g. cobbles) which were common during the 1999 survey, makes detachment of live mussels from these surfaces unlikely. The shear force required to remove them would likely be much greater than the forces required to carry the cobble with mussels attached downstream.

Also, although Effler et al. (1997) reported the August flow as a high flow event, a flow of comparable magnitude occurred in late June 1994 as well as over a two month period in November/December 1993. Even higher flow events of approximately 13,000 cfs, (USGS datum) nearly three times the flow of the August 1994 event, occurred over a considerable period in the spring of 1994. The presence of a multiple year class population in the Cut in June/July 1994 suggests that these prior high flow events did not appreciably scour the mussels from the substrate. A die-off of mussels in the Cut followed by a resuspension and subsequent deposition of the detached, empty zebra mussel shell downstream is a more likely hypothesis. The large rafts of zebra mussel shells in well defined depositional areas in Zone IV lends to support this hypothesis.

A similar event likely occurred in the outlet of Onondaga Lake (Zone XIV). Over 87 percent of the mussels in Zone XIV were less than 10 mm and only 7.6 percent were larger than 20 mm. A notable observation by the field personnel was that cobbles and other hard substrate in the outlet lacked the carpet of byssusses from detached adults. This would suggest that there is an annual low survivorship of adults in the outlet; either from a gradual chronic effect or an annual catastrophic event such as anoxia during Onondaga Lake's annual turnover events or changes in

some other water quality parameter. Alternatively, the population in the outlet could be increasing naturally. However, since mussels have been in the outlet since the early 1990's, this hypothesis is less likely. The third possibility is that a strong settlement year for mussels in the outlet occurred in 1999, preceded by a number of years when recruitment was minimal. Sampling in subsequent years could determine which of these hypotheses is true.

The presence of large numbers of byssusses from adult mussels found in the Cut and the rafts of adult shells downstream indicate that the catastrophic die-offs in the Cut are not annual events. Whether the trigger for these periodic events are precipitated by increases in mussel populations to levels exceeding the river's carrying capacity, or from irregular environmental occurrences, has not been determined. Regardless, this information strongly suggests that there are appreciable changes in the population of mussels in portions of the study area that could greatly impact the population's influence on water quality since many impacts on water quality caused by a zebra mussel population (e.g., oxygen depletion, ammonia excretion) are dependent on both the numbers of mussels and their size (Aldridge et al. 1995). This would suggest that periodic evaluation of the status of the zebra mussel populations in the Seneca River may be warranted to determine their impact to the water quality model.

In contrast to zones that have populations of zebra mussels that were predominately young-of-year, disproportionate numbers of larger individuals were present in Zones XVI through XVIII. These zones comprised a 3.9 mile long reach of the Seneca River from near Belgium, NY, to the confluence of the Seneca and Oswego Rivers (Figure 5). In these zones, between 64.7 and 70.0 percent of the mussels were greater than 20 mm. Also, less than 11 percent of the mussels were 10 mm or less. Overall densities of mussels were relatively high in Zones XVII (2.357 individuals/m^2) and XVIII (2,017 individuals/m^2). The density of mussels in Zone XVI was somewhat lower (549 individuals/m^2). The mean biomass in these zones ranged from 786 g/m^2 in Zone XVI to 3,441 g/m^2 in Zone XVII.

A possible explanation for the relatively low survivorship of young-of-year zebra mussels in these zones may be related to the substrate characteristics in this reach. Mussels collected in this reach

were generally attached to hard substrate including cobbles and boulders. However, the hard substrate in these zones was covered with a relatively thick (1 mm - 2 mm) coat of black, anhydric silt. All of the zebra mussels collected were similarly covered by this silt layer. This coating was not observed in other portions of the Seneca River. This silt layer would not be thick enough to impact the adult mussels, which could easily extend their inhalant siphons above the layer to feed. However, post-veliger mussels are generally less than 0.5 mm long when settlement occurs (Lewandowski 1982). Due to their small size relative to the thickness of the silt layer, the post-veligers would in effect be settling on the unconsolidated silt layer rather than the hard substrate. Smit et al. (1993) report that a silt layer over hard substrate is restrictive to settlement. The lack of younger cohorts successfully settling on the older mussels may enhance their growth and survival through a reduction in intra-specific competition and maintaining their ability to access resources by not being covered by increasingly thick layers of mussels.

In a lotic system such as the Seneca River, any positive or negative impacts that zebra mussels have on water quality would be cumulative as the water flow passes over and is filtered by existing populations of mussels. The density and biomass of the population in a particular reach of river as well as the rate of flow and amount of mixing of the water would affect the degree of impact. Figure 8 provides a profile of the mean density and mean weight of zebra mussels per square meter along the Seneca and Oneida Rivers from about 0.5 miles upstream of the State Ditch Cut to near Schroeppel Island on the Oneida River. Although the highest density of mussels existed in the Cut, the greatest biomass occurred in two reaches; 1) from downstream of the Cut to the Maloney Island Cut; and 2) just upstream of the Three Rivers area. Since biomass directly correlates with the impact of mussel physiology on water quality rather than the density of mussels present (Aldridge et al. 1995), the most profound impacts to water quality would be expected to occur in these reaches.

Effler et al. (1998) suggested that the mussel population in the Cut influenced the water quality in the Seneca River and that downstream populations of mussels were also influenced by the population in the Cut. They stated that major changes in water quality in the entire Oswego River was due to the population of mussels in the Cut. Although water quality changes likely occur at

the Cut, comparable changes are expected also to occur just upstream of the Three Rivers area where comparable mussel biomass exists. Whether this population was present during 1994 is unknown. Effler et al., however, only used a single transect to represent an approximate 10 mile reach of the Seneca River from the Onondaga Lake outlet to the Three Rivers area. Appreciable changes in substrate occurred in this area, including considerable reaches of silt where few mussels exist, and other areas of hard substrates that were heavily colonized. Effler et al. noted that their level of effort may have missed small localized colonies. However, the results of the intensive effort conducted for this study suggest that populations of mussels which could profoundly influence the water quality were missed.

The results provided in this report are one component of a larger study to develop information to estimate the impact of the Seneca River zebra mussel population on water quality. That information will be used to update a mathematical model, which will assist the County in making future management decisions concerning the treated wastewater into Onondaga Lake and the Seneca River system. By May 2000, Beak will have completed two laboratory studies that will provide additional information on key aspects of zebra mussel physiology. These studies will be conducted on Seneca River mussels, so results will be specific to the population described in this report.

The first laboratory study will be a modification of an experiment conducted by Aldridge et al. (1995) to determine the oxygen uptake, ammonia excretion rate and filtration rate of individual mussels acclimated to temperatures expected to be present in the Seneca River during the mussels' active period. The second study will provide information of the water quality impacts of colonies of Seneca River mussels. As planned, changes in total Kjeldahl nitroten, total organic carbon, ammonia, total phosphorus, soluable reactive phosphorus, and nitrates and nitrites caused by the mussel colonies will be determined. The second study will also be conducted on mussels acclimated to different temperatures.

The first laboratory study, which tests individual mussels, will independently evaluate three size ranges of mussels; mussels 10 mm and less, mussels greater than 10 mm to 20 mm; and mussels

greater than 20 mm. The second laboratory study will independently test colonies comprised of mussels 10 mm and less and mussels greater than 20 mm.

The information developed during these tests will be used with the results of this study on the density of zebra mussels by length increment and habitat zone to determine the impacts of a unit area of mussels on water quality in each habitat zone. This information will be incorporated into the County's model based on the location of the habitat zone relative to the model's cell structure. A summary of the density of mussels by length category to be used with the results the laboratory tests for each zone is provided in Table 5.

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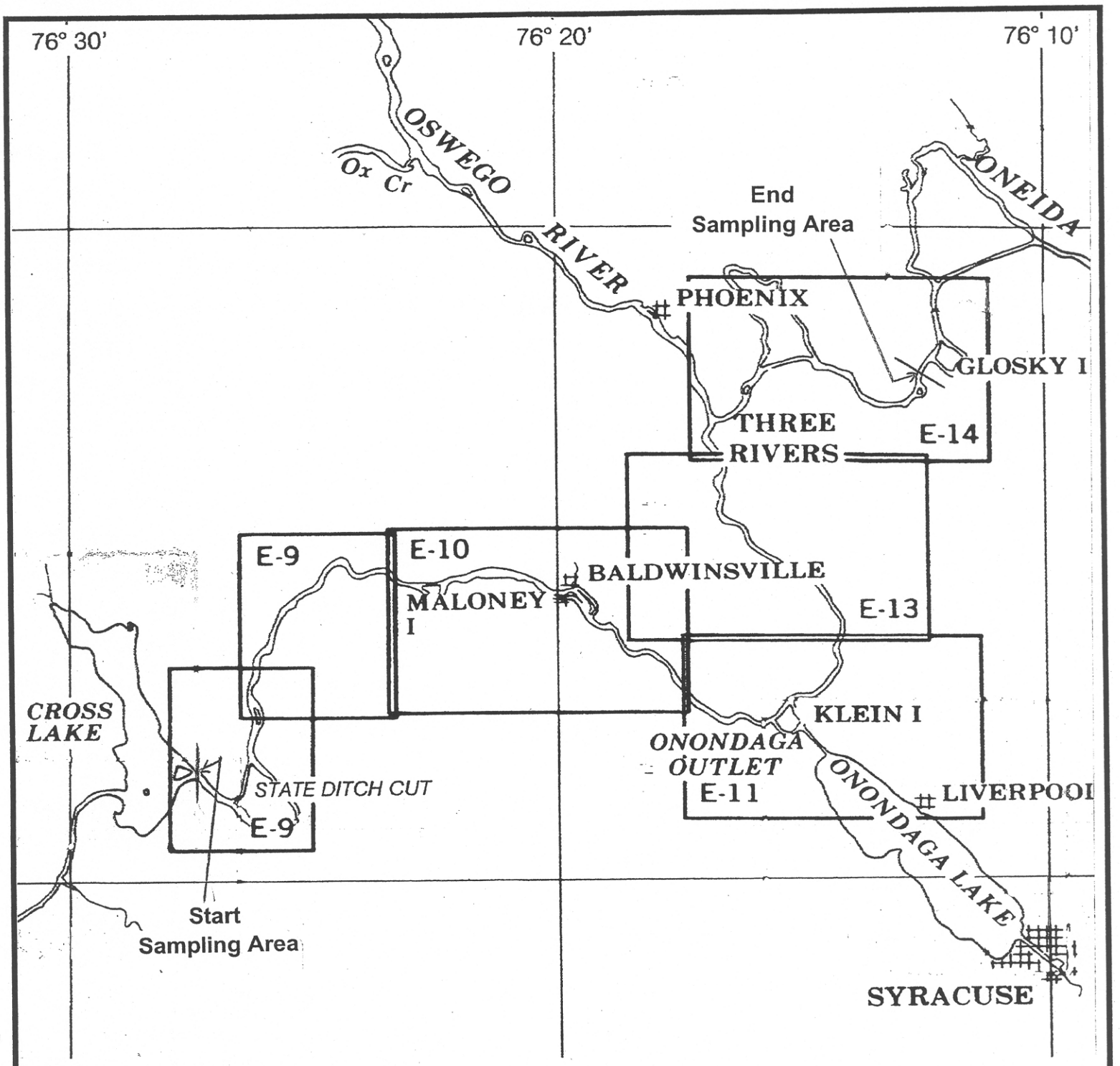
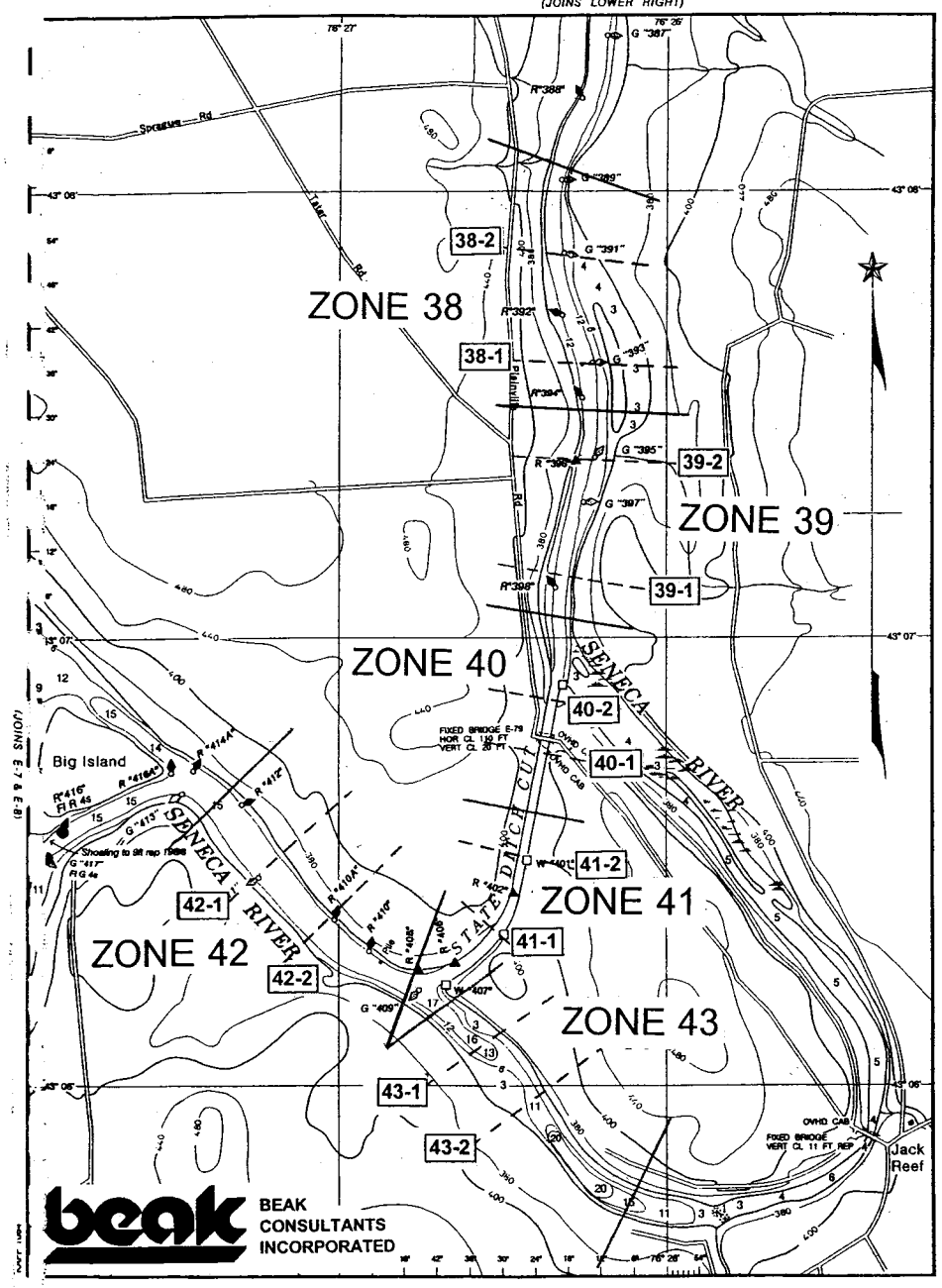
FIGURES



beak BEAK CONSULTANTS INCORPORATED	**Figure 1**	Map of Sampling Area, Seneca River Dreissenid Mussel Assessment, 1999	Scale: 1" = 2.75 Mi.



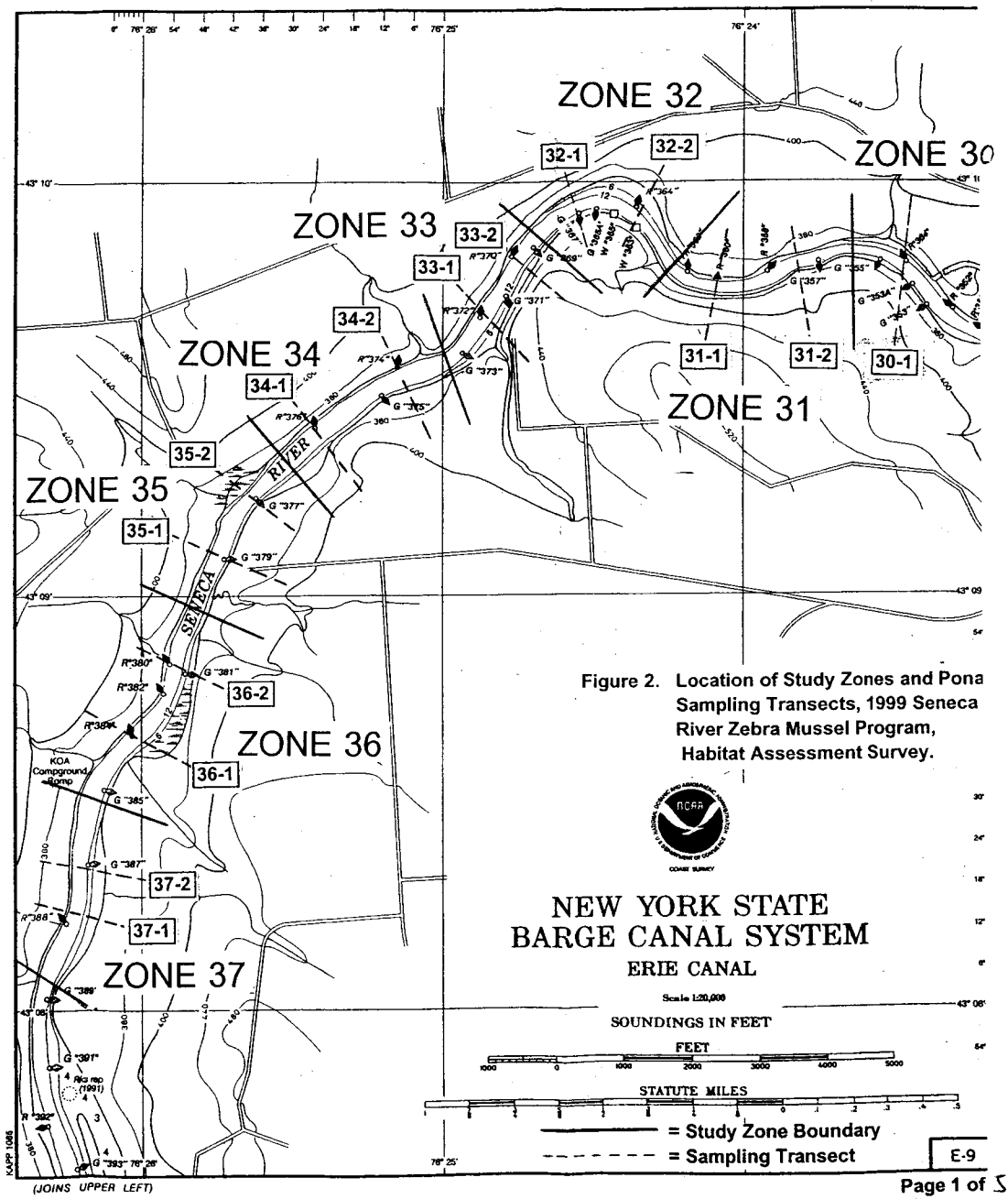
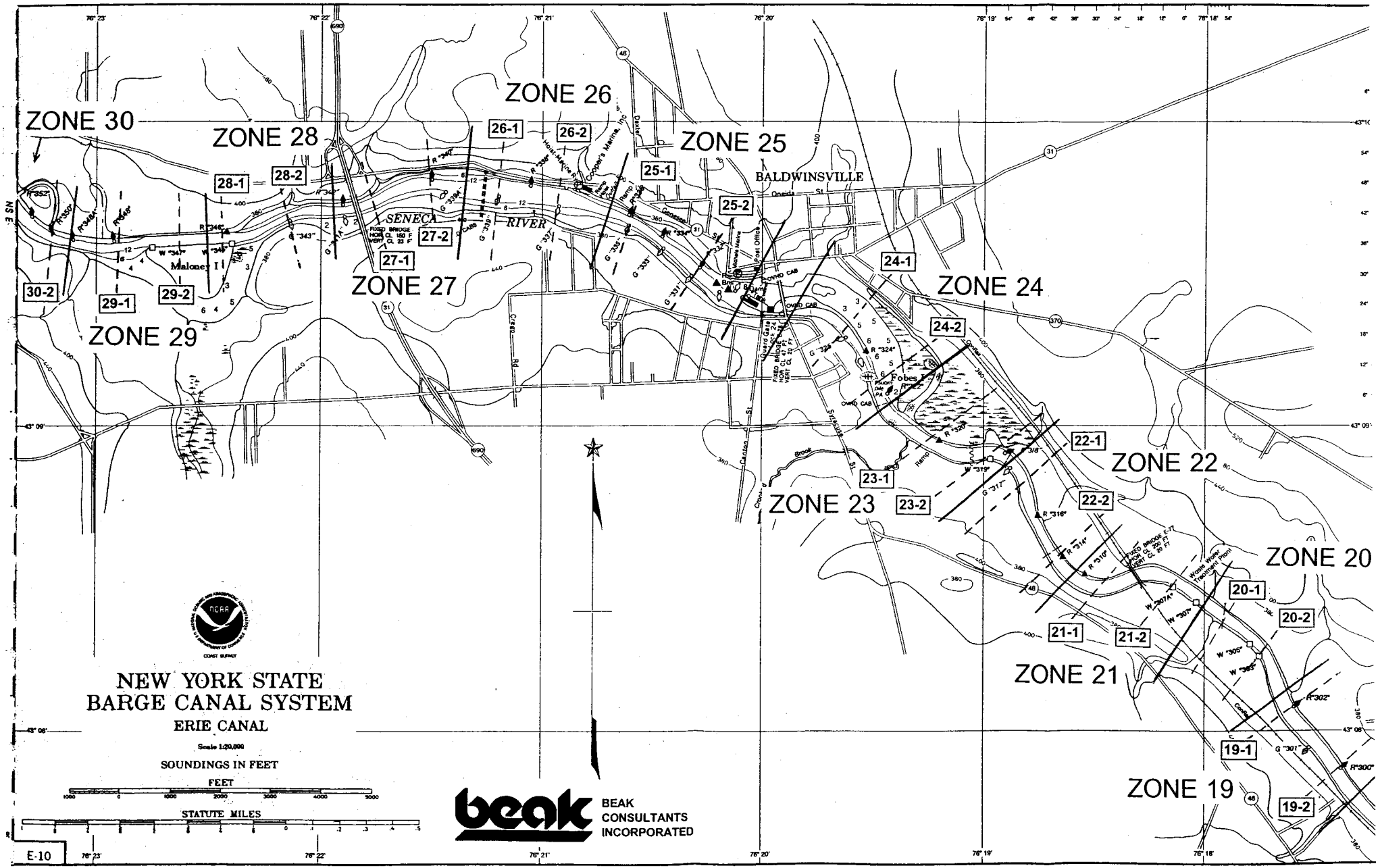
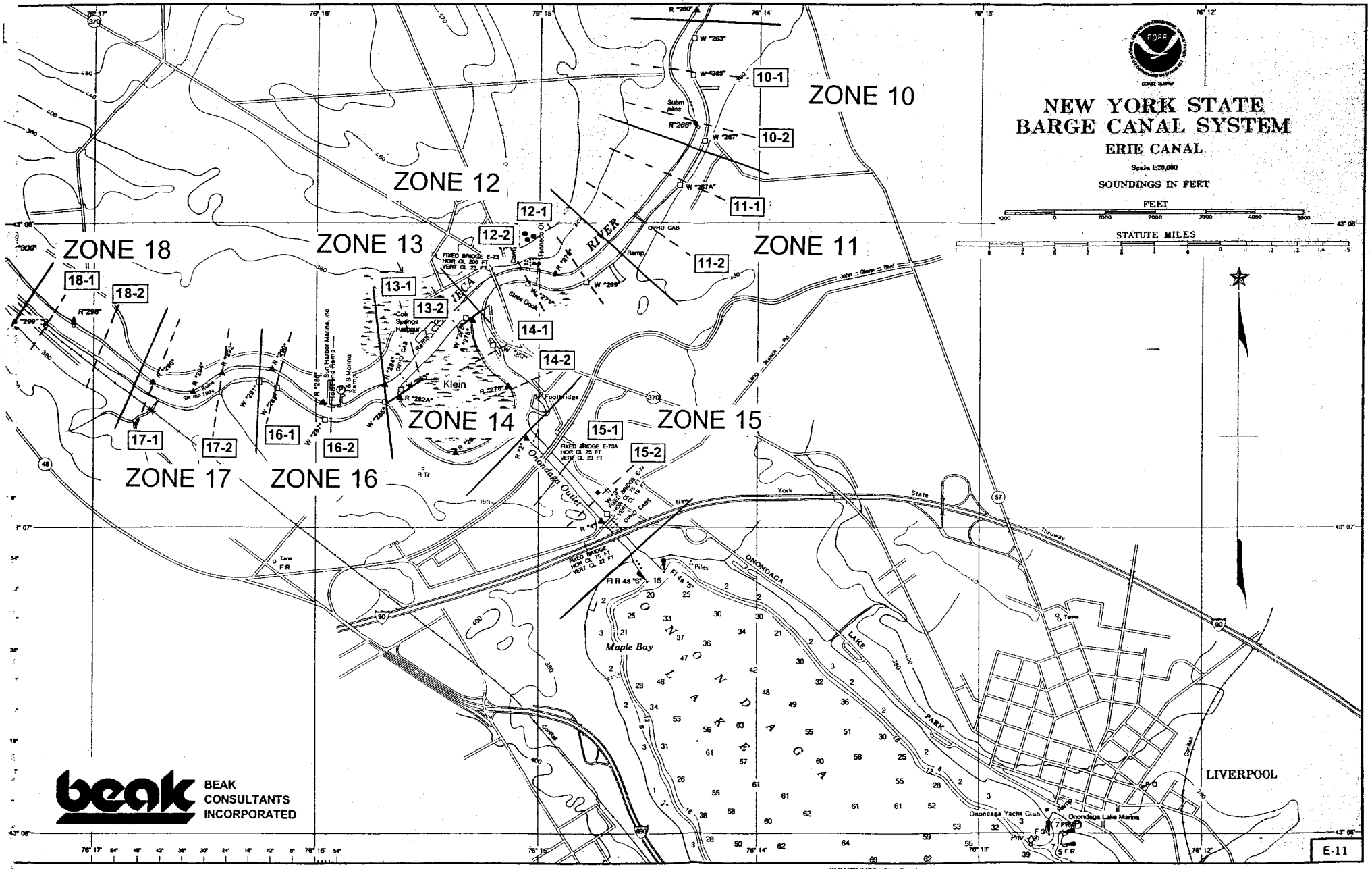


Figure 2. Location of Study Zones and Pona Sampling Transects, 1999 Seneca River Zebra Mussel Program, Habitat Assessment Survey.



14786 12th Ed. May 23/08

Figure 2. Page 2 of 5



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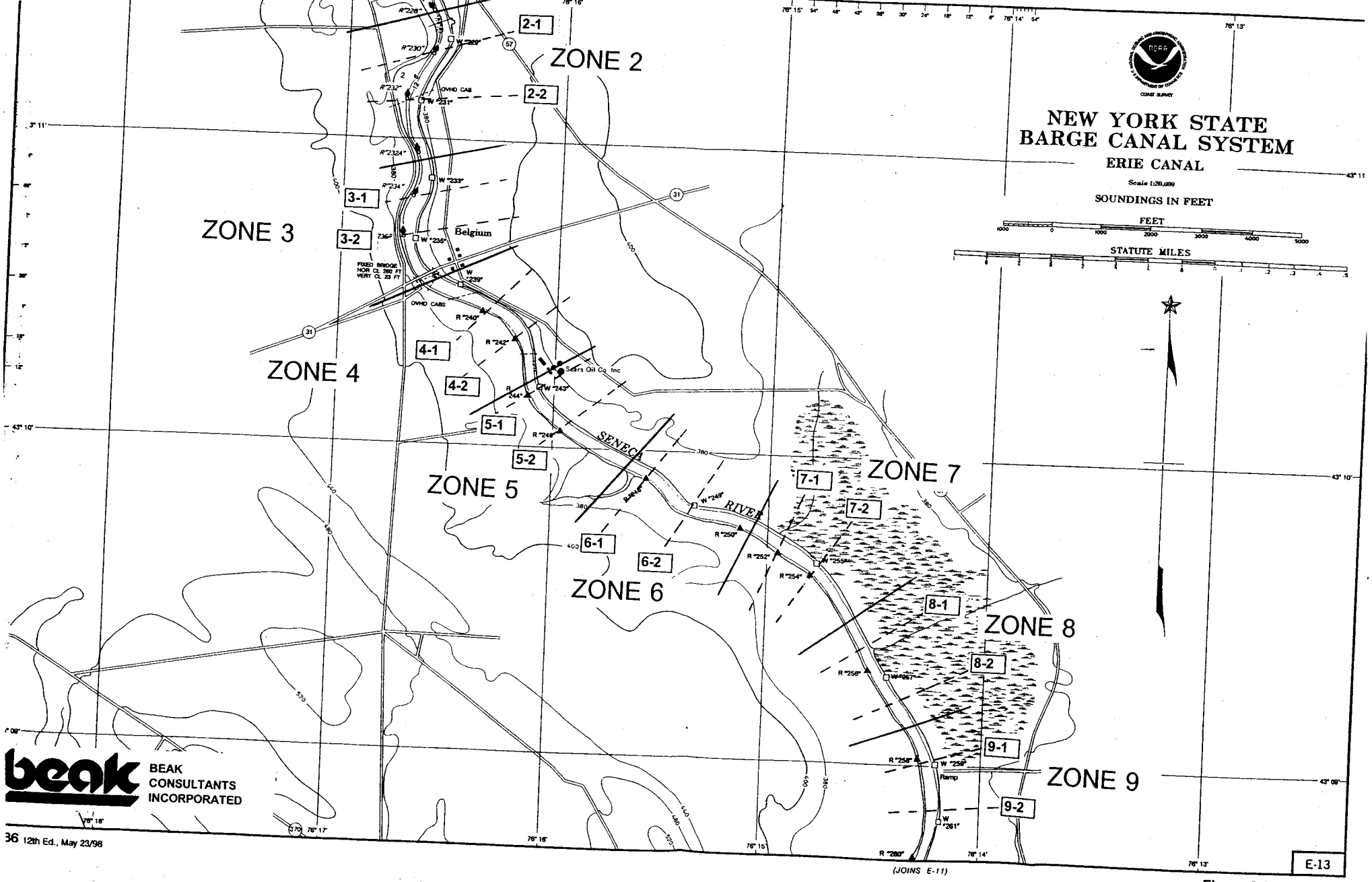


Figure 2. Page 4 of 5

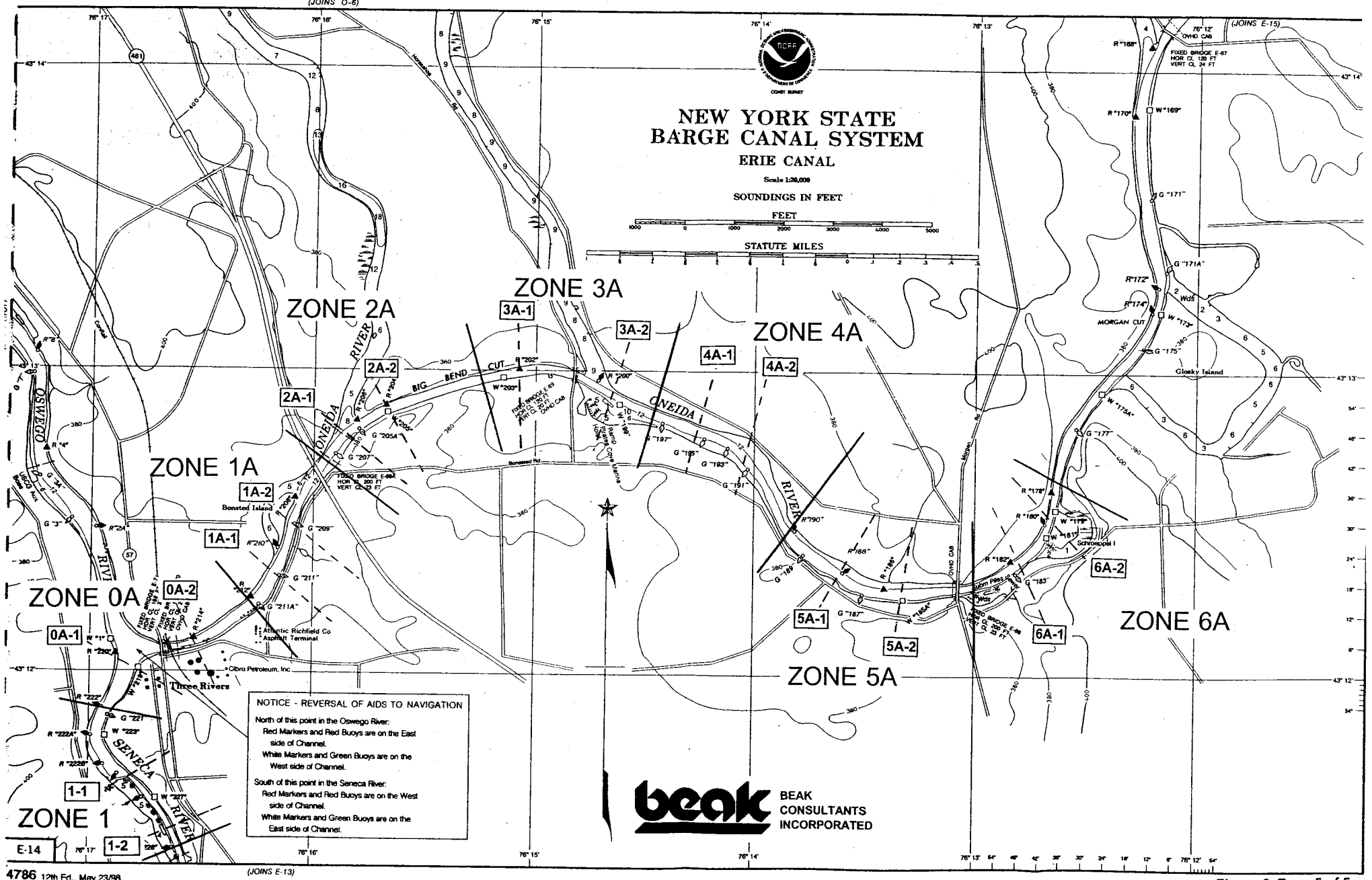
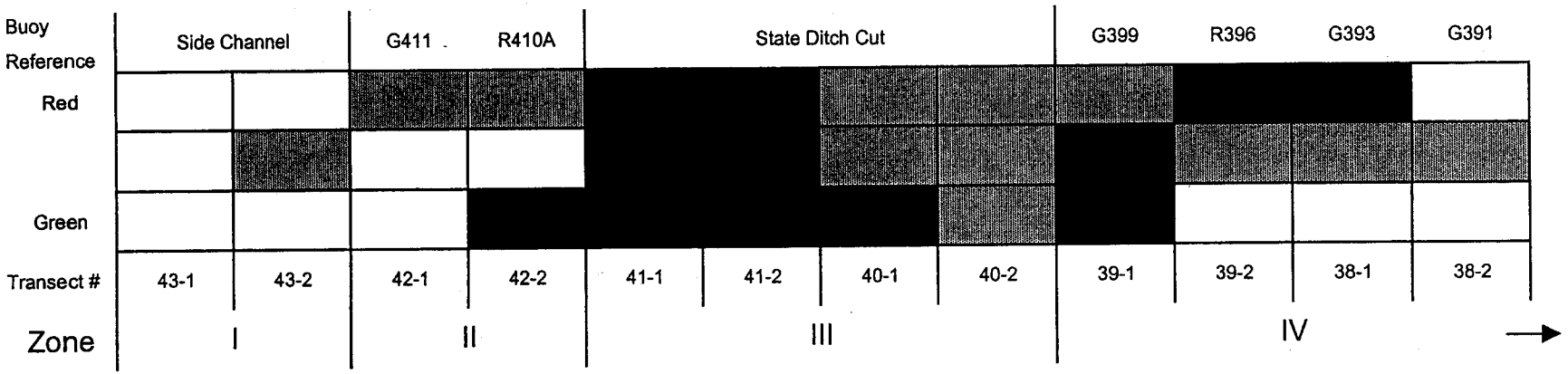
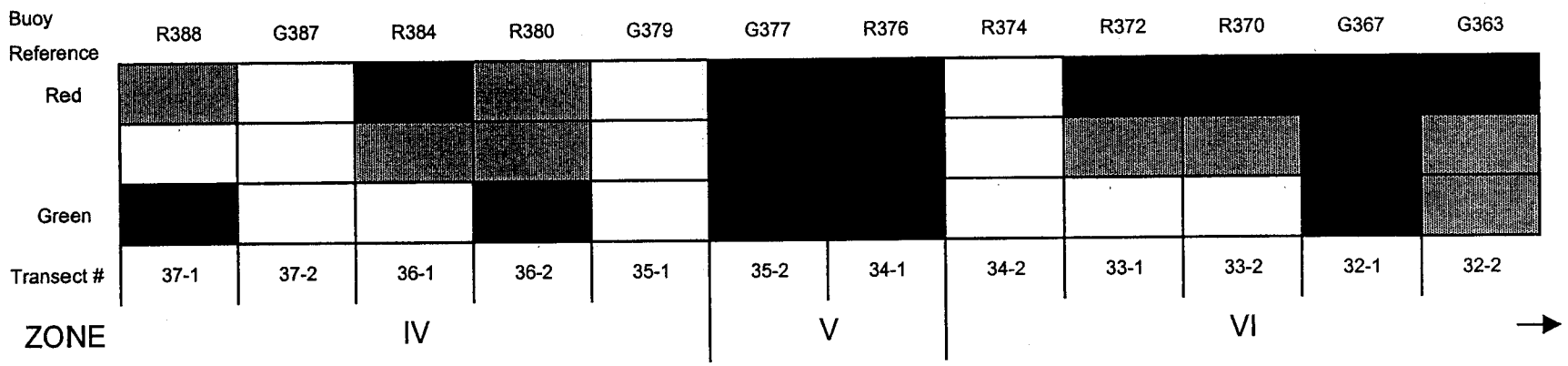


Figure 2. Page 5 of 5

Figure 3. Results of Habitat Assessment Survey-Habitat Type-Seneca River-1999





-HARD

-SAND/GRAVEL

-SOFT/MUCK

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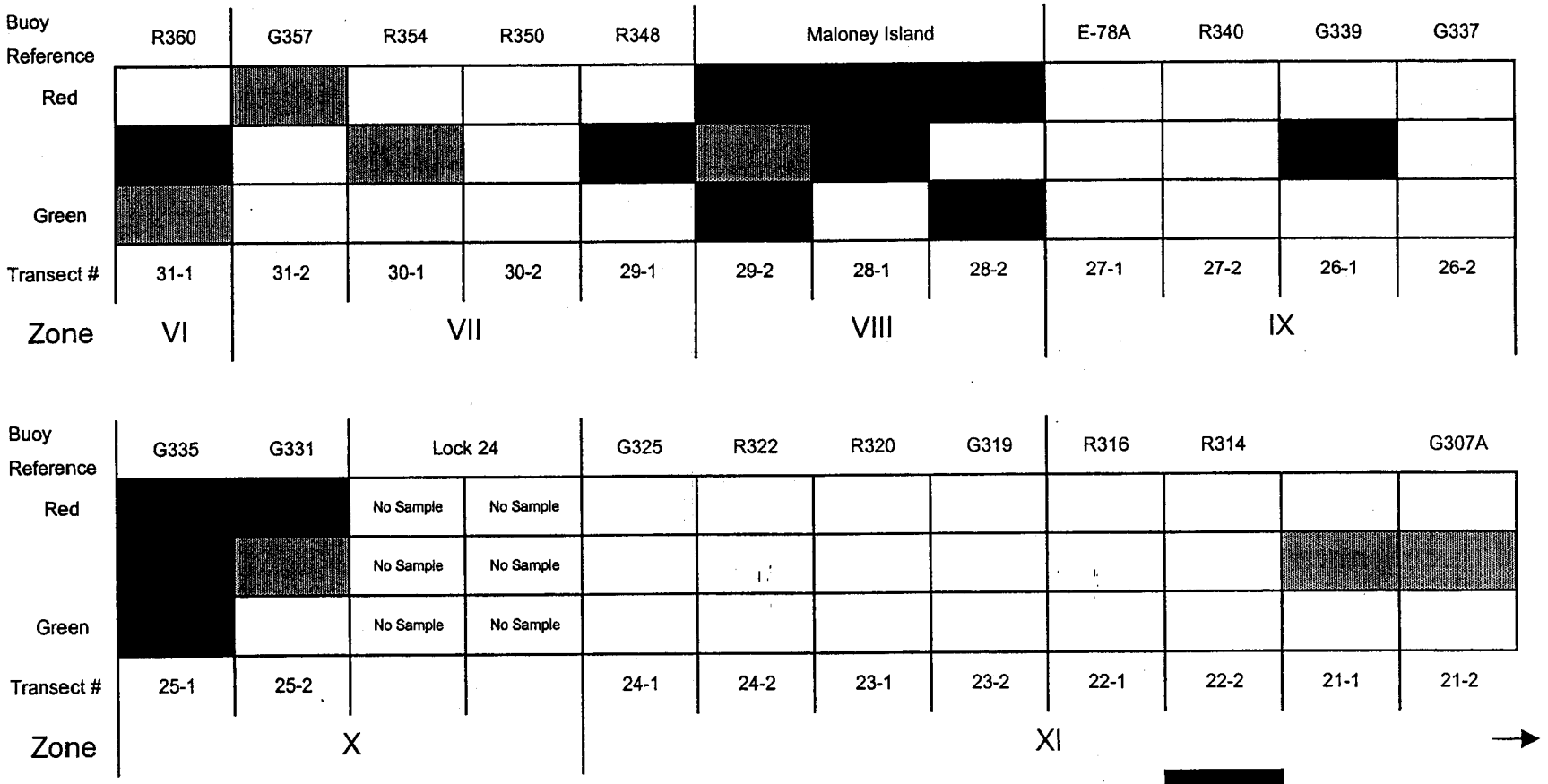
Figure 3. (cont.) Results of Habitat Assessment Survey-Habitat Type-Seneca River-1999



-HARD

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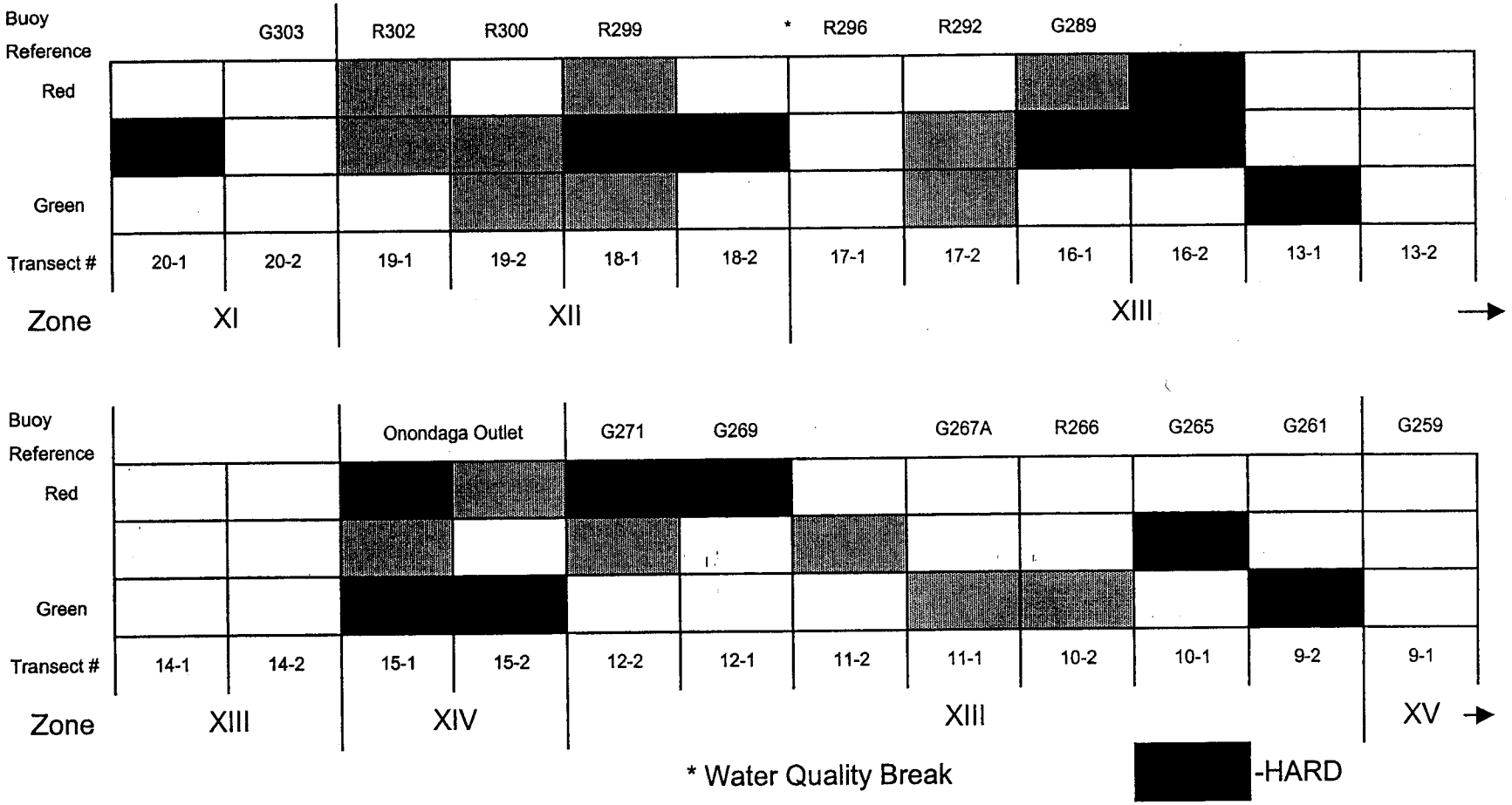

* Water Quality Break

-HARD

-SAND/GRAVEL

-SOFT/MUCK

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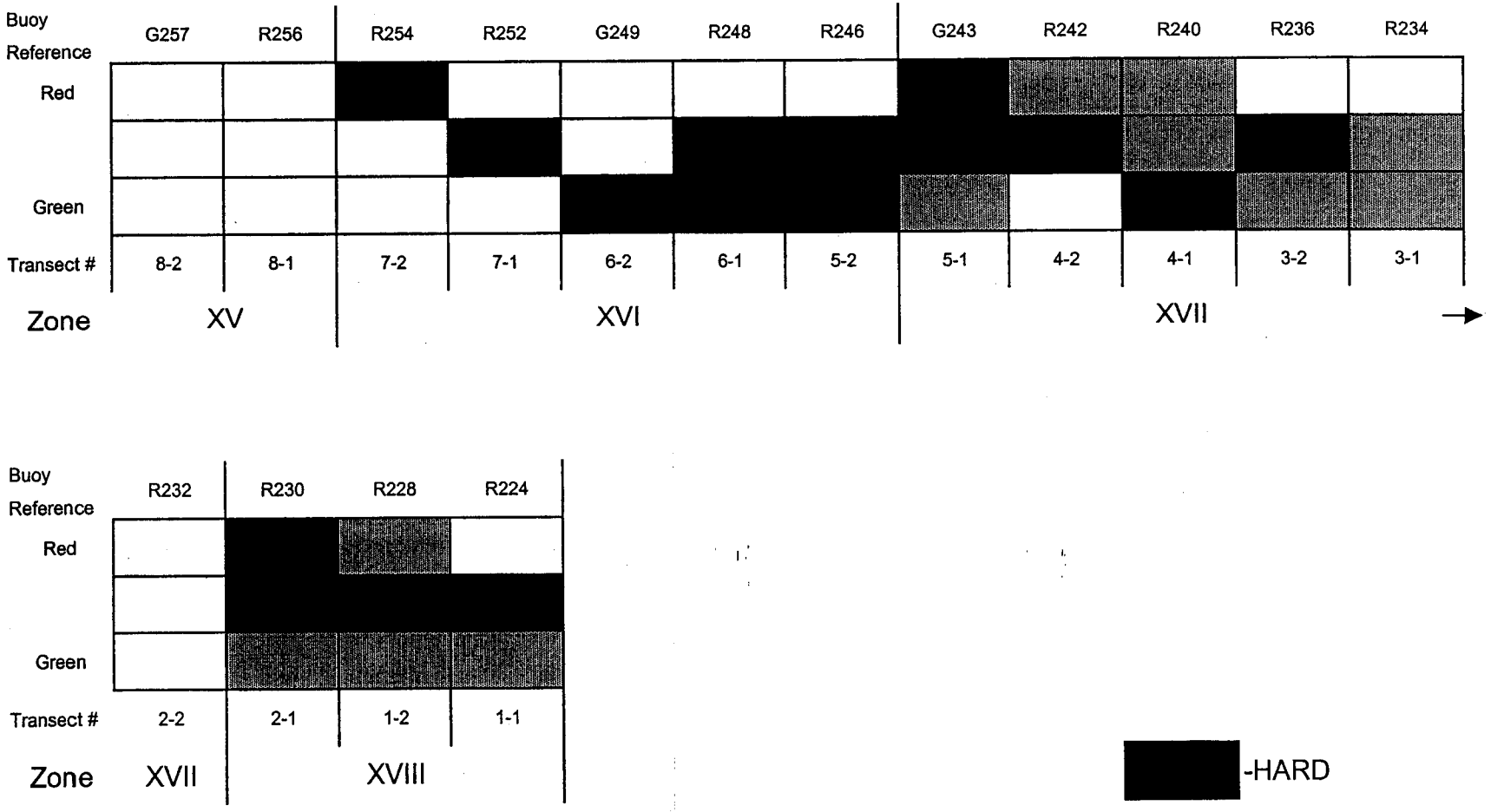

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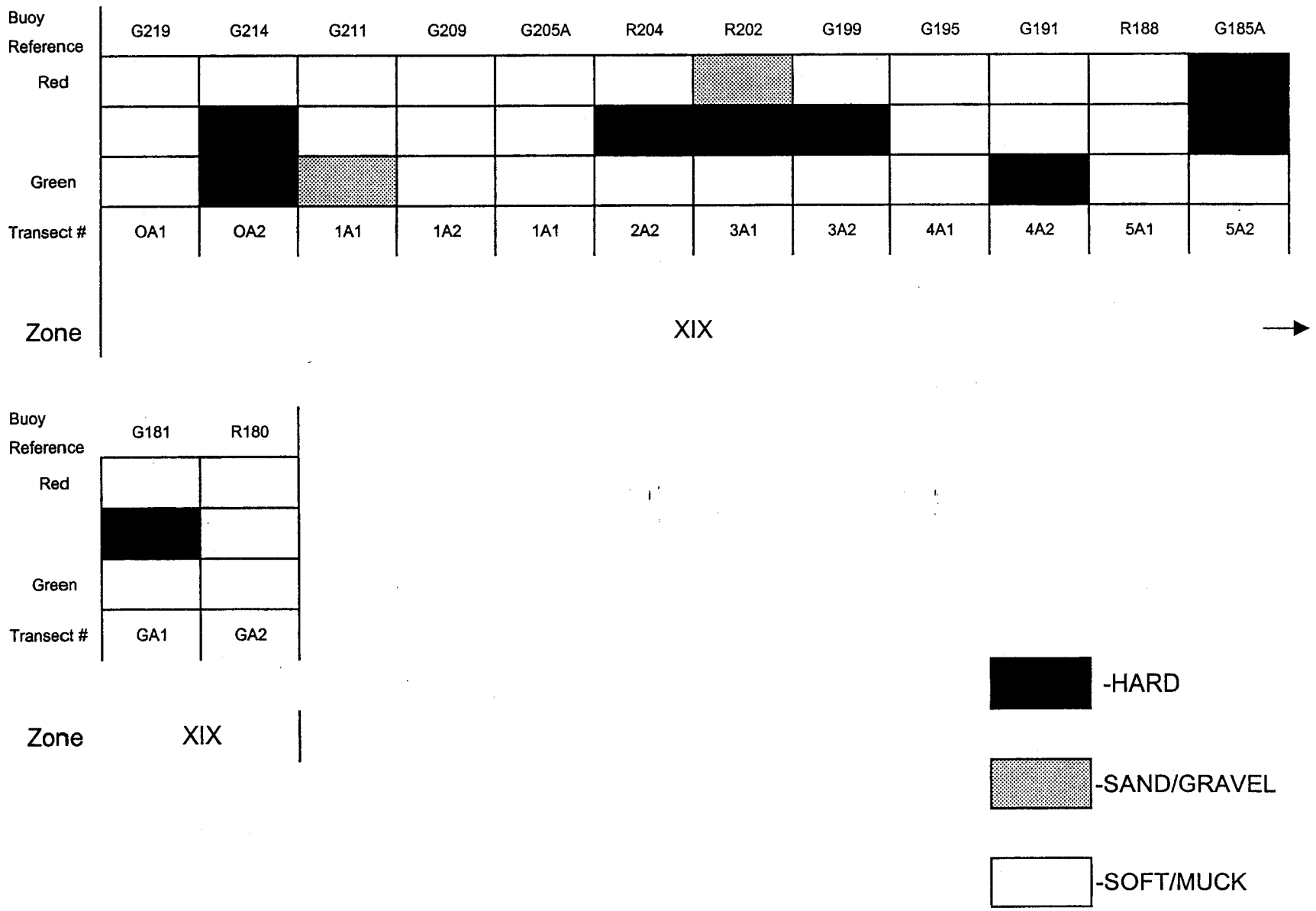

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Figure 4. Results of Habitat Assessment Survey-Zebra Mussel Densities-1999

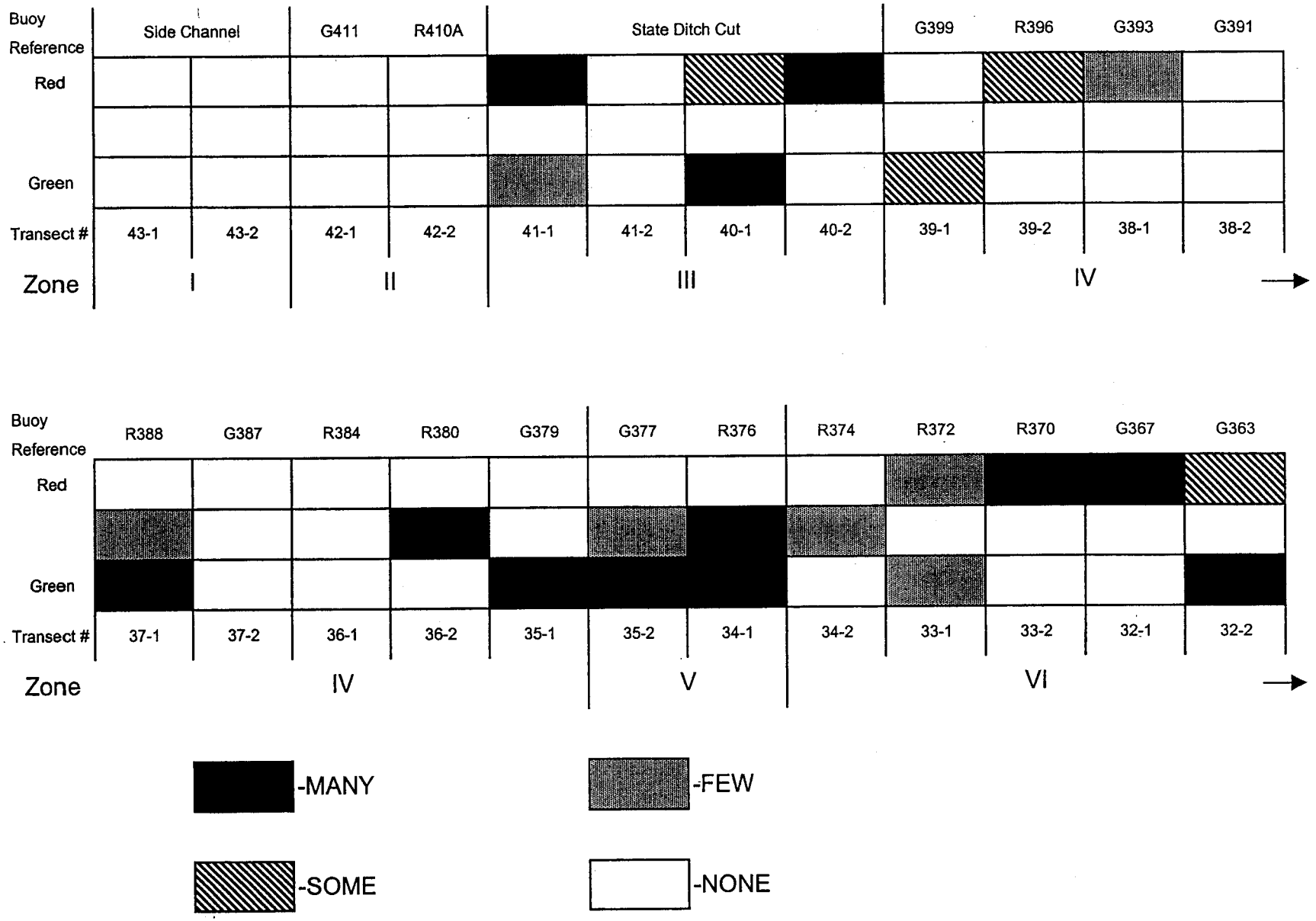

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Figure 4. (cont.) Results of Habitat Assessment Survey-Zebra Mussel Densities-1999

Buoy Reference	R360	G357	R354	R350	R348	Maloney Island			E-78A	R340	G399	G337
Red									*		*	
Green	*		*				*					*
Transect #	31-1	31-2	30-1	30-2	29-1	29-2	28-1	28-2	27-1	27-2	26-1	26-2
Zone	VI	VII				VIII			IX			

Buoy Reference	G335	G331	Lock 24		G325	R325	R320	R319	R316	R314		G307A
Red							*					
Green												
Transect #	25-1	25-2			24-1	24-2	23-1	23-2	22-1	22-2	21-1	21-2
Zone	X				XI							

-MANY

-FEW

-SOME

-NONE

*- ON VEGETATION ONLY

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Figure 4. (cont.) Results of Habitat Assessment Survey-Zebra Mussel Densities-1999

Buoy Reference		G303	R302	R300	R299	R298 +	R296	R292	G289	G287		
Red			*									
Green	*	*	*		*		*					
Transect #	20-1	20-2	19-1	19-2	18-1	18-2	17-1	17-2	16-1	16-2	13-1	13-2
Zone	XI		XII				XIII					→

Buoy Reference			Onondaga Outlet		G271	G269		G267A	R266	G265	G261	G259
Red												
Green												
Transect #	14-1	14-2	15-1	15-2	12-2	12-1	11-2	11-1	10-2	10-1	9-2	9-1
Zone	XIII		XIV				XIII					XV →

-MANY

-FEW

+ Water Quality Break

-SOME

-NONE

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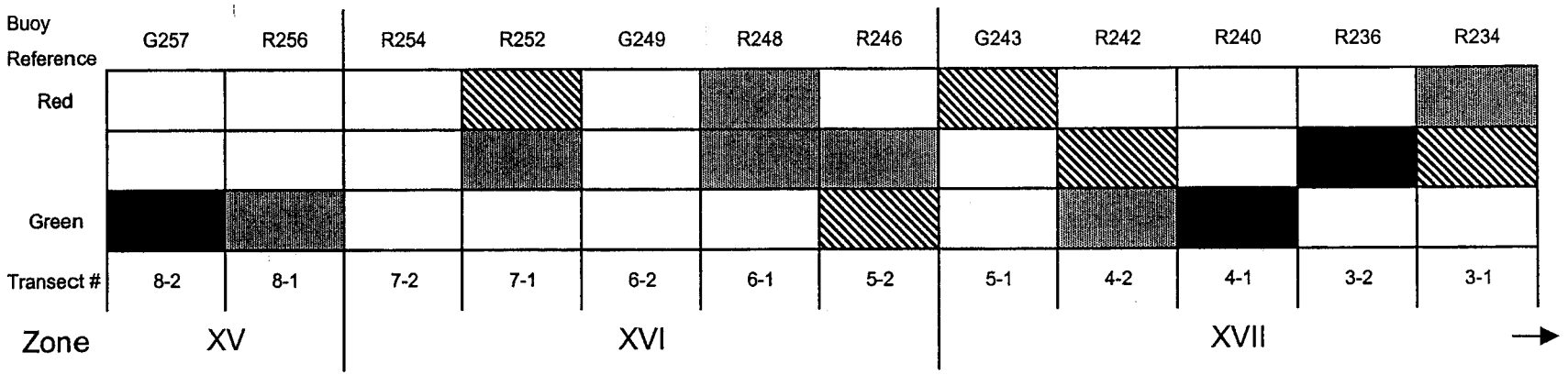
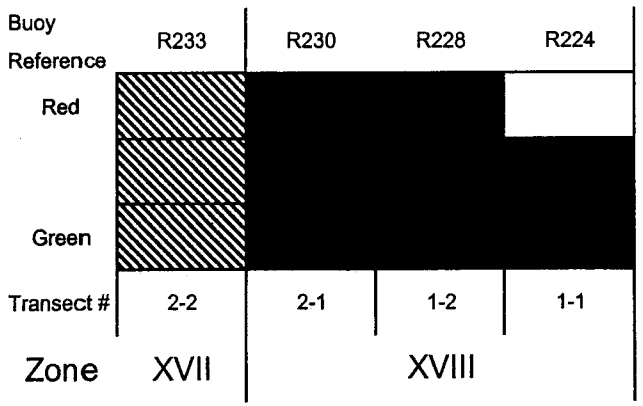
Figure 4. (cont.) Results of Habitat Assessment Survey-Zebra Mussel Densities-1999





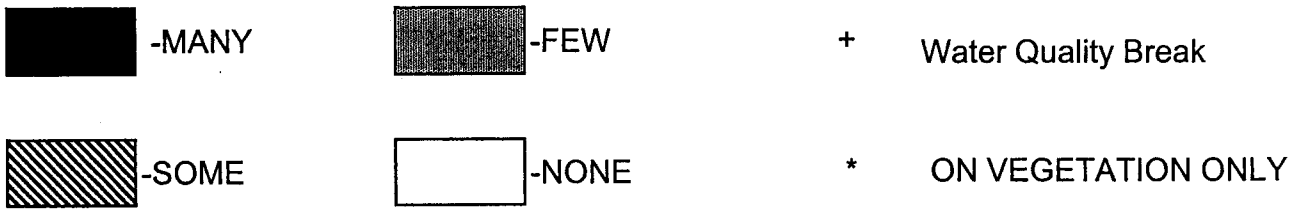


Figure 4. (cont.) Results of Habitat Assessment Survey-Zebra Mussel Densities-1999

Buoy Reference	G219	R214	G211	G209	G205A	R204	R202	G199	G195	G191	R188	G185A
Red												
Green												
Transect #	OA1	OA2	1A1	1A2	2A1	2A2	3A1	3A2	4A1	4A2	5A1	5A2
Zone	XIX											

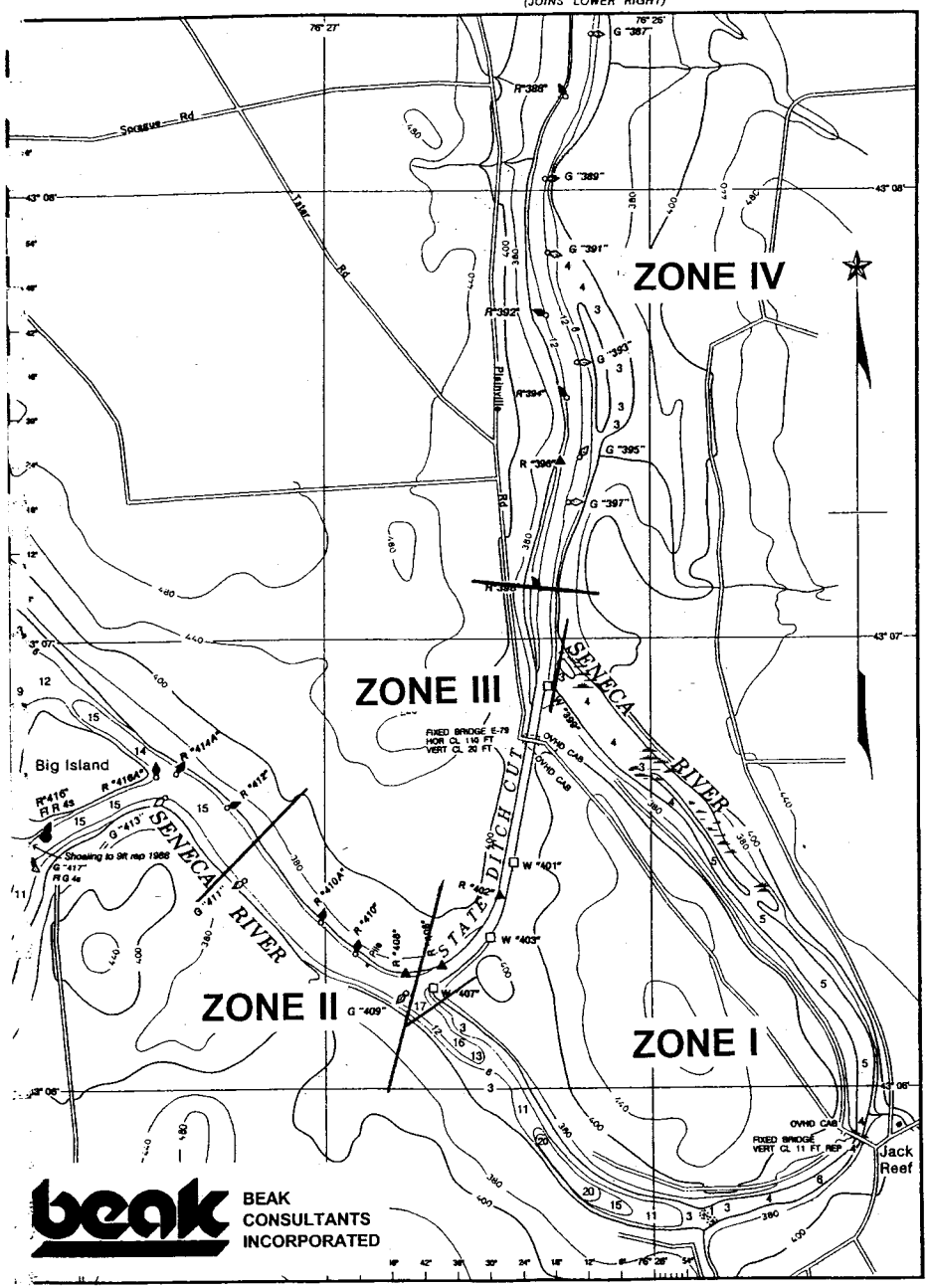
Buoy Reference	G181	G180
Red		
Green		
Transect #	25-1	25-2
Zone	XIX	

-MANY

-FEW

-SOME

-NONE



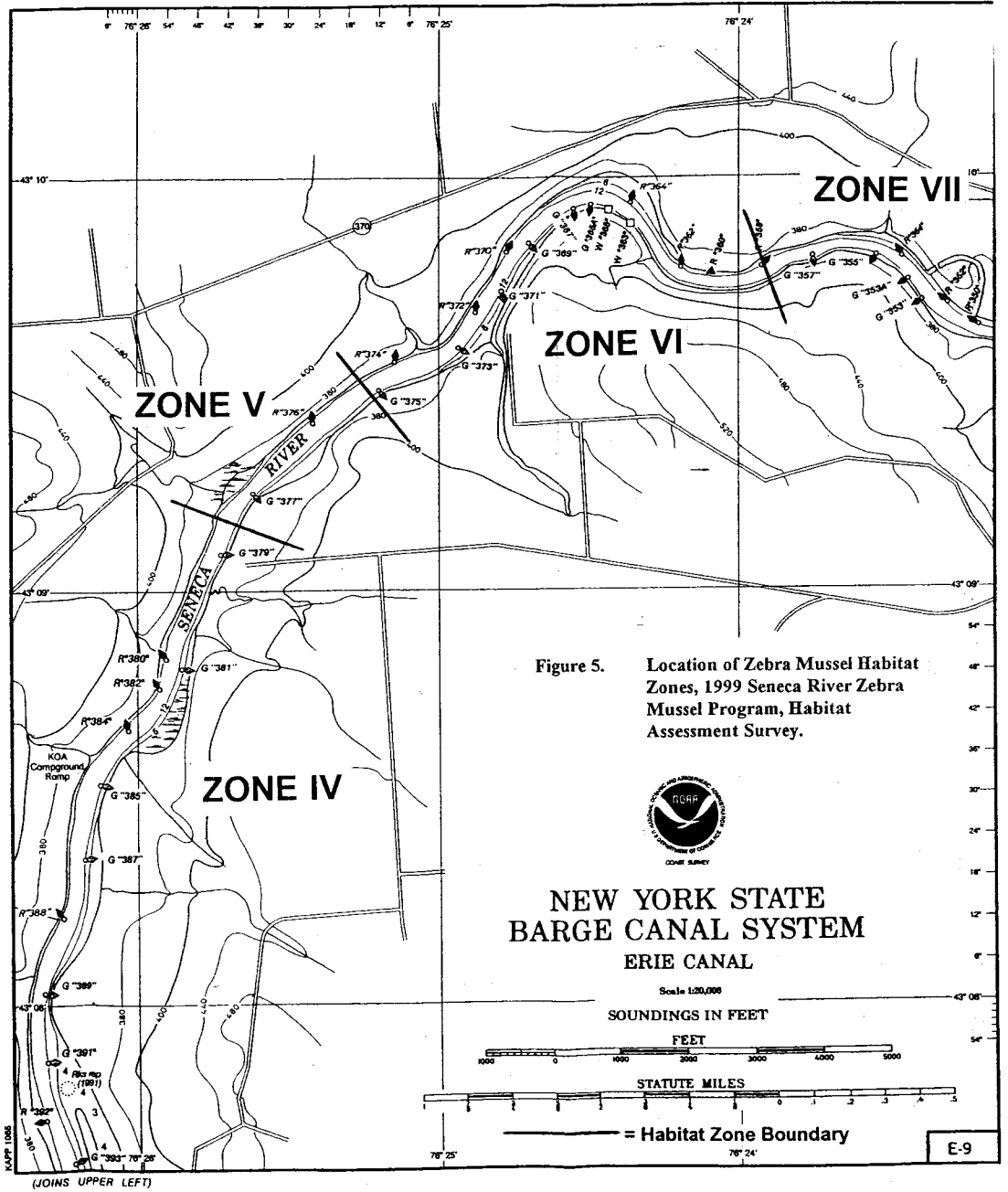
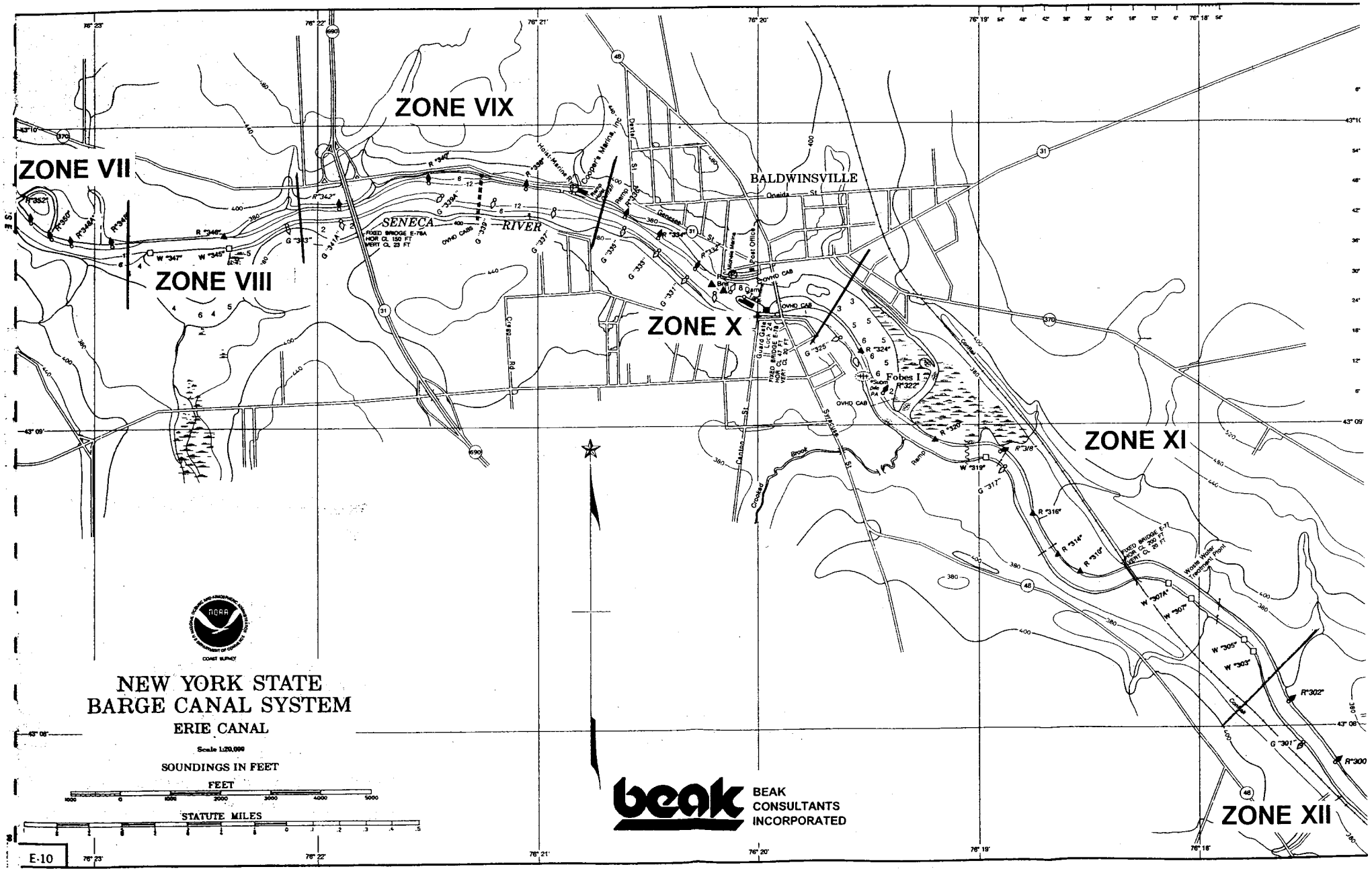


Figure 5. Location of Zebra Mussel Habitat Zones, 1999 Seneca River Zebra Mussel Program, Habitat Assessment Survey.


ZONE VIX
ZONE VII
ZONE VIII
ZONE X
ZONE XI
ZONE XII
BALDWINSVILLE
SENECA RIVER
Fobes I
NEW YORK STATE
BARGE CANAL SYSTEM
ERIE CANAL
Scale 1:20,000
SOUNDINGS IN FEET
FEET
STATUTE MILES
BEAK
CONSULTANTS
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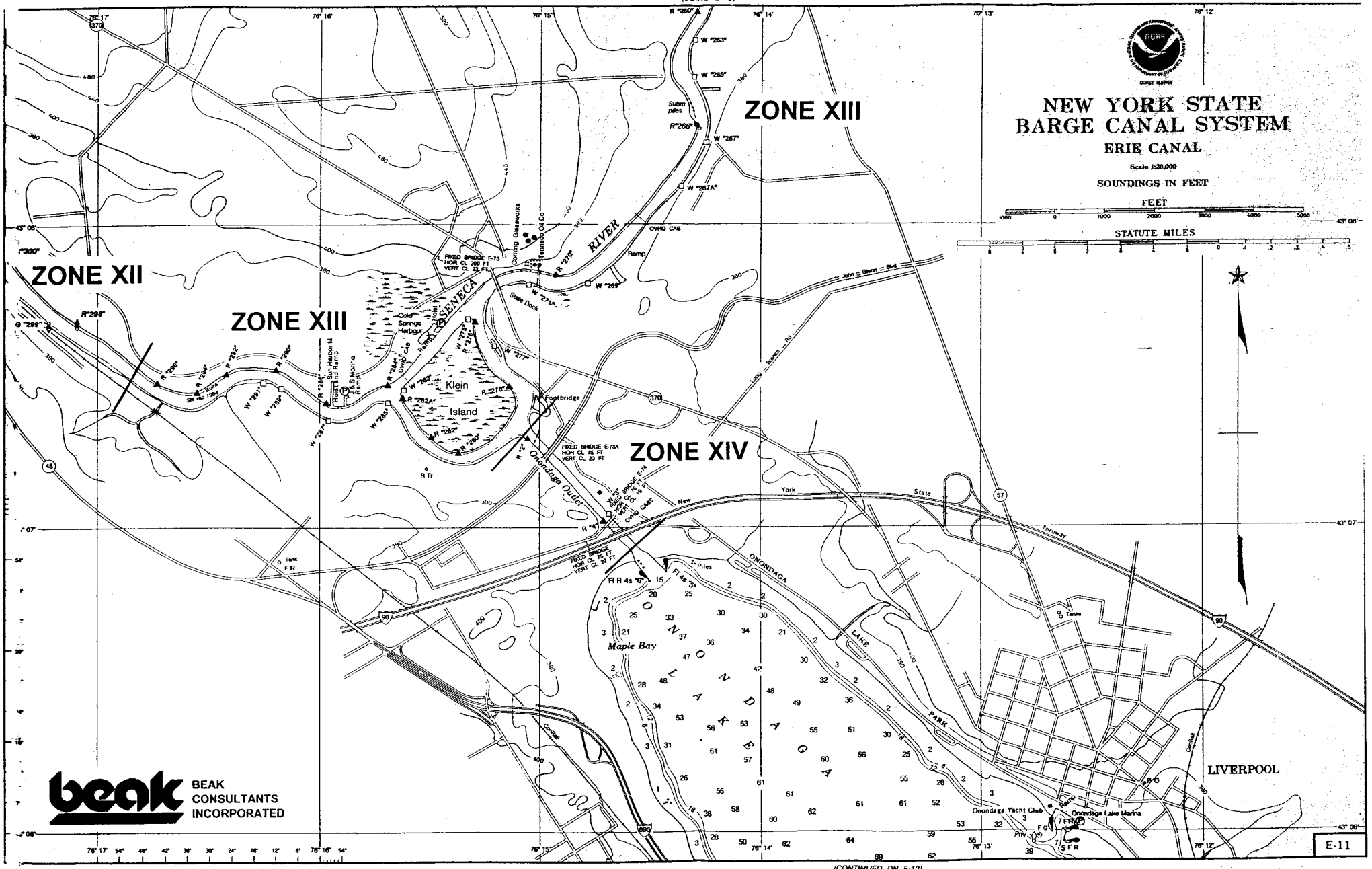
14786 12th Ed. May 23/08



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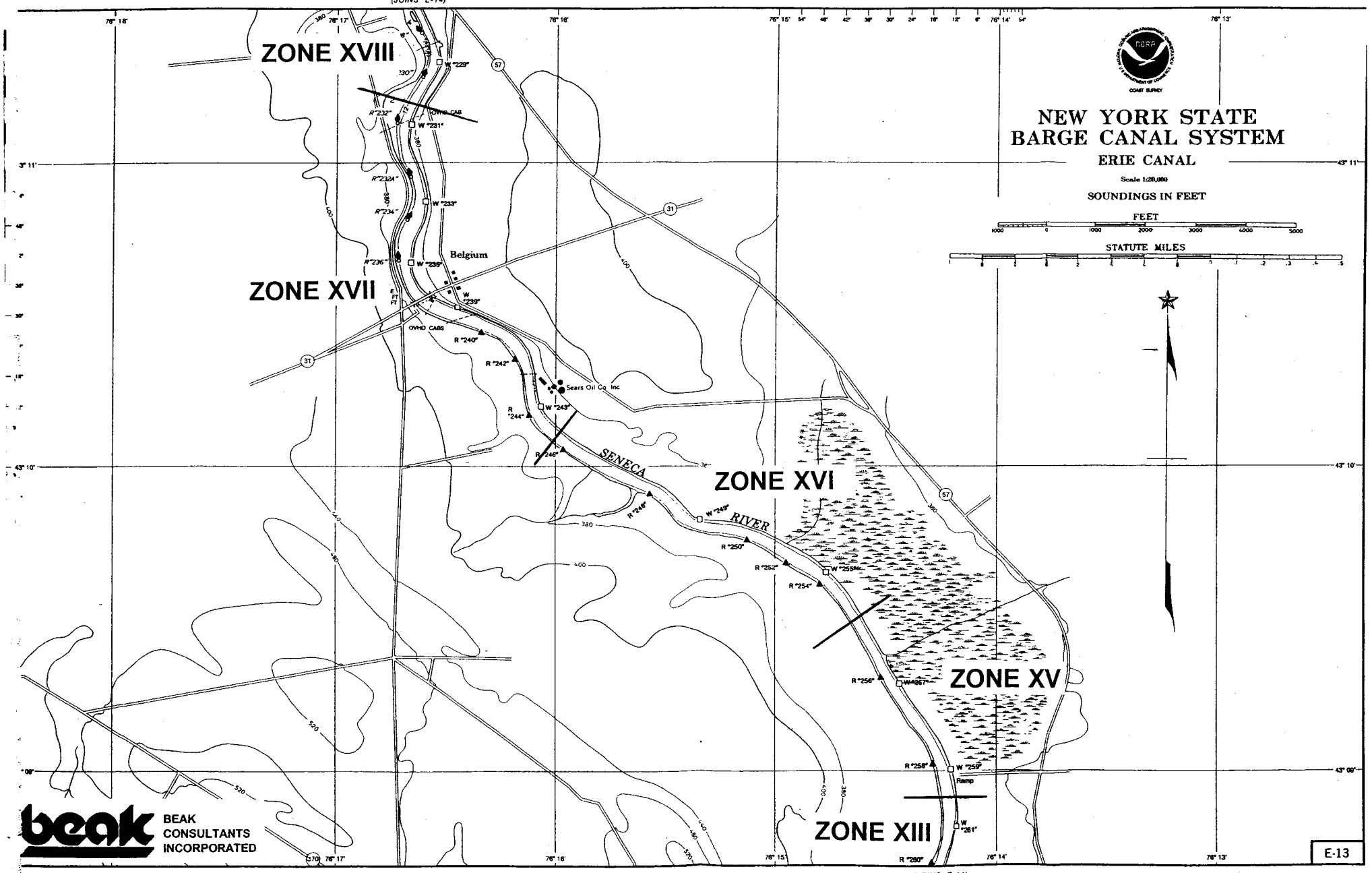
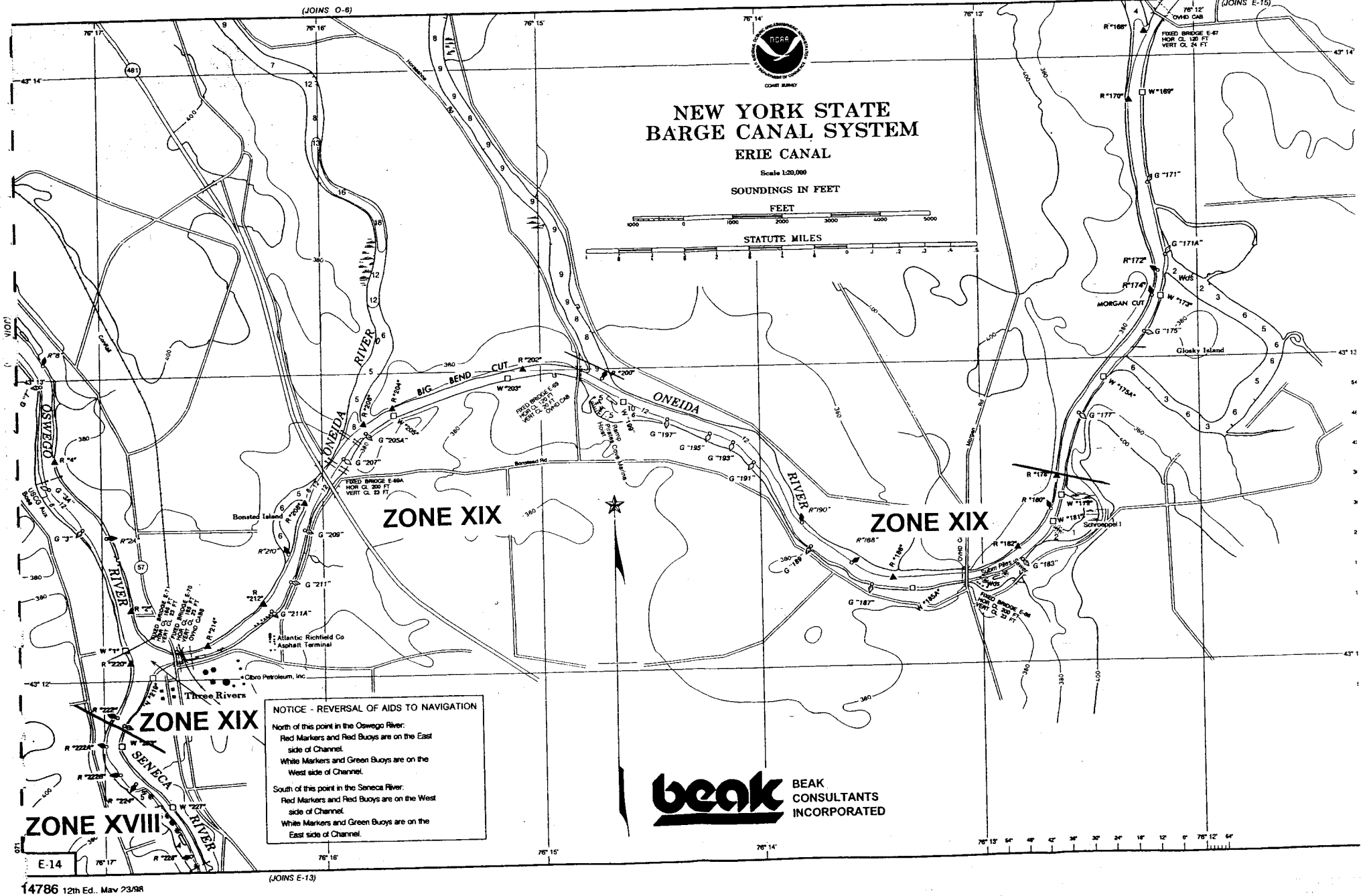

NEW YORK STATE
BARGE CANAL SYSTEM
ERIE CANAL
Scale 1:20,000
SOUNDINGS IN FEET
FEET
STATUTE MILES
ZONE XVIII
ZONE XVII
ZONE XVI
ZONE XV
ZONE XIII
Belgium
Sears Oil Co. Inc
SENECA
RIVER
OVHD CABS
Ramp
(JOINS E-14)
(JOINS E-11)
BEAK
CONSULTANTS
INCORPORATED
E-13



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14786 12th Ed., May 23/98

Figure 6. Length Frequency Distribution (5mm increments) of Zebra Mussels by Habitat Zone.

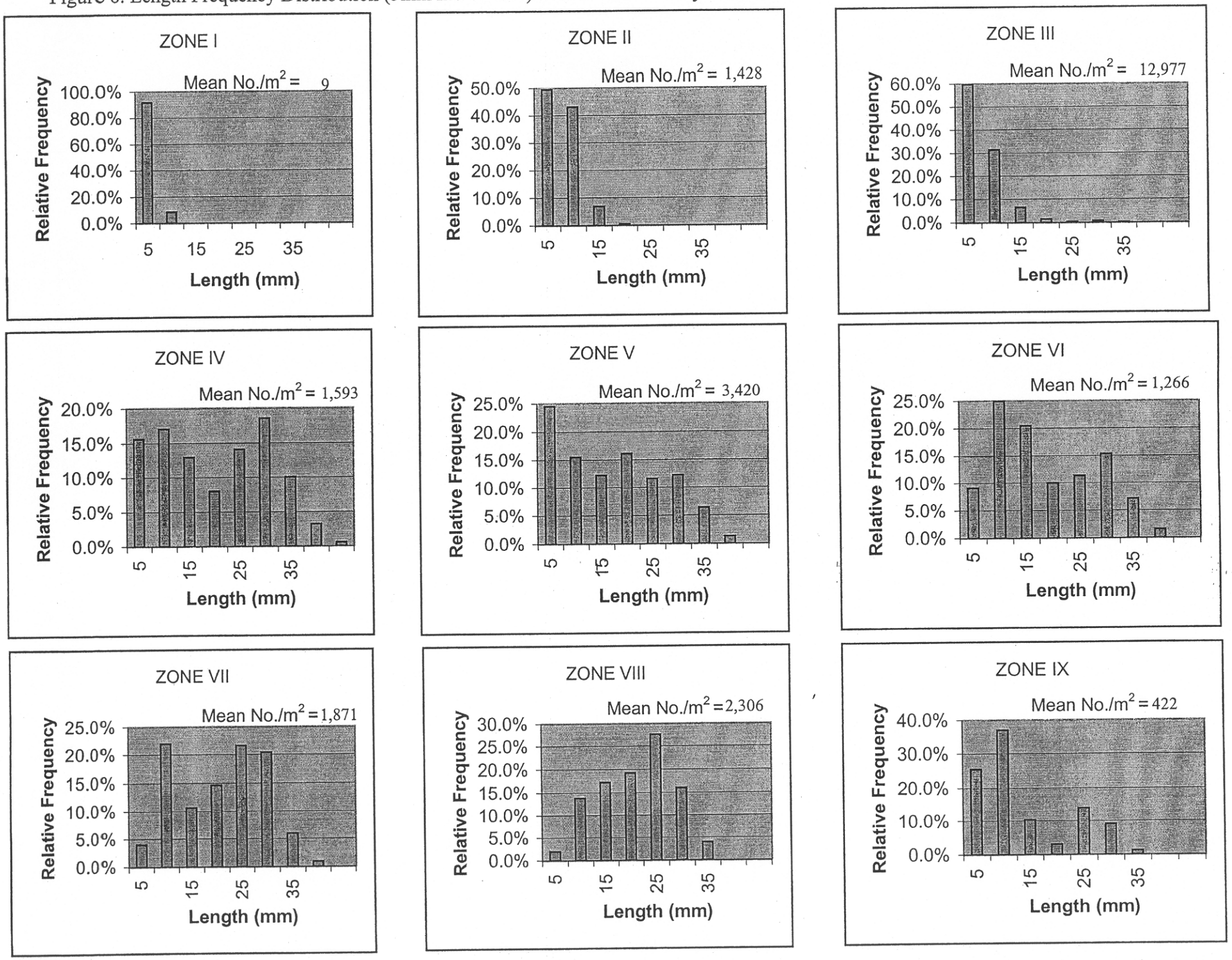


Figure 6. Length Frequency Distribution (5mm Increments) of Zebra Mussels by Habitat Zone.

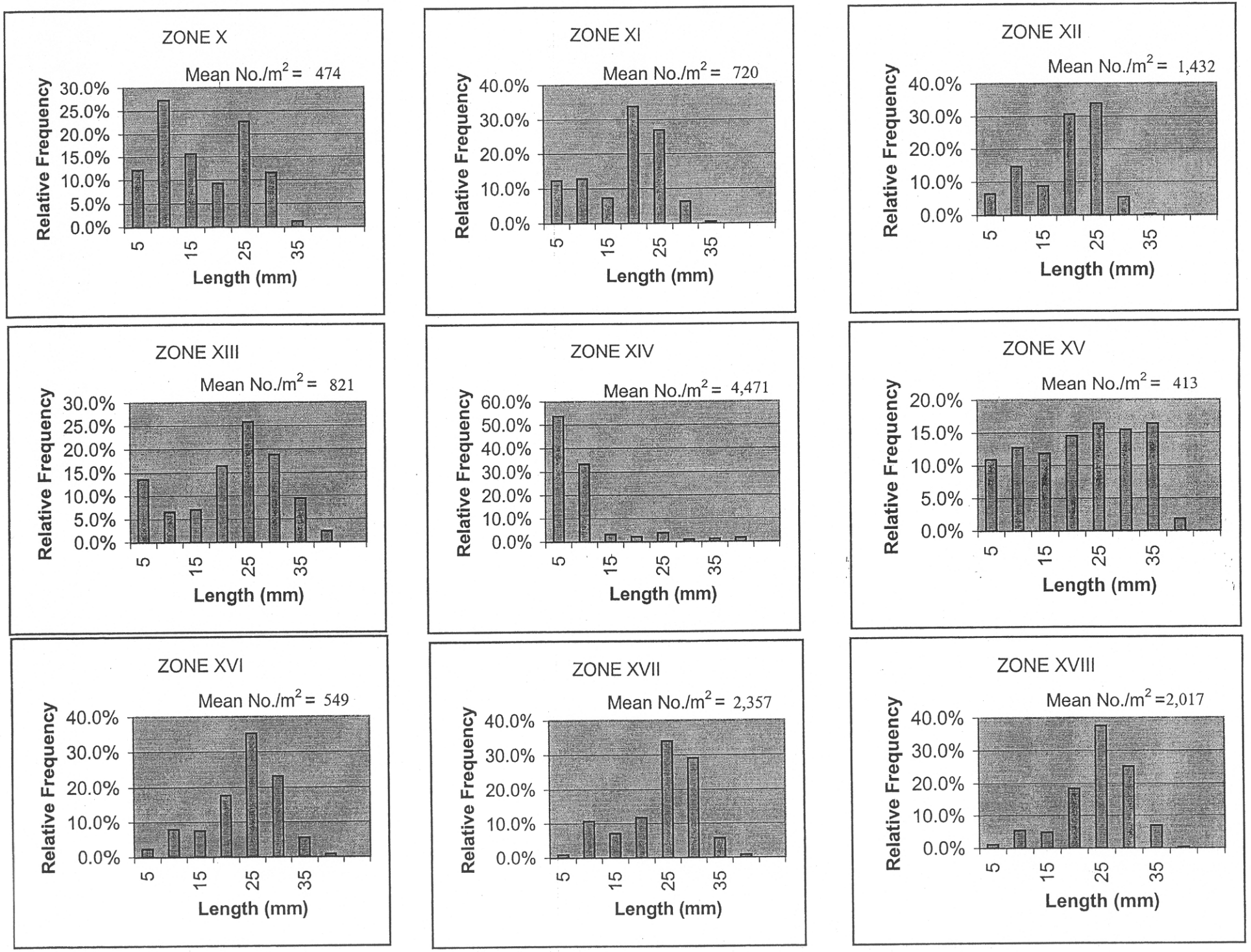


Figure 6. Length Frequency Distribution (5mm Increments) of Zebra Mussels by Habitat Zone.

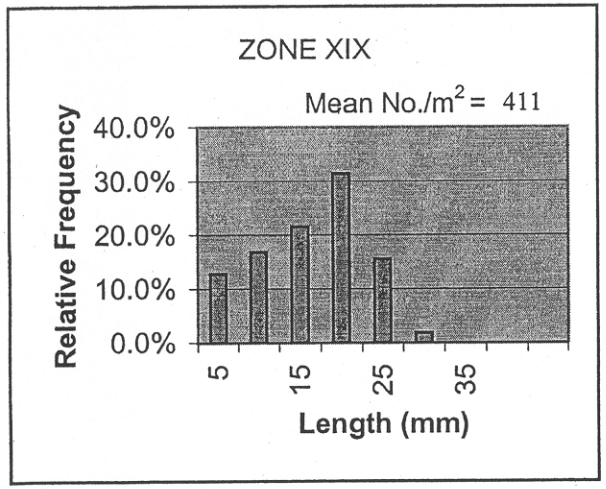
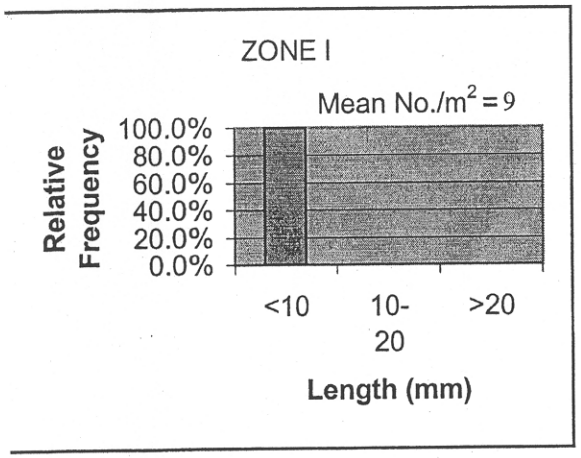
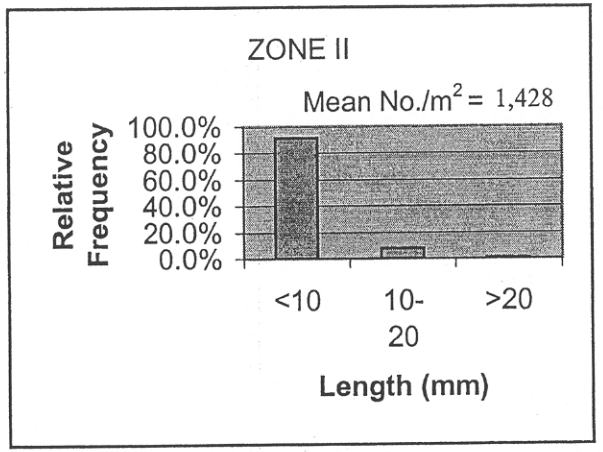
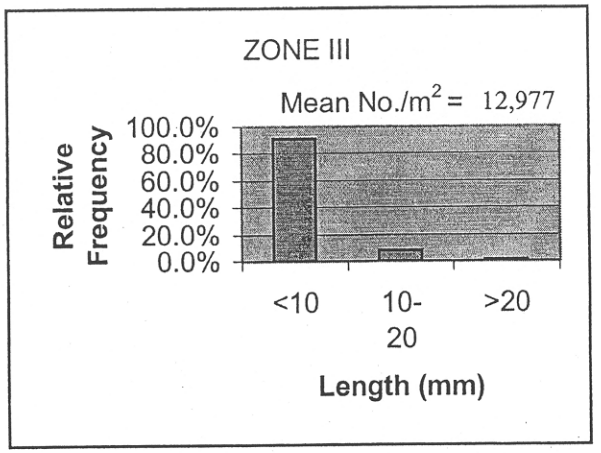
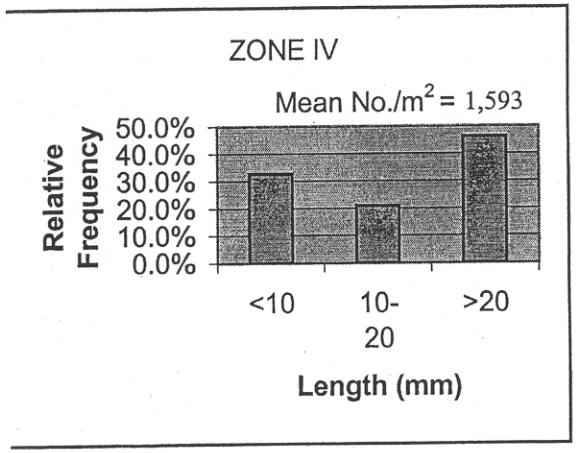


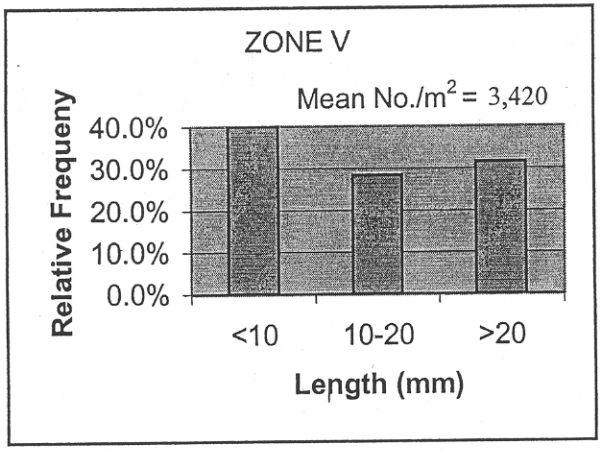
Figure 7. Length Frequency Distribution of Zebra Mussels by Length Increments Corresponding to Laboratory Studies.

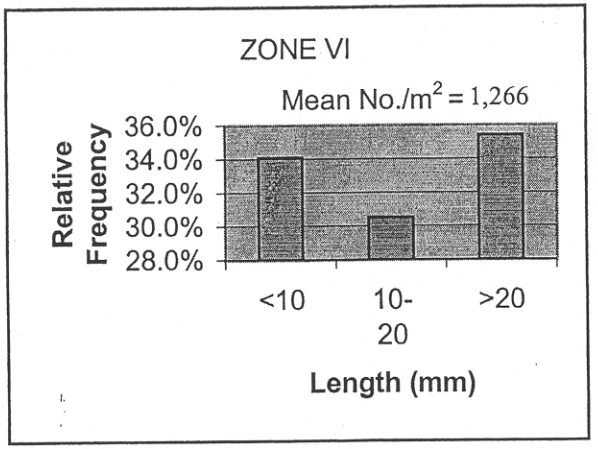


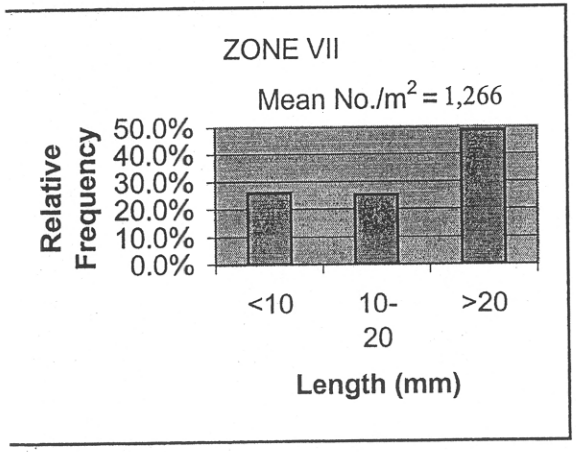


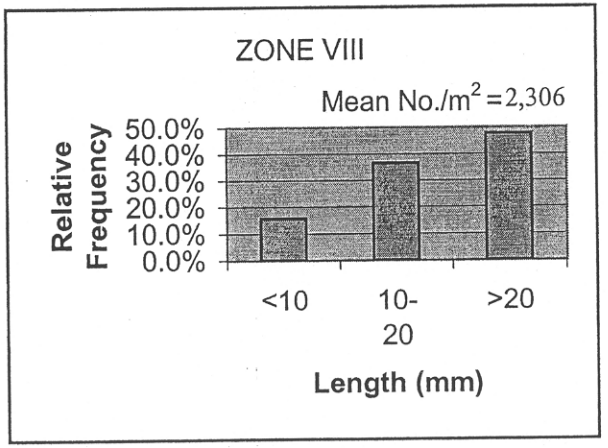












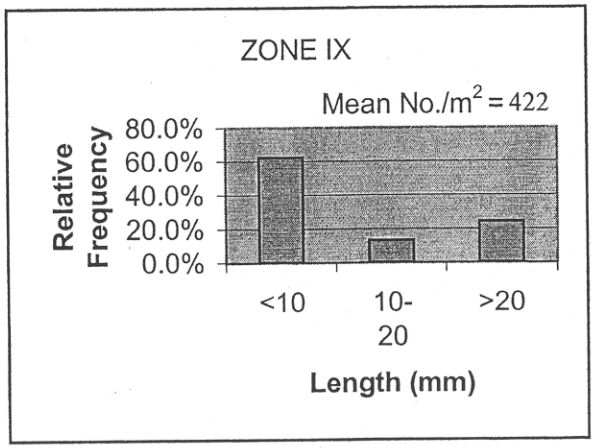
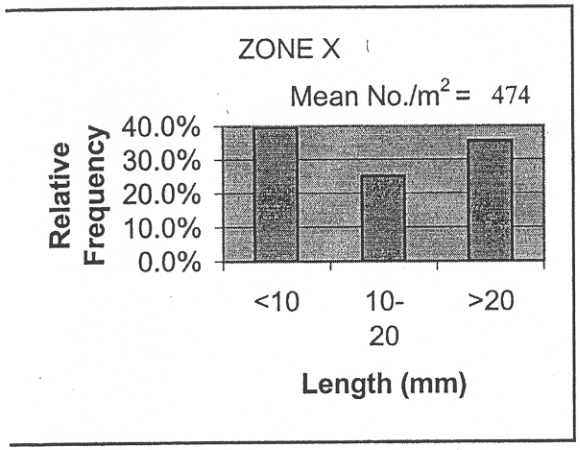
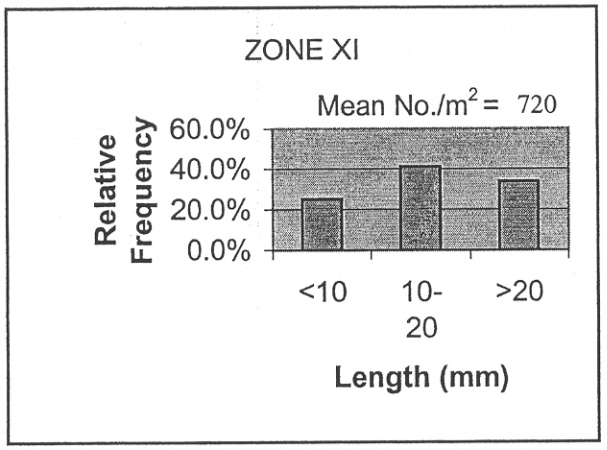
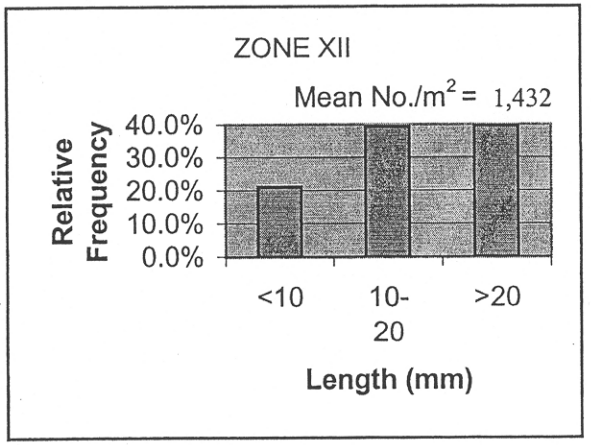
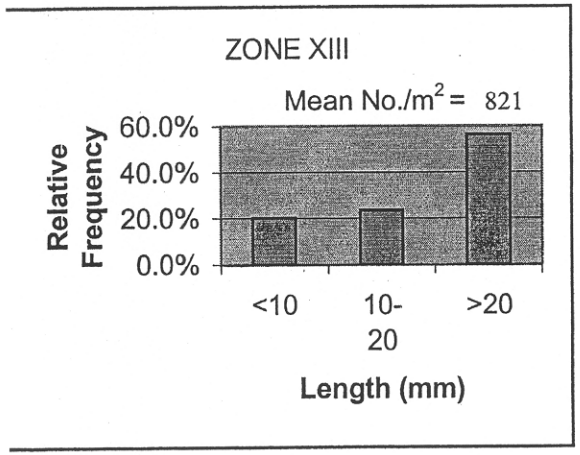


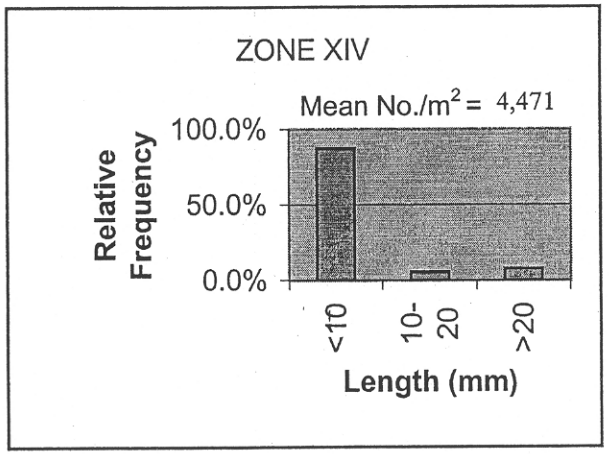
Figure 7. Length Frequency Distribution of Zebra Mussels by Length Increments Corresponding to Laboratory Studies.

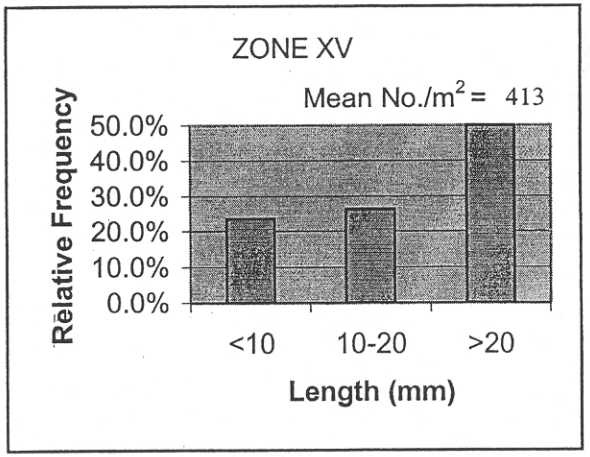


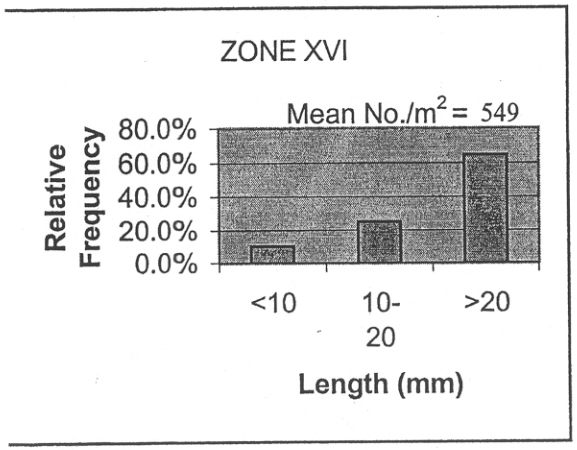


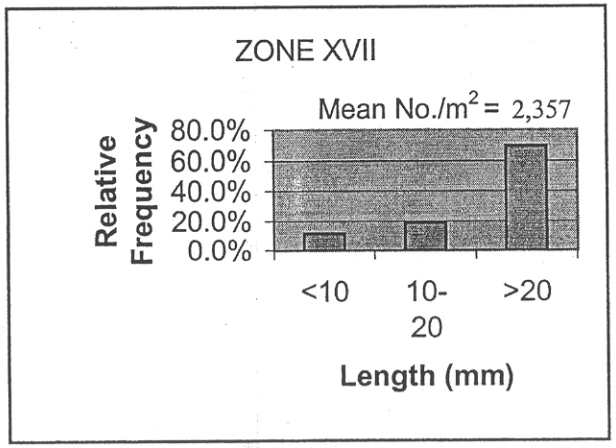












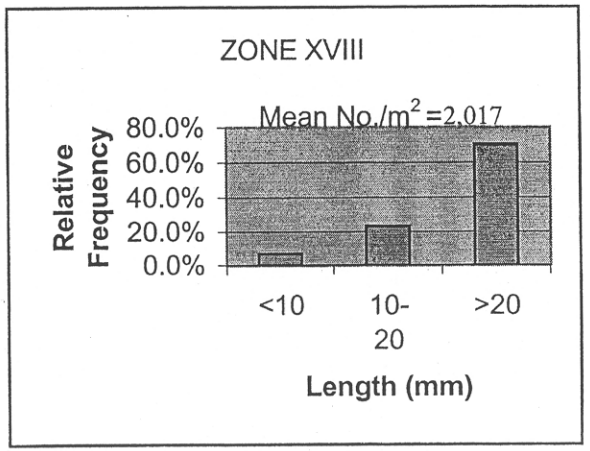


Figure 7. Length Frequency Distribution of Zebra Mussels by Length Increments Corresponding to Laboratory Studies.

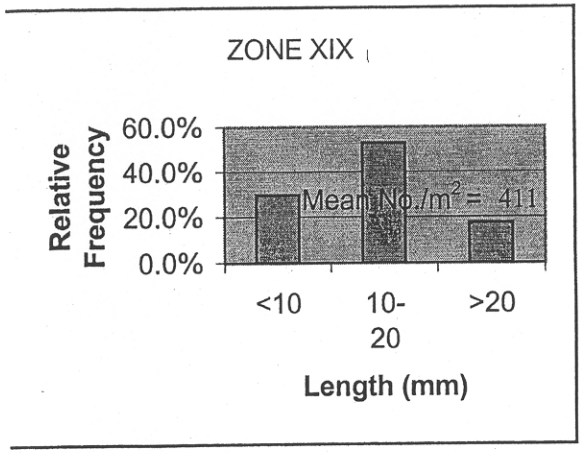


Figure 8. Mean Density and Mean Weight along the Seneca River Study Area, Dreissenid Mussel Sampling, 1999.

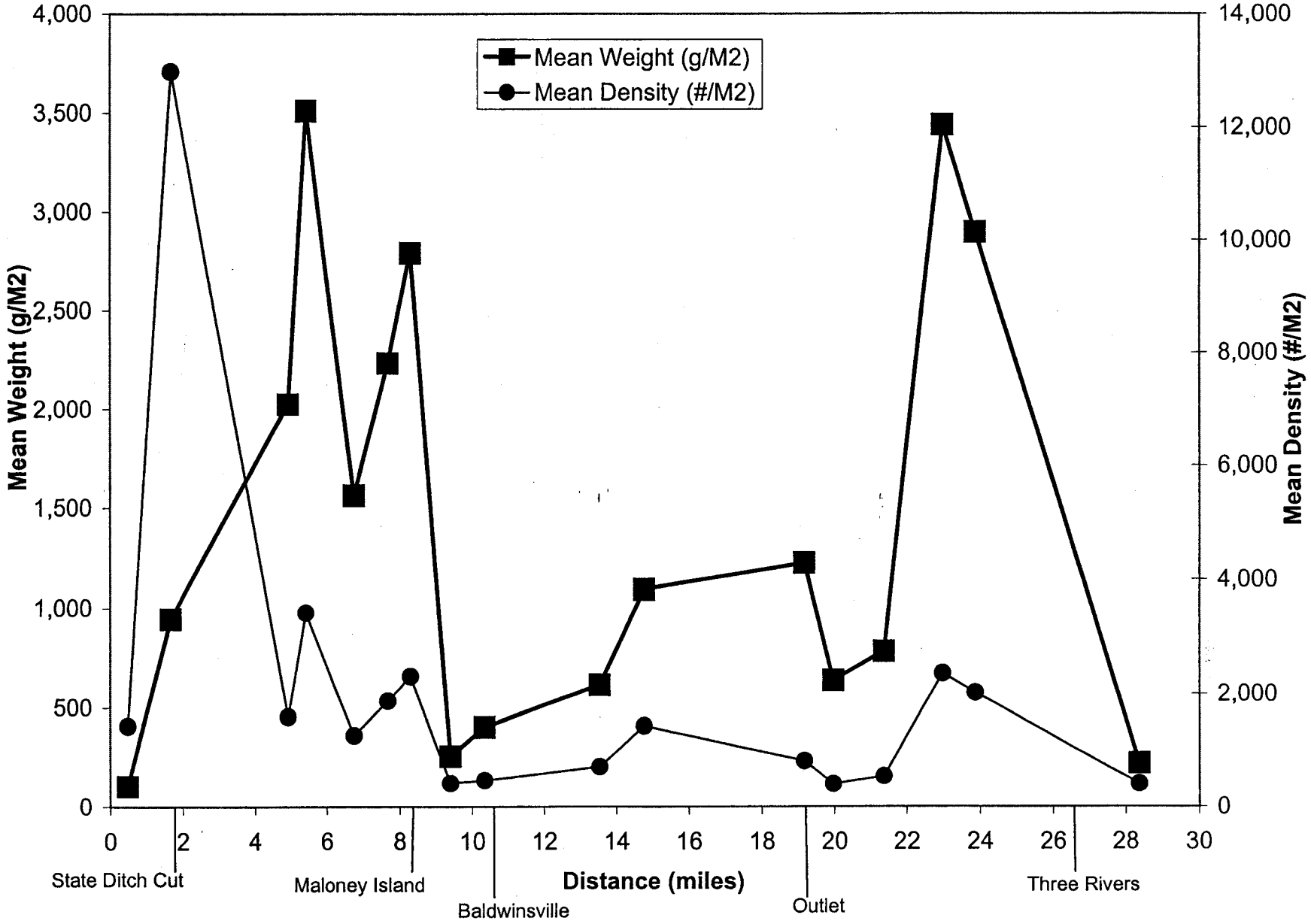


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Chart1

TABLES

TABLE 1. LENGTH, MEAN WIDTH AND ESTIMATED AREA OF HABITAT ZONES.
SENECA RIVER DREISSENID MUSSEL ASSESSMENT, 1999.

HABITAT ZONE	LENGTH(MILES)	WIDTH(MILES)	AREA(SQ MILES)	AREA(SQ METERS)
I	2.70	0.066	0.178	461,536
II	0.48	0.090	0.043	111,888
III	1.18	0.026	0.030	78,477
IV	3.25	0.050	0.163	420,873
V	0.50	0.050	0.025	64,750
VI	1.34	0.050	0.067	173,529
VII	0.93	0.040	0.037	96,348
VIII	0.62	0.030	0.019	48,172
IX	1.10	0.062	0.068	176,637
X	0.94	0.024	0.023	58,534
XI	3.20	0.042	0.134	348,094
XII	1.23	0.050	0.062	159,284
XIII	4.40	0.050	0.220	569,797
XIV	0.60	0.030	0.018	46,620
XV	0.80	0.050	0.040	103,600
XVI	1.40	0.040	0.056	145,039
XVII	1.60	0.030	0.048	124,319
XVIII	0.90	0.030	0.027	69,930
XIV	4.50	0.040	0.180	466,198
TOTAL	31.67	0.850	26.910	3,723,625

TABLE 2. SENECA RIVER ZEBRA MUSSEL HABITAT ASSESSMENT, WATER QUALITY RESULTS,1999.

SAMPLING ZONE	DATE	TEMP(C)	SP. COND	VELOCITY(FPS)	pH	DO	SECCHI(FT)	DEPTH(M)
43	Sep-99	19.16	0.784	0.96	8.52	11.5	4.0	1.1
42	Sep-99	18.39	0.780	1.26	7.86	7.29	4.0	4.9
41	Sep-99	18.47	0.779	0.65	7.90	7.96	4.0	3.6
40	Sep-99	18.78	0.779	0.67	8.08	9.04	4.0	3.2
39	Sep-99	19.00	0.783	0.79	8.20	9.79	4.0	2.0
38	Sep-99	18.95	0.783	0.86	8.16	9.42	4.0	3.0
37	Sep-99	19.07	0.781	0.86	8.14	9.34	4.0	1.9
36	Sep-99	19.12	0.782	0.90	8.08	9.23	4.0	3.2
35	Sep-99	19.23	0.778	0.90	8.08	9.20	4.0	3.5
34	Sep-99	19.11	0.779	0.79	7.95	8.54	4.0	4.0
33	Sep-99	19.23	0.780	0.76	8.02	9.14	3.0	3.0
32	Sep-99	19.95	0.780	0.52	7.88	8.34	4.5	3.6
31	Sep-99	19.04	0.779	0.58	7.89	8.42	—	2.9
30	Sep-99	19.02	0.779	0.66	7.86	8.36	4.0	3.1
29	Sep-99	19.00	0.777	1.52	7.81	8.06	4.5	1.8
28	Sep-99	18.97	0.779	0.46	7.78	7.91	5.0	3.7
27	Sep-99	18.68	0.784	0.73	7.70	7.21	4.5	4.0
26	Sep-99	20.00	0.780	0.61	8.73	9.72	4.5	0.7
25	Sep-99	18.64	0.785	0.31	7.76	7.55	5.0	3.3
24	Sep-99	19.18	0.787	0.44	7.76	7.95	7.0	2.5
23	Sep-99	18.88	0.788	1.08	7.71	7.5	5.5	5.5
22	Sep-99	18.87	0.782	0.66	7.71	7.46	5.0	4.9
21	Sep-99	18.66	0.787	0.61	7.69	7.21	6.0	3.2
20	Sep-99	18.69	0.787	0.67	7.67	7.29	6.5	4.6
19	Sep-99	18.82	0.784	0.84	7.72	7.63	7.0	2.8
18	Sep-99	18.18	0.786	0.72	7.76	7.83	6.5	3.9
17	Sep-99	18.41	2.06	0.55	7.63	6.6	7.0	5.4
16	Sep-99	18.54	2.14	0.49	7.7	6.99	7.5	6.1
15	Sep-99	19.24	1.96	0.31	7.91	9.14	7.0	3.7
14	Sep-99	19.54	2.23	0.00	7.97	9.87	8.0	4.4
13	Sep-99	18.68	0.909	0.62	7.68	7.63	7.5	3.1
12	Sep-99	18.29	2.14	0.00	7.52	5.16	8.0	8.4
11	Sep-99	18.46	2.13	0.00	7.61	5.96	7.0	6.5
10	Sep-99	17.88	2.12	0.00	7.47	4.43	8.0	7.2
9	Sep-99	19.95	2.13	0.76	7.44	3.76	6.5	8.9
8	Sep-99	18.07	2.03	0.00	7.47	4.75	8.0	7.3
7	Sep-99	18.05	1.91	0.63	7.47	4.95	8.0	6.3
6	Sep-99	18.00	1.83	0.93	7.42	4.48	7.0	6.0
5	Sep-99	18.00	1.80	0.96	7.38	4.01	8.0	5.3
4	Sep-99	18.03	1.71	1.09	7.39	4.30	—	5.4
3	Sep-99	18.53	1.07	1.08	7.57	6.90	—	3.6
2	Sep-99	18.59	1.01	1.19	7.51	6.07	—	3.4
1	Sep-99	18.59	1.12	0.00	7.46	6.37	—	3.8
0A	Nov-99	8.01	0.34	–	7.95	10.59	—	4.7
1A	Nov-99	7.79	0.34	–	7.94	10.53	—	5.0
2A	Nov-99	8.07	0.34	–	8.05	10.83	—	4.7
3A	Nov-99	8.05	0.34	–	8.09	10.78	—	4.8
4A	Nov-99	8.01	0.34	–	8.11	11.18	—	5.1
5A	Nov-99	7.92	0.34	–	8.00	10.88	—	4.8
6A	Nov-99	7.83	0.33	–	8.06	10.94	—	4.7

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Table 3. Density, Weight and Phi Values by Sample and Habitat Zone, Seneca River Dreissenid Assessment Program, 1999.

HABITAT ZONE	TRANSECT	SAMPLE	SAMPLE MEDIAN PARTICLE SIZE	ZONE MEAN PARTICLE SIZE	TOTAL WEIGHT g/M^2	MEAN WEIGHT g/M^2	TOTAL NUMBER PER M2	MEAN NUMBER PER M^2 ZONE
I	A	R	-4.40	**5.18**	5.93	**0.66**	79.04	**9**
I	A	M	6.50		0.00		0.00	
I	A	G	6.50		0.00	**Standard**	0.00	**Standard**
I	B	R	6.50		0.00	**Deviation**	0.00	**Deviation**
I	B	M	6.50		0.00	**2.00**	0.00	**26**
I	B	G	6.50		0.00		0.00	
I	C	R	5.55		0.00		0.00	
I	C	M	6.50		0.00		0.00	
I	C	G	6.50		0.00		0.00	
II	A	R	-3.70	**1.06**	217.36	**106.70**	3,344.00	**1,428**
II	A	M	-0.50		49.40		138.32	
II	A	G	6.50		0.00		0.00	
II	B	R	-0.50		0.00	**Standard**	0.00	**Standard**
II	B	M	5.55		0.00	**Deviation**	0.00	**Deviation**
II	B	G	5.55		0.00	**231.00**	0.00	**3,176**
II	C	R	-5.50		0.00		0.00	
II	C	M	6.50		0.00		0.00	
II	C	G	-4.40		693.58		9,372.65	
III	A	R	-7.36	**-7.22**	2,240.78	**946.72**	43,936.94	**12,977**
III	A	M	-7.36		942.55		32,501.79	
III	A	G	-7.36		171.91		2,728.76	
III	B	R	-7.36		17.78	**Standard**	1,323.92	**Standard**
III	B	M	-7.36		2,013.54	**Deviation**	21,651.01	**Deviation**
III	B	G	-7.36		628.37	**1,013.00**	6,283.68	**15,920**
III	C	R	-8.23		43.47		1,659.84	
III	C	M	-8.23		2,426.53		5,861.18	
III	C	G	-4.39		35.57		849.68	
IV	A	R	-3.70	**-0.91**	73.11	**2,024.68**	59.28	**1,593**
IV	A	M	-2.35		0.00		0.00	
IV	A	G	-4.05		1,339.73		4,684.36	
IV	B	R	-4.10		901.06		6,390.47	
IV	B	M	-3.70		1,023.57		533.52	
IV	B	G	-0.50		0.00		0.00	
IV	C	R	6.50		0.00	**Standard**	0.00	**Standard**
IV	C	M	-5.55		310.23	**Deviation**	19.76	**Deviation**
IV	C	G	0.00		11.86	**3,647.00**	39.52	**2,328**
IV	D	R	-5.50		7,914.87		4,688.90	
IV	D	M	6.50		0.00		0.00	
IV	D	G	-0.75		7,870.41		3,064.80	
IV	E	R	6.05		0.00		0.00	
IV	E	M	-2.00		10,925.30		4,416.05	
IV	E	G	-0.50		0.00		0.00	

HABITAT ZONE	TRANSECT	SAMPLE	SAMPLE MEDIAN PARTICLE SIZE	ZONE MEAN PARTICLE SIZE	TOTAL WEIGHT g/M^2	MEAN WEIGHT g/M^2	TOTAL NUMBER PER M2	MEAN NUMBER PER M^2 ZONE
V	A	R	4.25	**-0.42**	0.00	**3,510.91**	0.00	**3,420**
V	A	M	-1.50		0.00		0.00	
V	A	G	-9.97		23,957.02		25,033.46	
V	B	R	-3.00		393.22	**Standard**	98.80	**Standard**
V	B	M	4.60		0.00	**Deviation**	0.00	**Deviation**
V	B	G	6.50		0.00	**8,010.00**	0.00	**8,202**
V	C	R	-2.20		167.96		2,181.30	
V	C	M	0.50		7,080.01		3,463.80	
V	C	G	-3.00		0.00		0.00	
VI	A	R	-1.70	**-0.63**	316.16	**1,563.67**	1,007.76	**1,266**
VI	A	M	0.00		1,574.87		1,978.48	
VI	A	G	-1.85		1,958.22		1,363.44	
VI	B	R	-3.35		1,845.58	**Standard**	2,570.45	**Standard**
VI	B	M	-1.35		25.69	**Deviation**	237.12	**Deviation**
VI	B	G	-0.40		0.00	**2,601.00**	0.00	**1,352**
VI	C	R	6.05		0.00		0.00	
VI	C	M	-1.70		8,141.12		3,938.62	
VI	C	G	-1.35		211.43		296.40	
VII	A	R	-0.85	**-1.33**	2,509.52	**2,233.54**	2,036.95	**1,871**
VII	A	M	-0.50		1,778.40		1,185.60	
VII	A	G	-1.00		6,420.02		5,696.56	
VII	B	R	-3.40		800.28	**Standard**	3,008.57	**Standard**
VII	B	M	-3.40		4,821.44	**Deviation**	2,669.68	**Deviation**
VII	B	G	0.50		3,207.05	**2,241.00**	1,983.33	**1,825**
VII	C	R	-0.45		0.00		0.00	
VII	C	M	-1.35		476.22		177.84	
VII	C	G	-1.50		88.92		79.04	
VIII	A	R	6.50	**0.33**	0.00	**2,790.99**	0.00	**2,306**
VIII	A	M	-0.50		0.00		0.00	
VIII	A	G	-4.25		2,614.25		3,985.13	
VIII	B	R	-2.00		11,397.57	**Standard**	8,054.82	**Standard**
VIII	B	M	-0.50		6,983.18	**Deviation**	5,691.27	**Deviation**
VIII	B	G	0.50		0.00	**4,068.00**	0.00	**3,050**
VIII	C	R	0.50		0.00		0.00	
VIII	C	M	-2.90		4,123.91		3,021.18	
VIII	C	G	5.60		0.00		0.00	
IX	A	R	-2.00	**0.48**	0.00	**259.30**	0.00	**422**
IX	A	M	-5.80		2,223.00		2,592.19	
IX	A	G	6.05		0.00		0.00	
IX	B	R	-4.80		13.83	**Standard**	158.08	**Standard**
IX	B	M	-2.50		17.78	**Deviation**	79.04	**Deviation**
IX	B	G	6.50		0.00	**737.00**	0.00	**872**
IX	C	R	6.50		0.00		0.00	
IX	C	M	6.50		0.00		0.00	
IX	C	G	-6.15		79.04		968.24	
X	A	R	-3.20	**2.68**	2,942.26	**403.10**	2,984.04	**474**

HABITAT ZONE	TRANSECT	SAMPLE	SAMPLE MEDIAN PARTICLE SIZE	ZONE MEAN PARTICLE SIZE	TOTAL WEIGHT g/M^2	MEAN WEIGHT g/M^2	TOTAL NUMBER PER M2	MEAN NUMBER PER M^2 ZONE
X	A	M	-2.85		0.00		0.00	
X	A	G	-5.30		685.67		1,284.40	
X	B	R	3.90		0.00		0.00	
X	B	M	5.55		0.00		0.00	
X	B	G	6.50		0.00	**Standard**	0.00	**Standard**
X	C	R	6.50		0.00	**Deviation**	0.00	**Deviation**
X	C	M	6.50		0.00	**979.00**	0.00	**1,033**
X	C	G	6.50		0.00		0.00	
XI	A	R	6.50	**3.59**	0.00	**615.85**	0.00	**720**
XI	A	M	5.55		0.00		0.00	
XI	A	G	3.65		0.00		0.00	
XI	B	R	6.50		0.00	**Standard**	0.00	**Standard**
XI	B	M	4.60		0.00	**Deviation**	0.00	**Deviation**
XI	B	G	6.50		0.00	**1,273.00**	0.00	**1,414**
XI	C	R	-1.55		1,244.88		1,383.20	
XI	C	M	-3.70		3,819.61		4,244.01	
XI	C	G	4.25		478.19		849.68	
XII	A	R	-0.50	**-0.19**	19.76	**1,094.05**	158.08	**1,432**
XII	A	M	-4.50		1,191.53		1,521.52	
XII	A	G	-2.55		11.86		19.76	
XII	B	R	0.50		0.00	**Standard**	0.00	**Standard**
XII	B	M	-5.00		4,029.06	**Deviation**	5,916.39	**Deviation**
XII	B	G	4.60		2,321.80	**1,476.00**	2,969.05	**2,031**
XII	C	R	6.50		0.00		0.00	
XII	C	M	-4.40		2,272.40		2,304.67	
XII	C	G	3.65		0.00		0.00	
XIII	A	R	6.50	**5.45**	0.00	**1,226.31**	0.00	**821**
XIII	A	M	6.05		0.00		0.00	
XIII	A	G	6.05		0.00		0.00	
XIII	B	R	6.50		0.00	**Standard**	0.00	**Standard**
XIII	B	M	2.00		0.00	**Deviation**	0.00	**Deviation**
XIII	B	G	4.25		13,652.18	**3,648.00**	10,249.39	**2,662**
XIII	C	R	6.50		0.00		0.00	
XIII	C	M	6.50		0.00		0.00	
XIII	C	G	6.50		0.00		0.00	
XIII	D	R	4.70		0.00		0.00	
XIII	D	M	5.60		0.00		0.00	
XIII	D	G	6.50		0.00		0.00	
XIII	E	R	2.00		4,742.40		2,070.01	
XIII	E	M	6.50		0.00		0.00	
XIII	E	G	5.55		0.00		0.00	
XIV	A	R	-5.80	**-2.82**	5,888.48	**1,400.76**	21,335.07	**4,471**
XIV	A	M	-3.00		165.98		5,532.80	
XIV	A	G	-3.00		0.00		0.00	
XIV	B	R	-7.00		5,026.94	**Standard**	5,907.10	**Standard**
XIV	B	M	0.00		1,440.50	**Deviation**	3,925.08	**Deviation**

HABITAT ZONE	TRANSECT	SAMPLE	SAMPLE MEDIAN PARTICLE SIZE	ZONE MEAN PARTICLE SIZE	TOTAL WEIGHT g/M^2	MEAN WEIGHT g/M^2	TOTAL NUMBER PER M2	MEAN NUMBER PER M^2 ZONE
XIV	B	G	-3.00		0.00	**2,356.00**	0.00	**6,789**
XIV	C	R	2.00		0.00		0.00	
XIV	C	M	-0.50		0.00		0.00	
XIV	C	G	-5.10		84.97		3,540.33	
XV	A	R	6.05	**4.99**	0.00	**639.13**	0.00	**413**
XV	A	M	6.50		0.00		0.00	
XV	A	G	5.55		0.00		0.00	
XV	B	R	6.05		403.10	**Standard**	59.28	**Standard**
XV	B	M	6.50		0.00	**Deviation**	0.00	**Deviation**
XV	B	G	6.50		0.00	**1,771.00**	0.00	**1,216**
XV	C	R	-0.50		5,349.03		3,653.71	
XV	C	M	1.75		0.00		0.00	
XV	C	G	6.50		0.00		0.00	
XVI	A	R	-3.00	**-0.51**	2,932.38	**785.57**	1,738.88	**549**
XVI	A	M	1.75		0.00		0.00	
XVI	A	G	-1.10		0.00		0.00	
XVI	B	R	9.00		0.00	**Standard**	0.00	**Standard**
XVI	B	M	-5.80		733.10	**Deviation**	513.76	**Deviation**
XVI	B	G	6.50		0.00	**1,085.00**	0.00	**732**
XVI	C	R	-1.90		1,566.97		1,126.32	
XVI	C	M	-7.50		1,837.68		1,561.04	
XVI	C	G	-2.50		0.00		0.00	
XVII	A	R	9.00	**-1.06**	-0.00	**3,440.57**	0.00	**2,357**
XVII	A	M	-4.75		2,752.57		2,106.02	
XVII	A	G	6.50		0.00		0.00	
XVII	B	R	-3.00		11,027.27	**Standard**	7,760.22	**Standard**
XVII	B	M	-4.75		1,363.44	**Deviation**	889.20	**Deviation**
XVII	B	G	-3.00		3,659.55	**3,373.00**	2,344.36	**2,339**
XVII	C	R	-3.00		2,713.05		2,060.02	
XVII	C	M	-2.85		3,967.81		2,648.74	
XVII	C	G	-3.70		5,481.42		3,400.39	
XVIII	A	R	-7.00	**-1.79**	2,096.54	**2,897.47**	1,778.40	**2,017**
XVIII	A	M	-2.50		3,835.42		2,614.46	
XVIII	A	G	-3.00		8,832.72		5,908.17	
XVIII	B	R	6.50		0.00	**Standard**	0.00	**Standard**
XVIII	B	M	-2.50		2,404.79	**Deviation**	1,521.52	**Deviation**
XVIII	B	G	-5.85		4,197.02	**2,661.00**	3,665.52	**1,871**
XVIII	C	R	-2.50		1,813.97		869.44	
XVIII	C	M	-3.50		2,896.82		1,798.16	
XVIII	C	G	4.25		0.00		0.00	
XIX	A	R	6.50	**2.57**	0.00	**224.08**	0.00	**411**
XIX	A	M	-3.00		492.02		1,146.08	
XIX	A	G	-4.05		687.65		1,244.88	
XIX	B	R	6.75		0.00	**Standard**	0.00	**Standard**
XIX	B	M	4.60		0.00	**Deviation**	0.00	**Deviation**
XIX	B	G	6.50		0.00	**364.00**	0.00	**63**

HABITAT ZONE	TRANSECT	SAMPLE	SAMPLE MEDIAN PARTICLE SIZE	ZONE MEAN PARTICLE SIZE	TOTAL WEIGHT g/M^2	MEAN WEIGHT g/M^2	TOTAL NUMBER PER M2	MEAN NUMBER PER M^2 ZONE
XIX	C	R	6.75		0.00		0.00	
XIX	C	M	-4.75		266.76		671.84	
XIX	C	G	6.50		0.00		0.00	
XIX	D	R	6.50		0.00		0.00	
XIX	D	M	-8.00		1,069.02		1,521.52	
XIX	D	G	-5.45		823.99		1,521.52	
XIX	E	R	6.75		0.00		0.00	
XIX	E	M	6.50		21.74		59.28	
XIX	E	G	6.50		0.00		0.00	
			0.00					

Table 4. Relative Frequency of Total Lengths of Zebra Mussels in Habitat Zones I -XIX, Seneca River Dreissenid Program, 1999.

ZONE I			ZONE II			ZONE III			ZONE IV			ZONE V		
Length (mm)	Frequency	Relative Frq	Length (mm)	Frequency	Relative Frq	Length (mm)	Frequency	Relative Frq	Length (mm)	Frequency	Relative Frq	Length (mm)	Frequency	Relative Frq
5	11	91.7%	5	101	49.5%	5	474	59.7%	5	84	15.6%	5	76	24.5%
10	1	8.3%	10	88	43.1%	10	250	31.5%	10	92	17.1%	10	48	15.5%
15	0	0.0%	15	14	6.9%	15	51	6.4%	15	70	13.0%	15	38	12.3%
20	0	0.0%	20	1	0.5%	20	11	1.4%	20	43	8.0%	20	50	16.1%
25	0	0.0%	25	0	0.0%	25	2	0.3%	25	76	14.1%	25	36	11.6%
30	0	0.0%	30	0	0.0%	30	5	0.6%	30	100	18.6%	30	38	12.3%
35	0	0.0%	35	0	0.0%	35	1	0.1%	35	54	10.0%	35	20	6.5%
40	0	0.0%	40	0	0.0%	40	0	0.0%	40	17	3.2%	40	4	1.3%
> 40	0	0.0%	> 40	0	0.0%	> 40	0	0.0%	> 40	3	0.6%	> 40	0	0.0%
Length categories			Length categories			Length categories			Length categories			Length categories		
<10	12	100.0%	<10	195	91.5%	<10	724	91.2%	<10	176	32.7%	<10	124	40.0%
10-20	0	0.0%	10-20	17	8.0%	10-20	62	7.8%	10-20	113	21.0%	10-20	88	28.4%
>20	0	0.0%	>20	1	0.5%	>20	8	1.0%	>20	250	46.4%	>20	98	31.6%
TOTALS	12	100.0%	TOTALS	213	100.0%	TOTALS	794	100.0%	TOTALS	539	100.0%	TOTALS	310	100.0%

ZONE VI			ZONE VII			ZONE VIII			ZONE IX			ZONE X		
Length (mm)	Frequency	Relative Frq	Length (mm)	Frequency	Relative Frq	Length (mm)	Frequency	Relative Frq	Length (mm)	Frequency	Relative Frq	Length (mm)	Frequency	Relative Frq
5	41	9.1%	5	23	4.0%	5	8	2.0%	5	42	25.5%	5	21	12.2%
10	112	24.9%	10	126	22.0%	10	56	13.8%	10	61	37.0%	10	47	27.3%
15	92	20.5%	15	61	10.6%	15	70	17.3%	15	17	10.3%	15	27	15.7%
20	45	10.0%	20	84	14.6%	20	78	19.3%	20	5	3.0%	20	16	9.3%
25	51	11.4%	25	124	21.6%	25	112	27.7%	25	23	13.9%	25	39	22.7%
30	69	15.4%	30	117	20.4%	30	65	16.0%	30	15	9.1%	30	20	11.6%
35	32	7.1%	35	34	5.9%	35	16	4.0%	35	2	1.2%	35	2	1.2%
40	7	1.6%	40	5	0.9%	40	0	0.0%	40	0	0.0%	40	0	0.0%
> 40	0	0.0%	> 40	0	0.0%	> 40	0	0.0%	> 40	0	0.0%	> 40	0	0.0%
Length categories			Length categories			Length categories			Length categories			Length categories		
<10	153	34.1%	<10	149	26.0%	<10	64	15.8%	<10	103	62.4%	<10	68	39.5%
10-20	137	30.5%	10-20	145	25.3%	10-20	148	36.5%	10-20	22	13.3%	10-20	43	25.0%
>20	159	35.4%	>20	280	48.8%	>20	193	47.7%	>20	40	24.2%	>20	61	35.5%
TOTALS	449	100.0%	TOTALS	574	100.0%	TOTALS	405	100.0%	TOTALS	165	100.0%	TOTALS	172	100.0%

Table 4. Continued

ZONE XI			ZONE XII			ZONE XIII			ZONE XIV			ZONE XV		
Length (mm)	Frequency	Relative Frq	Length (mm)	Frequency	Relative Frq	Length (mm)	Frequency	Relative Frq	Length (mm)	Frequency	Relative Frq	Length (mm)	Frequency	Relative Frq
5	27	12.3%	5	25	6.4%	5	29	13.6%	5	271	53.8%	5	12	10.9%
10	28	12.8%	10	57	14.7%	10	14	6.6%	10	168	33.3%	10	14	12.7%
15	16	7.3%	15	34	8.7%	15	15	7.0%	15	16	3.2%	15	13	11.8%
20	74	33.8%	20	119	30.6%	20	35	16.4%	20	11	2.2%	20	16	14.5%
25	59	26.9%	25	132	33.9%	25	55	25.8%	25	19	3.8%	25	18	16.4%
30	14	6.4%	30	21	5.4%	30	40	18.8%	30	5	1.0%	30	17	15.5%
35	1	0.5%	35	1	0.3%	35	20	9.4%	35	6	1.2%	35	18	16.4%
40	0	0.0%	40	0	0.0%	40	5	2.3%	40	8	1.6%	40	2	1.8%
> 40	0	0.0%	> 40	0	0.0%	More	0	0.0%	More	0	0.0%	More	0	0.0%
Length categories			Length categories			Length categories			Length categories			Length categories		
<10	55	25.1%	<10	82	21.1%	<10	43	20.2%	<10	439	87.1%	<10	26	23.6%
10-20	90	41.1%	10-20	153	39.3%	10-20	50	23.5%	10-20	27	5.4%	10-20	29	26.4%
>20	74	33.8%	>20	154	39.6%	>20	120	56.3%	>20	38	7.5%	>20	55	50.0%
TOTALS	219	100.0%	TOTALS	389	100.0%	TOTALS	213	100.0%	TOTALS	504	100.0%	TOTALS	110	100.0%

ZONE XVI			ZONE XVII			ZONE XVIII			ZONE XIX		
Length (mm)	Frequency	Relative Frq	Length (mm)	Frequency	Relative Frq	Length (mm)	Frequency	Relative Frq	Length (mm)	Frequency	Relative Frq
5	6	2.4%	5	6	0.9%	5	7	1.2%	5	41	12.8%
10	20	7.8%	10	69	10.7%	10	33	5.5%	10	54	16.8%
15	19	7.5%	15	46	7.1%	15	30	5.0%	15	69	21.5%
20	45	17.6%	20	76	11.7%	20	111	18.4%	20	101	31.5%
25	90	35.3%	25	220	34.0%	25	227	37.6%	25	50	15.6%
30	59	23.1%	30	188	29.1%	30	152	25.2%	30	6	1.9%
35	14	5.5%	35	37	5.7%	35	42	7.0%	35	0	0.0%
40	2	0.8%	40	5	0.8%	40	2	0.3%	40	0	0.0%
More	0	0.0%	More	0	0.0%	More	0	0.0%	More	0	0.0%
Length categories			Length categories			Length categories			Length categories		
<10	26	10.2%	<10	75	11.6%	<10	40	6.6%	<10	95	29.6%
10-20	64	25.1%	10-20	122	18.9%	10-20	141	23.3%	10-20	170	53.0%
>20	165	64.7%	>20	450	69.6%	>20	423	70.0%	>20	56	17.4%
TOTALS	255	100.0%	TOTALS	647	100.0%	TOTALS	604	100.0%	TOTALS	321	100.0%

TABLE 5. ESTIMATE OF NUMBER AND TOTAL WEIGHT OF ZEBRA MUSSEL BY HABITAT ZONE

HABITAT ZONE	TOTAL AREA(SQ METERS)	MUSSELS/SQ M	WEIGHT/SQ M	TOTAL NUMBER(X1000)	TOTAL WEIGHT(KG)
I	461,536	9	0.66	4,153.82	304.61
II	111,888	1,428	106.70	159,776.06	11,938.45
III	78,477	12,977	946.72	1,018,396.03	74,295.75
IV	420,873	1,593	2,024.68	670,450.69	852,133.15
V	64,750	3,420	3,510.91	221,445.00	227,331.42
VI	173,529	1,266	1,563.67	219,687.71	271,342.09
VII	96,348	1,871	2,233.54	180,267.11	215,197.11
VIII	48,174	2,306	2,790.99	111,089.24	134,453.15
IX	176,637	422	259.30	74,540.81	45,801.97
X	58,534	474	403.10	27,745.12	23,595.06
XI	348,094	720	615.85	250,627.68	214,373.69
XII	159,284	1,432	1,094.05	228,094.69	174,264.66
XIII	569,797	821	1,226.31	467,803.34	698,747.76
XIV	46,620	4,471	1,400.76	208,438.02	65,303.43
XV	103,600	413	639.13	42,786.80	66,213.87
XVI	145,039	549	785.57	79,626.41	113,938.29
XVII	124,319	2,357	3,440.57	293,019.88	427,728.22
XVIII	69,930	2,017	2,897.47	141,048.81	202,620.08
XIX	466,198	411	224.08	191,607.38	104,465.65
TOTAL	3,723,627			4,586,450.79	3,923,743.79

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Table 6. Relative Mean Density of Zebra Mussels by Length Category, 1999 Dreissenid Mussel Program.

ZONE I				ZONE II				ZONE III			
Length (mm)	Frequency	Relative Frq.	Mean Number #/M^2	Length (mm)	Frequency	Relative Frq.	Mean Number #/M^2	Length (mm)	Frequency	Relative Frq.	Mean Number #/M^2
<10	12	100.0%	9	<10	195	91.5%	1,308	<10	724	91.2%	11,833
10-20	0	0.0%	0	10-20	17	8.0%	114	10-20	62	7.8%	1,013
>20	0	0.0%	0	>20	1	0.5%	7	>20	8	1.0%	131
TOTALS	12	100.0%	9	TOTALS	213	100.0%	1,428	TOTALS	794	100.0%	12,977

ZONE IV				ZONE V				ZONE VI			
Length (mm)	Frequency	Relative Frq.	Mean Number #/M^2	Length (mm)	Frequency	Relative Frq.	Mean Number #/M^2	Length (mm)	Frequency	Relative Frq.	Mean Number #/M^2
<10	176	32.7%	520	<10	124	40.0%	1,368	<10	153	34.1%	431
10-20	113	21.0%	334	10-20	88	28.4%	971	10-20	137	30.5%	386
>20	250	46.4%	739	>20	98	31.6%	1,081	>20	159	35.4%	448
TOTALS	539	100.0%	1,593	TOTALS	310	100.0%	3,420	TOTALS	449	100.0%	1,266

ZONE VII				ZONE VIII				ZONE IX			
Length (mm)	Frequency	Relative Frq.	Mean Number #/M^2	Length (mm)	Frequency	Relative Frq.	Mean Number #/M^2	Length (mm)	Frequency	Relative Frq.	Mean Number #/M^2
<10	149	26.0%	485.6	<10	64	15.8%	364	<10	103	62.4%	263
10-20	145	25.3%	472.6	10-20	148	36.5%	843	10-20	22	13.3%	56
>20	280	48.8%	912.6	>20	193	47.7%	1,099	>20	40	24.2%	102
TOTALS	574	100.0%	1,870.8	TOTALS	405	100.0%	2,306	TOTALS	165	100.0%	422

ZONE X				ZONE XI				ZONE XII			
Length (mm)	Frequency	Relative Frq.	Mean Number #/M^2	Length (mm)	Frequency	Relative Frq.	Mean Number #/M^2	Length (mm)	Frequency	Relative Frq.	Mean Number #/M^2
<10	68	39.5%	188	<10	55	25.1%	181	<10	82	21.1%	302
10-20	43	25.0%	119	10-20	90	41.1%	296	10-20	153	39.3%	563
>20	61	35.5%	168	>20	74	33.8%	243	>20	154	39.6%	567
TOTALS	172	100.0%	474	TOTALS	219	100.0%	720	TOTALS	389	100.0%	1,432

Table 6. Continued.

ZONE XIII			
Length (mm)	Frequency	Relative Frq.	Mean Number #/M^2
<10	43	20.2%	166
10-20	50	23.5%	193
>20	120	56.3%	463
TOTALS	213	100.0%	821

ZONE XIV			
Length (mm)	Frequency	Relative Frq.	Mean Number #/M^2
<10	439	87.1%	3,895
10-20	27	5.4%	240
>20	38	7.5%	337
TOTALS	504	100.0%	4,471

ZONE XV			
Length (mm)	Frequency	Relative Frq.	Mean Number #/M^2
<10	26	23.6%	98
10-20	29	26.4%	109
>20	55	50.0%	206
TOTALS	110	100.0%	413

ZONE XVI			
Length (mm)	Frequency	Relative Frq.	Mean Number #/M^2
<10	26	10.2%	56
10-20	64	25.1%	138
>20	165	64.7%	355
TOTALS	255	100.0%	549

ZONE XVII			
Length (mm)	Frequency	Relative Frq.	Mean Number #/M^2
<10	75	11.6%	273
10-20	122	18.9%	444
>20	450	69.6%	1,639
TOTALS	647	100.0%	2,357

ZONE XVIII			
Length (mm)	Frequency	Relative Frq.	Mean Number #/M^2
<10	40	6.6%	134
10-20	141	23.3%	471
>20	423	70.0%	1,413
TOTALS	604	100.0%	2,017

ZONE XIX			
Length (mm)	Frequency	Relative Frq.	Mean Number #/M^2
<10	95	29.6%	121.6
10-20	170	53.0%	217.7
>20	56	17.4%	71.7
TOTALS	321	100.0%	411.0

APPENDIX

Appendix A. Length and Weight Data, Seneca River Dreissenid Assessment Program, 1999.

HABITAT ZONE	TRANSECT	SAMPLE	DEPTH	SAMPLE MEDIAN PARTICLE SIZE	ZONE MEAN PARTICLE SIZE	NUMBERS PER SUBSAMPLE	WEIGHT PER SUBSAMPLE g/M^2	WEIGHT PER SAMPLE g/M^2	TOTAL WEIGHT g/M2	ZONE MEAN WEIGHT g/M2	TOTAL NUMBER Per Sample	TOTAL NUMBER PER M2	MEAN NUMBER PER M^2 ZONE
I	A	R	9	-4.40	**5.18**	4	0.3	0.3	5.93	**0.66**	4	79.04	**9**
I	A	M	19	6.50		0	0	0	0.00		0	0.00	
I	A	G	19	6.50		0	0	0	0.00	**Standard**	0	0.00	**Standard**
I	B	R	7	6.50		0	0	0	0.00	**Deviation**	0	0.00	**Deviation**
I	B	M	8.5	6.50		0	0	0	0.00	**2.00**	0	0.00	**26**
I	B	G	8.5	6.50		0	0	0	0.00		0	0.00	
I	C	R	3	5.55		0	0	0	0.00		0	0.00	
I	C	M	6.6	6.50		0	0	0	0.00		0	0.00	
I	C	G	9.8	6.50		0	0	0	0.00		0	0.00	
II	A	R	4	-3.70	**1.06**	100	6.5	11	217.36	**106.70**	169	3,344.00	**1,428**
II	A	M	15	-0.50		7	2.5	2.5	49.40		7	138.32	
II	A	G	8	6.50		0	0	0	0.00		0	0.00	
II	B	R	8	-0.50		0	0	0	0.00	**Standard**	0	0.00	**Standard**
II	B	M	18	5.55		0	0	0	0.00	**Deviation**	0	0.00	**Deviation**
II	B	G	23	5.55		0	0	0	0.00	**231.00**	0	0.00	**3,176**
II	C	R	12.2	-5.50		0	0	0	0.00		0	0.00	
II	C	M	21	6.50		0	0	0	0.00		0	0.00	
II	C	G	20.6	-4.40		100	7.4	35.1	693.58		474	9,372.65	
III	A	R	NA	-7.36	**-7.22**	100	5.1	113.4	2,240.78	**946.72**	2224	43,936.94	**12,977**
III	A	M	NA	-7.36		100	2.9	47.7	942.55		1645	32,501.79	
III	A	G	14	-7.36		100	6.3	8.7	171.91		138	2,728.76	
III	B	R	14	-7.36		67	0.9	0.9	17.78	**Standard**	67	1,323.92	**Standard**
III	B	M	14	-7.36		100	9.3	101.9	2,013.54	**Deviation**	1096	21,651.01	**Deviation**
III	B	G	14	-7.36		100	10	31.8	628.37	**1,013.00**	318	6,283.68	**15,920**
III	C	R	14	-8.23		84	2.2	2.2	43.47		84	1,659.84	
III	C	M	14	-8.23		100	41.4	122.8	2,426.53		297	5,861.18	
III	C	G	14	-4.39		43	1.8	1.8	35.57		43	849.68	
IV	A	R	NA	-3.70	**-0.91**	3	3.7	3.7	73.11	**2,024.68**	3	59.28	**1,593**
IV	A	M	12	-2.35		0	0	0	0.00		0	0.00	
IV	A	G	4	-4.05		100	28.6	67.8	1,339.73		237	4,684.36	
IV	B	R	6	-4.10		100	14.1	45.6	901.06		323	6,390.47	
IV	B	M	10	-3.70		27	51.8	51.8	1,023.57		27	533.52	
IV	B	G	6	-0.50		0	0	0	0.00		0	0.00	
IV	C	R	8	6.50		0	0	0	0.00	**Standard**	0	0.00	**Standard**
IV	C	M	14	-5.55		1	15.7	15.7	310.23	**Deviation**	1	19.76	**Deviation**
IV	C	G	4	0.00		2	0.6	0.6	11.86	**3,647.00**	2	39.52	**2,328**

HABITAT ZONE	TRANSECT	SAMPLE	DEPTH	SAMPLE MEDIAN PARTICLE SIZE	ZONE MEAN PARTICLE SIZE	NUMBERS PER SUBSAMPLE	WEIGHT PER SUBSAMPLE g/M²	WEIGHT PER SAMPLE g/M²	TOTAL WEIGHT g/M2	ZONE MEAN WEIGHT g/M2	TOTAL NUMBER Per Sample	TOTAL NUMBER PER M2	MEAN NUMBER PER M² ZONE
IV	D	R	12	-5.50		100	168.8	400.55	7,914.87		237	4,688.90	
IV	D	M	15	6.50		0	0	0	0.00		0	0.00	
IV	D	G	8	-0.75		100	256.8	398.3	7,870.41		155	3,064.80	
IV	E	R	8	6.05		0	0	0	0.00		0	0.00	
IV	E	M	15	-2.00		100	247.4	552.9	10,925.30		223	4,416.05	
IV	E	G	5	-0.50		0	0	0	0.00		0	0.00	
V	A	R	5	4.25	**-0.42**	0	0	0	0.00	**3,510.91**	0	0.00	**3,420**
V	A	M	NA	-1.50		0	0	0	0.00		0	0.00	
V	A	G	4	-9.97		100	95.7	1212.4	23,957.02		1267	25,033.46	
V	B	R	6	-3.00		5	19.9	19.9	393.22	**Standard**	5	98.80	**Standard**
V	B	M	10	4.60		0	0	0	0.00	**Deviation**	0	0.00	**Deviation**
V	B	G	4	6.50		0	0	0	0.00	**8,010.00**	0	0.00	**8,202**
V	C	R	10	-2.20		100	7.7	8.5	167.96		110	2,181.30	
V	C	M	10	0.50		100	204.4	358.3	7,080.01		175	3,463.80	
V	C	G	5	-3.00		0	0	0	0.00		0	0.00	
VI	A	R	8	-1.70	**-0.63**	51	16	16	316.16	**1,563.67**	51	1,007.76	**1,266**
VI	A	M	10	0.00		100	79.6	79.7	1,574.87		100	1,978.48	
VI	A	G	6	-1.85		69	99.1	99.1	1,958.22		69	1,363.44	
VI	B	R	8	-3.35		100	71.8	93.4	1,845.58	**Standard**	130	2,570.45	**Standard**
VI	B	M	10	-1.35		12	1.3	1.3	25.69	**Deviation**	12	237.12	**Deviation**
VI	B	G	7	-0.40		0	0	0	0.00	**2,601.00**	0	0.00	**1,352**
VI	C	R	6	6.05		0	0	0	0.00		0	0.00	
VI	C	M	9	-1.70		100	206.7	412	8,141.12		199	3,938.62	
VI	C	G	6	-1.35		15	10.7	10.7	211.43		15	296.40	
VII	A	R	8	-0.85	**-1.33**	100	123.2	127	2,509.52	**2,233.54**	103	2,036.95	**1,871**
VII	A	M	9	-0.50		60	90	90	1,778.40		60	1,185.60	
VII	A	G	6	-1.00		100	112.7	324.9	6,420.02		288	5,696.56	
VII	B	R	5	-3.40		100	26.6	40.5	800.28	**Standard**	152	3,008.57	**Standard**
VII	B	M	10	-3.40		100	180.6	244	4,821.44	**Deviation**	135	2,669.68	**Deviation**
VII	B	G	7	0.50		100	161.7	162.3	3,207.05	**2,241.00**	100	1,983.33	**1,825**
VII	C	R	8	-0.45		0	0	0	0.00		0	0.00	
VII	C	M	12	-1.35		9	24.1	24.1	476.22		9	177.84	
VII	C	G	10	-1.50		4	4.5	4.5	88.92		4	79.04	
VIII	A	R	9	6.50	**0.33**	0	0	0	0.00	**2,790.99**	0	0.00	**2,306**
VIII	A	M	7	-0.50		0	0	0	0.00		0	0.00	
VIII	A	G	7	-4.25		100	65.6	132.3	2,614.25		202	3,985.13	
VIII	B	R	9	-2.00		100	141.5	576.8	11,397.57	**Standard**	408	8,054.82	**Standard**
VIII	B	M	10	-0.50		100	122.7	353.4	6,983.18	**Deviation**	288	5,691.27	**Deviation**
VIII	B	G	9	0.50		0	0	0	0.00	**4,068.00**	0	0.00	**3,050**

HABITAT ZONE	TRANSECT	SAMPLE	DEPTH	SAMPLE MEDIAN PARTICLE SIZE	ZONE MEAN PARTICLE SIZE	NUMBERS PER SUBSAMPLE	WEIGHT PER SUBSAMPLE g/M^2	WEIGHT PER SAMPLE g/M^2	TOTAL WEIGHT g/M2	ZONE MEAN WEIGHT g/M2	TOTAL NUMBER Per Sample	TOTAL NUMBER PER M2	MEAN NUMBER PER M^2 ZONE
VIII	C	R	10	0.50		0	0	0	0.00		0	0.00	
VIII	C	M	6	-2.90		100	136.5	208.7	4,123.91		153	3,021.18	
VIII	C	G	6	5.60		0	0	0	0.00		0	0.00	
IX	A	R	10	-2.00	**0.48**	0	0	0	0.00	**259.30**	0	0.00	**422**
IX	A	M	10	-5.80		99	84.9	112.5	2,223.00		131	2,592.19	
IX	A	G	3	6.05		0	0	0	0.00		0	0.00	
IX	B	R	7	-4.80		8	0.7	0.7	13.83	**Standard**	8	158.08	**Standard**
IX	B	M	9	-2.50		4	0.9	0.9	17.78	**Deviation**	4	79.04	**Deviation**
IX	B	G	6	6.50		0	0	0	0.00	**737.00**	0	0.00	**872**
IX	C	R	6	6.50		0	0	0	0.00		0	0.00	
IX	C	M	9	6.50		0	0	0	0.00		0	0.00	
IX	C	G	7	-6.15		49	4	4	79.04		49	968.24	
X	A	R	6	-3.20	**2.68**	100	98.6	148.9	2,942.26	**403.10**	151	2,984.04	**474**
X	A	M	9	-2.85		0	0	0	0.00		0	0.00	
X	A	G	10	-5.30		65	34.7	34.7	685.67		65	1,284.40	
X	B	R	8	3.90		0	0	0	0.00	**Standard**	0	0.00	**Standard**
X	B	M	10	5.55		0	0	0	0.00	**Deviation**	0	0.00	**Deviation**
X	B	G	8	6.50		0	0	0	0.00	**979.00**	0	0.00	**1,033**
X	C	R	5	6.50		0	0	0	0.00		0	0.00	
X	C	M	8	6.50		0	0	0	0.00		0	0.00	
X	C	G	7	6.50		0	0	0	0.00		0	0.00	
XI	A	R	8	6.50	**3.59**	0	0	0	0.00	**615.85**	0	0.00	**720**
XI	A	M	9	5.55		0	0	0	0.00		0	0.00	
XI	A	G	6	3.65		0	0	0	0.00		0	0.00	
XI	B	R	9	6.50		0	0	0	0.00	**Standard**	0	0.00	**Standard**
XI	B	M	9	4.60		0	0	0	0.00	**Deviation**	0	0.00	**Deviation**
XI	B	G	5	6.50		0	0	0	0.00	**1,273.00**	0	0.00	**1,414**
XI	C	R	9	-1.55		70	63	63	1,244.88		70	1,383.20	
XI	C	M	8	-3.70		100	90	193.3	3,819.61		215	4,244.01	
XI	C	G	6	4.25		43	24.2	24.2	478.19		43	849.68	
XII	A	R	6	-0.50	**-0.19**	8	1	1	19.76	**1,094.05**	8	158.08	**1,432**
XII	A	M	10	-4.50		77	60.3	60.3	1,191.53		77	1,521.52	
XII	A	G	5	-2.55		1	0.6	0.6	11.86		1	19.76	
XII	B	R	5	0.50		0	0	0	0.00	**Standard**	0	0.00	**Standard**
XII	B	M	NA	-5.00		100	68.1	203.9	4,029.06	**Deviation**	299	5,916.39	**Deviation**
XII	B	G	NA	4.60		100	78.2	117.5	2,321.80	**1,476.00**	150	2,969.05	**2,031**
XII	C	R	NA	6.50		0	0	0	0.00		0	0.00	
XII	C	M	16	-4.40		100	98.6	115	2,272.40		117	2,304.67	
XII	C	G	5	3.65		0	0	0	0.00		0	0.00	

HABITAT ZONE	TRANSECT	SAMPLE	DEPTH	SAMPLE MEDIAN PARTICLE SIZE	ZONE MEAN PARTICLE SIZE	NUMBERS PER SUBSAMPLE	WEIGHT PER SUBSAMPLE g/M²	WEIGHT PER SAMPLE g/M²	TOTAL WEIGHT g/M2	ZONE MEAN WEIGHT g/M2	TOTAL NUMBER Per Sample	TOTAL NUMBER PER M2	MEAN NUMBER PER M² ZONE
XIII	A	R	8	6.50	**5.45**	0	0	0	0.00	**1,226.31**	0	0.00	**821**
XIII	A	M	16	6.05		0	0	0	0.00		0	0.00	
XIII	A	G	6	6.05		0	0	0	0.00		0	0.00	
XIII	B	R	4	6.50		0	0	0	0.00	**Standard**	0	0.00	**Standard**
XIII	B	M	8	2.00		0	0	0	0.00	**Deviation**	0	0.00	**Deviation**
XIII	B	G	5	4.25		100	133.2	690.9	13,652.18	**3,648.00**	519	10,249.39	**2,662**
XIII	C	R	5	6.50		0	0	0	0.00		0	0.00	
XIII	C	M	9	6.50		0	0	0	0.00		0	0.00	
XIII	C	G	8	6.50		0	0	0	0.00		0	0.00	
XIII	D	R	10	4.70		0	0	0	0.00		0	0.00	
XIII	D	M	16	5.60		0	0	0	0.00		0	0.00	
XIII	D	G	9	6.50		0	0	0	0.00		0	0.00	
XIII	E	R	7	2.00		100	229.1	240	4,742.40		105	2,070.01	
XIII	E	M	20	6.50		0	0	0	0.00		0	0.00	
XIII	E	G	8	5.55		0	0	0	0.00		0	0.00	
XIV	A	R	8	-5.80	**-2.82**	100	27.6	298	5,888.48	**1,400.76**	1080	21,335.07	**4,471**
XIV	A	M	9	-3.00		100	3	8.4	165.98		280	5,532.80	
XIV	A	G	6	-3.00		0	0	0	0.00		0	0.00	
XIV	B	R	8	-7.00		100	85.1	254.4	5,026.94	**Standard**	299	5,907.10	**Standard**
XIV	B	M	14	0.00		100	36.7	72.9	1,440.50	**Deviation**	199	3,925.08	**Deviation**
XIV	B	G	5	-3.00		0	0	0	0.00	**2,356.00**	0	0.00	**6,789**
XIV	C	R	4	2.00		0	0	0	0.00		0	0.00	
XIV	C	M	9	-0.50		0	0	0	0.00		0	0.00	
XIV	C	G	7	-5.10		100	2.4	4.3	84.97		179	3,540.33	
XV	A	R	6	6.05	**4.99**	0	0	0	0.00	**639.13**	0	0.00	**413**
XV	A	M	20	6.50		0	0	0	0.00		0	0.00	
XV	A	G	20	5.55		0	0	0	0.00		0	0.00	
XV	B	R	20	6.05		3	20.4	20.4	403.10	**Standard**	3	59.28	**Standard**
XV	B	M	20	6.50		0	0	0	0.00	**Deviation**	0	0.00	**Deviation**
XV	B	G	20	6.50		0	0	0	0.00	**1,771.00**	0	0.00	**1,216**
XV	C	R	20	-0.50		100	146.4	270.7	5,349.03		185	3,653.71	
XV	C	M	20	1.75		0	0	0	0.00		0	0.00	
XV	C	G	18	6.50		0	0	0	0.00		0	0.00	
XVI	A	R	20	-3.00	**-0.51**	88	148.4	148.4	2,932.38	**785.57**	88	1,738.88	**549**
XVI	A	M	20	1.75		0	0	0	0.00		0	0.00	
XVI	A	G	20	-1.10		0	0	0	0.00		0	0.00	
XVI	B	R	15	9.00		0	0	0	0.00	**Standard**	0	0.00	**Standard**
XVI	B	M	20	-5.80		26	37.1	37.1	733.10	**Deviation**	26	513.76	**Deviation**
XVI	B	G	20	6.50		0	0	0	0.00	**1,085.00**	0	0.00	**732**

HABITAT ZONE	TRANSECT	SAMPLE	DEPTH	SAMPLE MEDIAN PARTICLE SIZE	ZONE MEAN PARTICLE SIZE	NUMBERS PER SUBSAMPLE	WEIGHT PER SUBSAMPLE g/M^2	WEIGHT PER SAMPLE g/M^2	TOTAL WEIGHT g/M2	ZONE MEAN WEIGHT g/M2	TOTAL NUMBER Per Sample	TOTAL NUMBER PER M2	MEAN NUMBER PER M^2 ZONE
XVI	C	R	15	-1.90		57	79.3	79.3	1,566.97		57	1,126.32	
XVI	C	M	20	-7.50		79	93	93	1,837.68		79	1,561.04	
XVI	C	G	20	-2.50		0	0	0	0.00		0	0.00	
XVII	A	R	15	9.00	**-1.06**	0	0	0	0.00	**3,440.57**	0	0.00	**2,357**
XVII	A	M	20	-4.75		100	130.7	139.3	2,752.57		107	2,106.02	
XVII	A	G	15	6.50		0	0	0	0.00		0	0.00	
XVII	B	R	15	-3.00		100	142.1	558.06	11,027.27	**Standard**	393	7,760.22	**Standard**
XVII	B	M	15	-4.75		45	69	69	1,363.44	**Deviation**	45	889.20	**Deviation**
XVII	B	G	15	-3.00		100	156.1	185.2	3,659.55	**3,373.00**	119	2,344.36	**2,339**
XVII	C	R	12	-3.00		100	131.7	137.3	2,713.05		104	2,060.02	
XVII	C	M	20	-2.85		100	149.8	200.8	3,967.81		134	2,648.74	
XVII	C	G	12	-3.70		100	161.2	277.4	5,481.42		172	3,400.39	
XVIII	A	R	NA	-7.00	**-1.79**	90	106.1	106.1	2,096.54	**2,897.47**	90	1,778.40	**2,017**
XVIII	A	M	20	-2.50		100	146.7	194.1	3,835.42		132	2,614.46	
XVIII	A	G	12	-3.00		100	149.5	447	8,832.72		299	5,908.17	
XVIII	B	R	6	6.50		0	0	0	0.00	**Standard**	0	0.00	**Standard**
XVIII	B	M	18	-2.50		77	121.7	121.7	2,404.79	**Deviation**	77	1,521.52	**Deviation**
XVIII	B	G	18	-5.85		100	114.5	212.4	4,197.02	**2,661.00**	186	3,665.52	**1,871**
XVIII	C	R	18	-2.50		44	91.8	91.8	1,813.97		44	869.44	
XVIII	C	M	20	-3.50		91	146.6	146.6	2,896.82		91	1,798.16	
XVIII	C	G	12	4.25		0	0	0	0.00		0	0.00	
XIX	A	R	16.5	6.50	**2.57**	0	0	0	0.00	**224.08**	0	0.00	**411**
XIX	A	M	17.5	-3.00		58	24.9	24.9	492.02		58	1,146.08	
XIX	A	G	17.5	-4.05		63	34.8	34.8	687.65		63	1,244.88	
XIX	B	R	15	6.75		0	0	0	0.00	**Standard**	0	0.00	**Standard**
XIX	B	M	16.9	4.60		0	0	0	0.00	**Deviation**	0	0.00	**Deviation**
XIX	B	G	11.8	6.50		0	0	0	0.00	**364.00**	0	0.00	**63**
XIX	C	R	15	6.75		0	0	0	0.00		0	0.00	
XIX	C	M	18.9	-4.75		34	13.5	13.5	266.76		34	671.84	
XIX	C	G	8.3	6.50		0	0	0	0.00		0	0.00	
XIX	D	R	17	6.50		0	0	0	0.00		0	0.00	
XIX	D	M	18.5	-8.00		77	54.1	54.1	1,069.02		77	1,521.52	
XIX	D	G	12	-5.45		77	41.7	41.7	823.99		77	1,521.52	
XIX	E	R	15	6.75		0	0	0	0.00		0	0.00	
XIX	E	M	18.6	6.50		3	1.1	1.1	21.74		3	59.28	
XIX	E	G	15	6.50		0	0	0	0.00		0	0.00	
				0.00									