NOAA Technical Memorandum GLERL-144

ABUNDANCES OF THE AMPHIPOD *DIPOREIA* SPP. AND THE MUSSELS *DREISSENA POLYMORPHA* AND *DREISSENA ROSTRIFORMIS BUGENSIS* IN LAKE MICHIGAN IN 1994-1995, 2000, AND 2005

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September 2008

UNITED STATES
DEPARTMENT OF COMMERCE

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NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION

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1. INTRODUCTION

This technical report provides basic results of benthic surveys conducted in Lake Michigan in 1994-1995, 2000, and 2005. The focus of these surveys was to assess lakewide trends in abundances of the amphipod *Diporeia* spp., the zebra mussel (*Dreissena polymorpha*), and the quagga mussel (*Dreissena rostriformis bugensis*). These lakewide surveys were an expansion of a monitoring program in the southern basin that has examined trends in the abundance and composition of the macroinvertebrate community since 1980 (Nalepa 1987, Nalepa et al. 1998). The original purpose of the monitoring program was to assess the response of the benthic community to phosphorus abatement efforts in the mid-1970s (Nalepa 1987). However, after *D. polymorpha* became established in the southwestern portion of the lake in 1989 (Marsden et al. 1993), the monitoring program detected several dramatic changes in the benthic community in the early 1990s. For one, the *Diporeia* population began to systematically disappear (Nalepa et al. 1998). Also, *D. polymorpha* rapidly expanded and soon became dominant in the nearshore region. To determine if the same dramatic changes in the southern basin were occurring over a broader lake area, the monitoring program was expanded in 1994-1995 to include the entire lake. Sampling in these two years was conducted jointly with several other Lake Michigan programs -- Environmental Monitoring and Assessment (EMAP) and Lake Michigan Mass Balance (LMMB). After 1994-1995, lakewide monitoring of *Diporeia* and *Dreissena* populations continued at 5-year intervals (i.e., in 2000 and 2005) as part of a regular monitoring program.

The purpose of this report is to provide all abundance data collected in 1994-1995, 2000, and 2005, and to provide basic details of the lakewide sampling program, including station locations, sampling methods, and laboratory procedures. Data are presented with little attempt at interpretation; detailed analysis and discussions of relevance will be provided in other publications (see Nalepa et al. in press).

2. MATERIALS AND METHODS

Sampling Sites

The location and depth of sites sampled in 1994-1995, 2000, and 2005 are given in Table 1. For organizational purposes, the sites were placed into five regions of the lake: southern, central, northern, Green Bay, and Grand Traverse Bay. In 1994-1995, samples were collected at 88 sites during two cruises in 1994 (late July and early September), and one cruise in 1995 (late August/early September). Sampling sites were part of either EMAP, LMMB, or the GLERL monitoring program in the southern basin. Site locations in EMAP were based on a random, probabilistic design (Stevens 1997) within the 85 m contour, while site locations in LMMB were focused in offshore, depositional areas. Sites in the GLERL monitoring program were located at various depths throughout the southern basin (Nalepa et al. 1985). Of the sites sampled in 1994-1995, there were 49, 33, and 6 sites sampled within each of these programs,

respectively. The number of sites sampled was expanded to 157 in 2000. Included were 21 EMAP and 10 LMMB sites that were sampled in 1994-1995, and all 40 sites that were part of the GLERL monitoring program and regularly sampled since 1980. The other sites (n = 86) were added to provide broader spatial coverage of the lake. Added sites were mostly along transects at 20, 30, 45, 60 m, and 80 m on both the east and west sides of the lake. In Green Bay, 2 of the 5 sites sampled in 1994-1995 were not sampled in 2000 and 2005, but 5 sites were added as part of an assessment of food resources available to lake whitefish. One site was sampled in Grand Traverse Bay in 1994-1995; this site was sampled in 2000 and 2005 along with 20 additional sites that were also part of the food resource assessment. All sites sampled in 2000 were re-sampled in 2005, plus an additional 3 sites located in the southern basin. The location of sites within each of the five regions is given in Figure 1, and by-region site designations are given in Figures 2-6.

Sample Collection and Processing

Sampling procedures were the same at all sites on all sampling dates. Samples were taken in triplicate at each site with a Ponar grab (sampling area = 0.046 m^2). Sediments were washed through an elutriation device fitted with a 0.5-mm mesh net, and retained residue was preserved in 5 % formalin containing rose bengal stain.

In the laboratory, all *Diporeia* spp. and dreissenids were picked and counted under a low-power magnifier lamp (1.5 X). In replicates with high numbers of individuals, the sample was randomly subdivided and only a portion of the total sample counted. For *Diporeia* spp., the sample was split using a folsom plankton splitter. For dreissenids, the sample was randomly placed into a divided tray (4 quadrants) and a subsample counted. For both taxa, at least 300 individuals were counted in a given replicate.

3. RESULTS AND DISCUSSION

Data collected in each survey period are given in Appendix 1 (excel file). Values for *Diporeia, D. polymorpha*, and *D. r. bugensis* are provided as the number found in each replicate grab in each of the three sampling periods. The three taxa are coded as DIPO, DPOL, and DBUG in the file, respectively. To convert to number per m^2, multiply values by 21.42.

To briefly summarize temporal trends, sites in the main basin (i.e. not within Grand Traverse Bay or Green Bay) were placed into four depth intervals (≤ 30 m, 31-50 m, 51-90 m, > 90 m) and mean (± SE) densities of the three taxa were determined for each interval. Sites in Grand Traverse Bay and Green Bay were excluded since most were not sampled all three periods. Differences between sampling periods and intervals were tested with a two-way ANOVA (period x interval) after ln +1 transformation. If sampling periods were significantly different, a multiple range test was performed (Tukey's LSD).

Over the 10-year sampling period, dramatic changes occurred in populations of *Diporeia* and *D .r. bugensis*. For *Diporeia*, overall densities were significantly different between the three sampling periods ($P < 0.001$). Densities were significantly lower in 2000 compared to 1994/1995 ($P < 0.001$), and significantly lower in 2005 compared to 2000 ($P < 0.001$). The year x interval interaction was also significant ($P < 0.001$). Declines over the 10-year period in the ≤ 30 m, 31-50 m, 51-90 m, and > 90 m depth intervals were 96.9 %, 99.6 %, 91.6 % and 72.8 %, respectively (Figure 7). Declines were most evident in the southeastern, eastern, and northern portions of the lake between 1994-1995 and 2000, while declines in the western portion of the lake were most severe between 2000 and 2005 (Figure 8).

In contrast, *D. r. bugensis* increased dramatically over the same period. It was not found at any site in 1994-1995, and mean densities in 2000 were only 37/m^2, 25/m^2, 0/m^2, and 0/m^2 at the four depth intervals, respectively. However, by 2005 mean densities increased to 6,125/m^2, 16,017/m^2, 6,472/m^2, and 13/m^2 (Figure 9). Differences between the three sampling periods were significant ($P < 0.01$, year x interval interaction: $P < 0.01$). *D .r. bugensis* was found only in the northern region of the lake in 2000 and, although it was found throughout the lake by 2005, densities remained highest in that region in 2005 (Figure 10).

Densities of *D. polymorpha* increased between 1994/1995 and 2000, but then decreased between 2000 and 2005 (Figure 11). Differences between these three periods were significant ($P < 0.01$; year x interval interaction: $P < 0.01$). *D. polymorpha* was mainly found at the two shallowest depth intervals (≤ 30 m and 31-50 m) over the entire 10-year sampling period. Peak mean density was 1,836/m^2 at the ≤ 30 m interval in 2000. Like *D. r. bugensis*, densities of *D. polymorpha* tended to be greater in the northern portion of the lake (Figure 12).

In summary, *Diporeia* and *D. polymorpha* declined, while *D. r. bugensis* increased in Lake Michigan between 1994-1995 and 2005. The decline of *Diporeia* has been linked to the expansion of dreissenids, but exact mechanisms for the negative response are not entirely clear (Nalepa et al. 2006). Lower abundances of *D. polymorpha* in 2005 compared to 2000 were temporally coincident with the increase in *D. r. bugensis*, and similar declines relative to *D. r. bugensis* have been documented in Lake Ontario (Mills et al. 1999). Based on laboratory experiments, *D. polymorpha* has a lower assimilation rate and a higher respiration rate compared to *D. r. bugensis*, and is therefore likely to be outcompeted for available food resources (Stoeckmann 2003). In 2005, the *D. r. bugensis* population was still expanding at all depth intervals, so it is not yet apparent at what level the population will stabilize and reach an equilibrium with the surrounding environment. A lakewide survey planned for 2010 should provide an answer to this important question.

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Table 1. Location and depth of sites sampled in 1994-1995, 2000, and 2005. Station designations and locations were associated with the following sampling programs: EMAP = Environmental Monitoring and Assessment Program; LMMB = Lake Michigan Mass Balance; GLERL = Great Lakes Environmental Research Lab, southern basin monitoring; GLERL* = Great Lakes Environmental Research Lab, 5-year lake-wide survey.

					Survey Year			
Station	**Program**	**Depth**	**Latitude**	**Longitude**	**1994**	**1995**	**2000**	**2005**
Southern Region								
A-1	GLERL	18	42°06.50	86°32.00			X	X
A-2	GLERL	35	42°06.00	86°37.00			X	X
A-4	GLERL*	74	42°03.50	87°06.50			X	X
B-2	GLERL	47	42°24.00	86°27.00			X	X
B-3	GLERL	68	42°24.00	86°35.50			X	X
B-4	GLERL	129	42°23.50	87°01.00			X	X
B-5	GLERL	108	42°22.50	87°21.00			X	X
B-6	GLERL	83	42°22.50	87°30.00			X	X
B-7	GLERL	45	42°22.00	87°40.00	X		X	X
C-1	GLERL	20	42°49.67	86°14.83			X	X
C-2	GLERL*	46	42°49.67	86°18.14			X	X
C-3	GLERL	77	42°49.17	86°28.42	X		X	X
C-5	GLERL	157	42°49.00	86°50.00			X	X
C-6	GLERL	93	42°47.67	87°26.83			X	X
C-7	GLERL	55	42°47.50	87°34.50	X		X	X
C-45	GLERL*	45	42°09.56	87°30.20			X	X
EG-12	GLERL	56	42°20.90	87°37.00			X	X
EG-14	GLERL	95	42°22.70	86°46.50			X	X
EG-18	GLERL	57	42°17.60	86°38.57	X		X	X
EG-22	GLERL	45	43°06.20	86°22.00			X	X
F-2	GLERL*	45	42°30.05	86°21.86			X	X
F-3	GLERL*	72	42°30.10	86°31.50			X	X
G-45	GLERL*	45	41°56.96	87°13.44			X	X
H-8	GLERL	19	42°23.92	87°46.25			X	X
H-9	GLERL	37	42°26.75	87°42.35			X	X
H-11	GLERL	73	42°33.25	87°35.83			X	X
H-13	GLERL	19	41°55.58	87°29.42			X	X
H-14	GLERL	37	42°04.33	87°27.17			X	X
H-15	GLERL	55	42°09.50	87°26.00			X	X
H-18	GLERL	19	41°59.00	86°36.00			X	X
H-19	GLERL	37	42°00.00	86°41.08			X	X
H-20	GLERL	55	42°00.83	86°45.17	X		X	X
H-21	GLERL	73	42°02.42	86°53.00			X	X
H-22	GLERL	46	42°08.35	86°39.83			X	X
H-24	GLERL	19	42°23.25	86°20.00			X	X
H-28	GLERL	19	42°37.80	86°15.92			X	X
H-29	GLERL	37	42°37.80	86°18.35			X	X
H-30	GLERL	73	42°37.80	86°26.00			X	X

Table 1. (Continued).

Station	Program	Depth	Latitude	Longitude	Survey Year			
					1994	1995	2000	2005
H-31	GLERL	46	43°02.47	86°19.99	X		X	X
M-45	GLERL*	45	43°11.43	86°25.72			X	X
N-2	GLERL*	40	41°53.50	86°52.00			X	X
N-3	GLERL*	61	41°58.00	86°59.00			X	X
Q-13	GLERL*	13	42°50.63	87°47.92				X
Q-30	GLERL*	30	42° 50.61	87°39.24				X
R-20	GLERL*	20	42°45.04	87°41.78				X
R-45	GLERL*	45	42°45.00	87°36.33			X	X
S-2	GLERL	17	41°45.90	87°23.47			X	X
S-3	GLERL	25	41°51.00	87°19.20			X	X
S-4	GLERL	40	41°56.10	87°15.10			X	X
SAU-45	GLERL*	45	42°41.14	86°18.90			X	X
T-3	GLERL*	73	42°10.00	86°43.00			X	X
V-1	GLERL	16	41°41.80	87°00.80			X	X
V-2	GLERL	29	41°49.00	87°02.90			X	X
X-1	GLERL	36	43°08.25	86°21.70			X	X
X-2	GLERL	93	43°12.00	86°31.00			X	X
100	LMMB	100	43°01.02	86°37.02	X			
822	LMMB	52	42°08.52	86°39.72	X			
9211	LMMB	73	43°00.96	86°24.42	X			
9222	LMMB	124	42°29.76	86°49.74	X			
9224	LMMB	73	42°30.18	86°31.74	X			
9511	LMMB	87	42° 07.20	87°03.12		X		
9531	LMMB	145	42°40.14	87°15.06		X		
9534	LMMB	157	42°46.26	87°04.56		X		
9544	LMMB	93	42°57.12	87°18.54		X		
20148	LMMB	54	42°00.81	86°45.18	X			
31916	LMMB	26	41°49.98	86°54.36	X			
73452	EMAP	17	42°50.09	86°14.76	X			
73472	EMAP	45	42°22.02	86°26.58	X			
73492	EMAP	17	41°54.00	86°38.98	X			
75000	EMAP	28	43°06.72	86°19.74	X			
75010	EMAP	58	42°52.74	86°21.42	X			
75030	EMAP	70	42°23.10	86°35.46	X			
75040	EMAP	79	42°10.50	86°44.04	X			
75050	EMAP	47	41°56.58	86°49.74	X			
75060	EMAP	6	41°42.78	86°55.98	X			
76570	EMAP	104	43°03.54	86°39.72	X			
76580	EMAP	108	42°49.68	86°45.54	X			
76590	EMAP	145	42°35.22	86°51.36	X			
76611	EMAP	65	42°59.04	87°00.84	X			
76620	EMAP	43	41°53.16	87°09.24	X			
76622	EMAP	20	41°47.40	87°17.58	X			
78150	EMAP	89	43°00.30	86°59.22	X			
78190	EMAP	51	42°03.96	87°22.80	X			

Table 1. (Continued).

Station	Program	Depth	Latitude	Longitude	Survey Year			
					1994	1995	2000	2005
79752	EMAP	80	42°37.14	87°33.24	X			
79760	EMAP	88	42°28.86	87°30.60	X			
79781	EMAP	8	41°52.32	87°35.88	X			
81340	EMAP	46	42°53.70	87°38.46	X			
89195	LMMB	52	42°17.10	86°37.92	X			
Central Region								
E-1	GLERL*	44	44°37.50	86°18.20			X	X
K-2	GLERL*	45	43°20.10	86°29.80			X	X
KE-1	GLERL*	20	44°23.30	87°28.52			X	X
KE-2	GLERL*	30	44°23.30	87°27.64			X	X
KE-3	GLERL*	45	44°23.30	87°26.34			X	X
KE-5	GLERL*	80	44°23.30	87°23.98			X	X
L-220	GLERL*	20	43°30.05	86°30.14			X	X
L-230	GLERL*	30	43°30.05	86°31.12			X	X
L-245	GLERL*	45	43°30.05	86°31.88			X	X
L-260	GLERL*	60	43°30.05	86°33.29			X	X
L-280	GLERL*	80	43°30.05	86°36.22			X	X
LU-1	GLERL*	20	43°56.64	86°32.10			X	X
LU-3	GLERL*	45	43°56.64	86°36.49			X	X
LU-4	GLERL*	60	43°56.64	86°37.60			X	X
LU-5	GLERL*	80	43°56.64	86°39.00			X	X
MAN-1	GLERL*	20	44°24.78	86°16.93			X	X
MAN-2	GLERL*	30	44°24.78	86°17.18			X	X
MAN-3	GLERL*	45	44°24.78	86°19.91			X	X
MAN-4	GLERL*	60	44°24.78	86°20.37			X	X
MAN-5	GLERL*	80	44°24.78	86°20.82			X	X
PW-2	GLERL*	30	43°26.82	87°46.92			X	X
PW-3	GLERL*	45	43°26.82	87°46.19			X	X
PW-4	GLERL*	60	43°26.82	87°44.04			X	X
PW-5	GLERL*	80	43°26.82	87°41.90			X	X
SY-1	GLERL*	20	43°55.09	87°39.83			X	X
SY-2	GLERL*	30	43°55.09	87°38.86			X	X
SY-4	GLERL*	60	43°55.09	87°30.32			X	X
SY-5	GLERL*	80	43°55.09	87°22.54			X	X
9552	LMMB	86	43°11.10	87°12.54		X	X	X
9554	LMMB	114	43°14.28	86°53.22		X	X	X
9556	LMMB	71	43°18.30	87°46.32		X	X	X
9559	LMMB	80	43°25.14	87°06.54		X		
9561	LMMB	138	43°28.26	86°47.04		X		
9562	LMMB	129	43°30.00	87°37.02		X	X	X
9564	LMMB	140	43°36.06	87°20.46		X	X	X
9570	LMMB	174	43°53.16	86°54.48		X		
9574	LMMB	148	44°04.08	87°08.82		X	X	X
9576	LMMB	175	44°09.06	86°37.26		X	X	X
9577	LMMB	63	44°14.58	87°22.44		X	X	X

Table 1. (Continued).

Station	Program	Depth	Latitude	Longitude	Survey Year			
					1994	1995	2000	2005
9582	LMMB	128	44°24.48	86°22.14		X	X	X
9587	LMMB	207	44°37.26	86°21.18		X		
19163	LMMB	116	43°12.00	86°42.00	X			
76560	EMAP	90	43°17.70	86°33.48	X			
78110	EMAP	30	43°56.64	86°34.72	X		X	X
78140	EMAP	112	43°14.35	86°53.18	X			
79730	EMAP	84	43°11.10	87°12.96	X			
79732	EMAP	67	43°05.34	87°21.48	X			
81330	EMAP	88	43°07.80	87 32.70	X			
82882	EMAP	60	44°23.30	87°25.40	X		X	X
82902	EMAP	40	43°55.09	87°37.44	X		X	X
82922	EMAP	8	43°26.82	87°48.54	X		X	X
Northern Region								
EA-7	GLERL*	43	45°17.00	85°20.06			X	X
FR-1	GLERL*	20	44°49.00	86°08.36			X	X
FR-2	GLERL*	30	44°49.00	86°09.31			X	X
FR-3	GLERL*	45	44°49.00	86°10.13			X	X
FR-4	GLERL*	60	44°49.00	86°11.07			X	X
FR-5	GLERL*	80	44°49.00	86°11.77			X	X
PET-1	GLERL*	17	45°26.74	85°04.26			X	X
PET-2	GLERL*	32	45°26.74	85°04.53			X	X
PET-3	GLERL*	43	45°26.74	85°11.21			X	X
SB-2	GLERL*	30	44°51.44	87°10.04			X	X
SB-3	GLERL*	45	44°51.44	87°09.06			X	X
SB-4	GLERL*	60	44°51.44	87°08.21			X	X
SB-5	GLERL*	80	44°51.44	87°05.19			X	X
SC-2	GLERL*	30	45°50.47	86°06.32			X	X
SC-3	GLERL*	45	45°49.03	86°06.32			X	X
SC-4	GLERL*	60	45°47.41	86°06.32			X	X
SC-5	GLERL*	82	45°45.37	86°06.32			X	X
WI-1	GLERL*	20	45°14.85	86°54.30			X	X
WI-2	GLERL*	30	45°14.85	86°52.57			X	X
WI-3	GLERL*	45	45°14.85	86°49.80			X	X
WI-5	GLERL*	80	45°14.85	86°38.20			X	X
9597	LMMB	164	44° 58.32	86°22.20		X	X	X
9599	LMMB	208	45° 00.24	86°43.44		X		
74880	EMAP	23	45°54.54	85°01.50	X		X	X
74900	EMAP	55	45°26.74	85°13.31	X		X	X
76442	EMAP	20	46°00.06	85°24.60	X		X	X
76451	EMAP	17	45°43.36	85°19.89	X		X	X
76462	EMAP	55	45°32.10	85°38.16	X		X	X
76471	EMAP	32	45°14.52	85°33.36	X		X	X
76482	EMAP	28	45°04.14	85°51.42	X		X	X
78030	EMAP	35	45°48.72	85°43.08	X		X	X
79612	EMAP	21	45°54.00	86°06.32	X		X	X

Table 1. (Continued).

Station	Program	Depth	Latitude	Longitude	Survey Year			
					1994	1995	2000	2005
81220	EMAP	39	45°42.60	86°24.54	X		X	X
81240	EMAP	57	45°14.85	86°40.11	X		X	X
82851	EMAP	81	45°00.03	86°55.38	X		X	X
82862	EMAP	12	44°51.44	87°11.40	X		X	X
95116	LMMB	37	45°24.00	85°35.46		X		
95118	LMMB	89	45°28.32	86°31.02		X		
95120	LMMB	140	45°31.44	86°10.14		X		
95122	LMMB	92	45°34.44	85°49.50		X		
95126	LMMB	96	45°45.36	86°03.48		X		
Green Bay								
BBDN-1	GLERL*	12	45°42.00	86°44.50			X	X
BBDN-2	GLERL*	24	45°37.25	86°44.50			X	X
BBDN-3	GLERL*	24	45°32.50	86°44.50			X	X
LBDN-2	GLERL*	15	45°30.00	87°00.00			X	X
LBDN-3	GLERL*	25	45°30.00	87°05.83			X	X
82842	EMAP	37	45°19.62	87°00.54	X		X	X
84450	EMAP	11	45°36.18	87°05.82	X		X	X
84470	EMAP	23	45°08.04	87°18.36	X		X	X
86101	EMAP	16	44°56.40	87°36.12	X			
86112	EMAP	8	44°44.82	87°53.70	X			
Grand Traverse Bay								
EA-1	GLERL*	45	44°47.00	85°31.00			X	X
EA-2	GLERL*	45	44°47.00	85°33.00			X	X
EA-3	GLERL*	40	44°51.00	85°27.80			X	X
EA-4	GLERL*	40	44°54.00	85°26.12			X	X
EA-5	GLERL*	47	44°54.00	85°29.00			X	X
EA-6	GLERL*	20	45°02.00	85°23.65			X	X
EA-61	GLERL*	45	45°02.00	85°24.43			X	X
EA-62	GLERL*	70	45°02.00	85°25.01			X	X
GT-1	GLERL*	98	44°50.00	85°37.00			X	X
GT-3	GLERL*	112	44°59.00	85°34.80			X	X
GT-11	GLERL*	60	44°50.00	85°38.48			X	X
GT-12	GLERL*	45	44°50.00	85°38.63			X	X
GT-13	GLERL*	30	44°50.00	85°38.70			X	X
GT-31	GLERL*	75	44°59.00	85°35.30			X	X
GT-32	GLERL*	55	44°59.00	85°35.45			X	X
GT-33	GLERL*	45	44°59.00	85°35.47			X	X
GT-34	GLERL*	25	44 59.00	85°35.50			X	X
GT-35	GLERL*	17	44°59.00	85°35.62			X	X
SG-5	GLERL*	120	44°57.40	85°34.00			X	X
SG-38	GLERL*	115	45°01.75	85°32.80			X	X
74920	EMAP	51	45°07.86	85°27.24	X		X	X

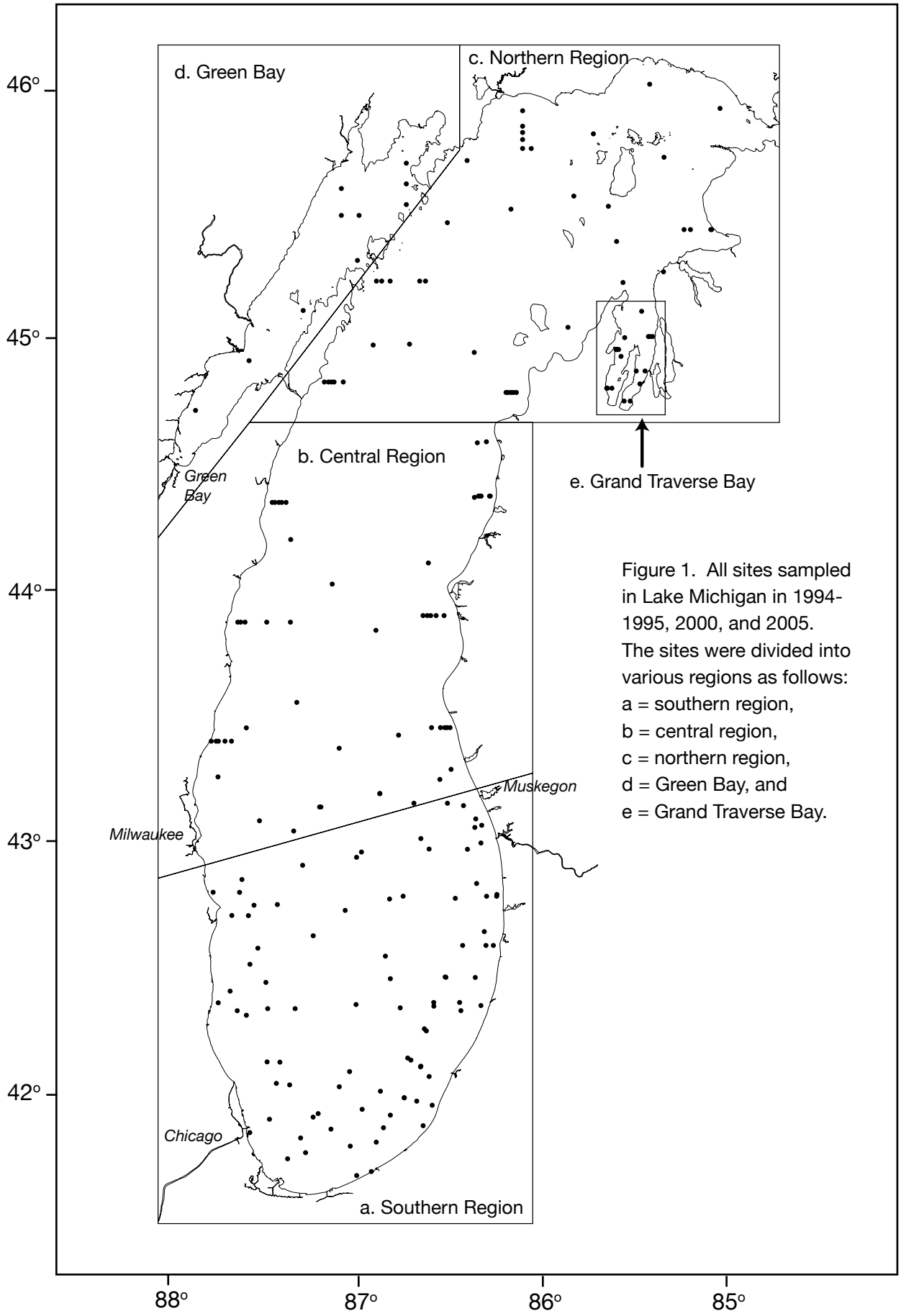

Figure 1. All sites sampled in Lake Michigan in 1994-1995, 2000, and 2005. The sites were divided into various regions as follows: a = southern region, b = central region, c = northern region, d = Green Bay, and e = Grand Traverse Bay.

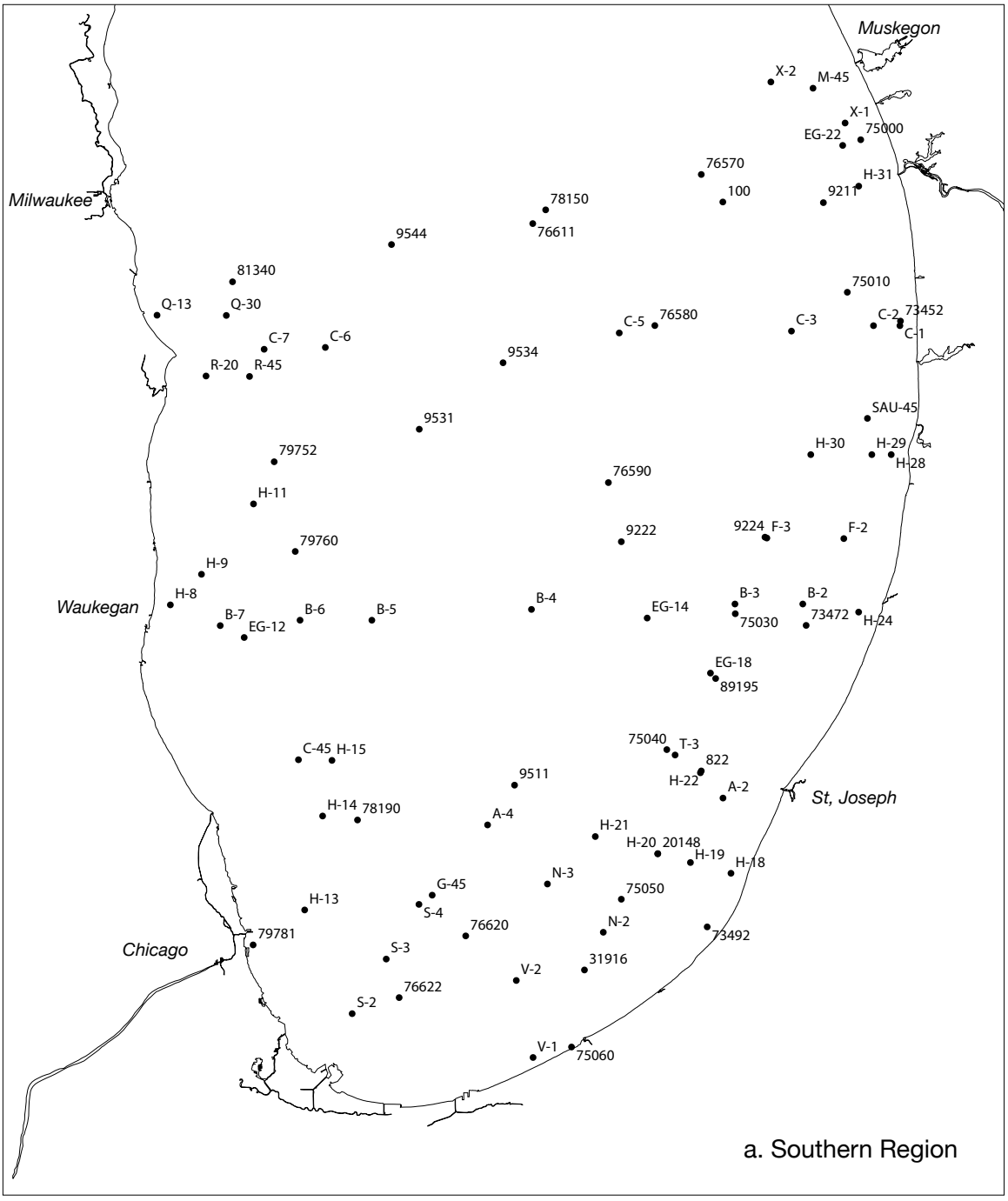

Figure 2. Designation of sites sampled in 1994-1995, 2000, and 2005 that were located in the southern region of Lake Michigan. Site coordinates are given in Table 1.

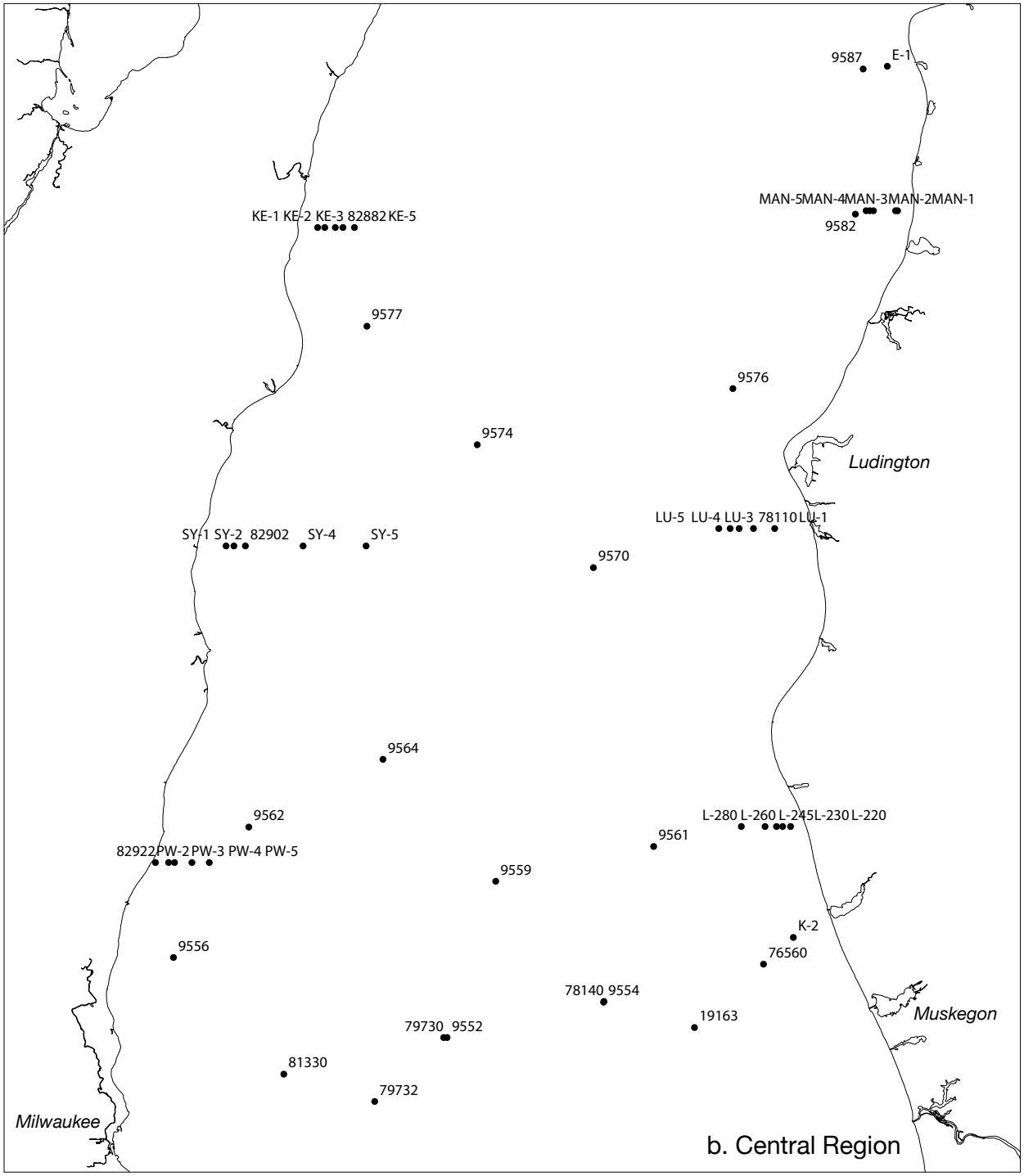

Figure 3. Designation of sites sampled in 1994-1995, 2000, and 2005 that were located in the central region of Lake Michigan. Site coordinates are given in Table 1.

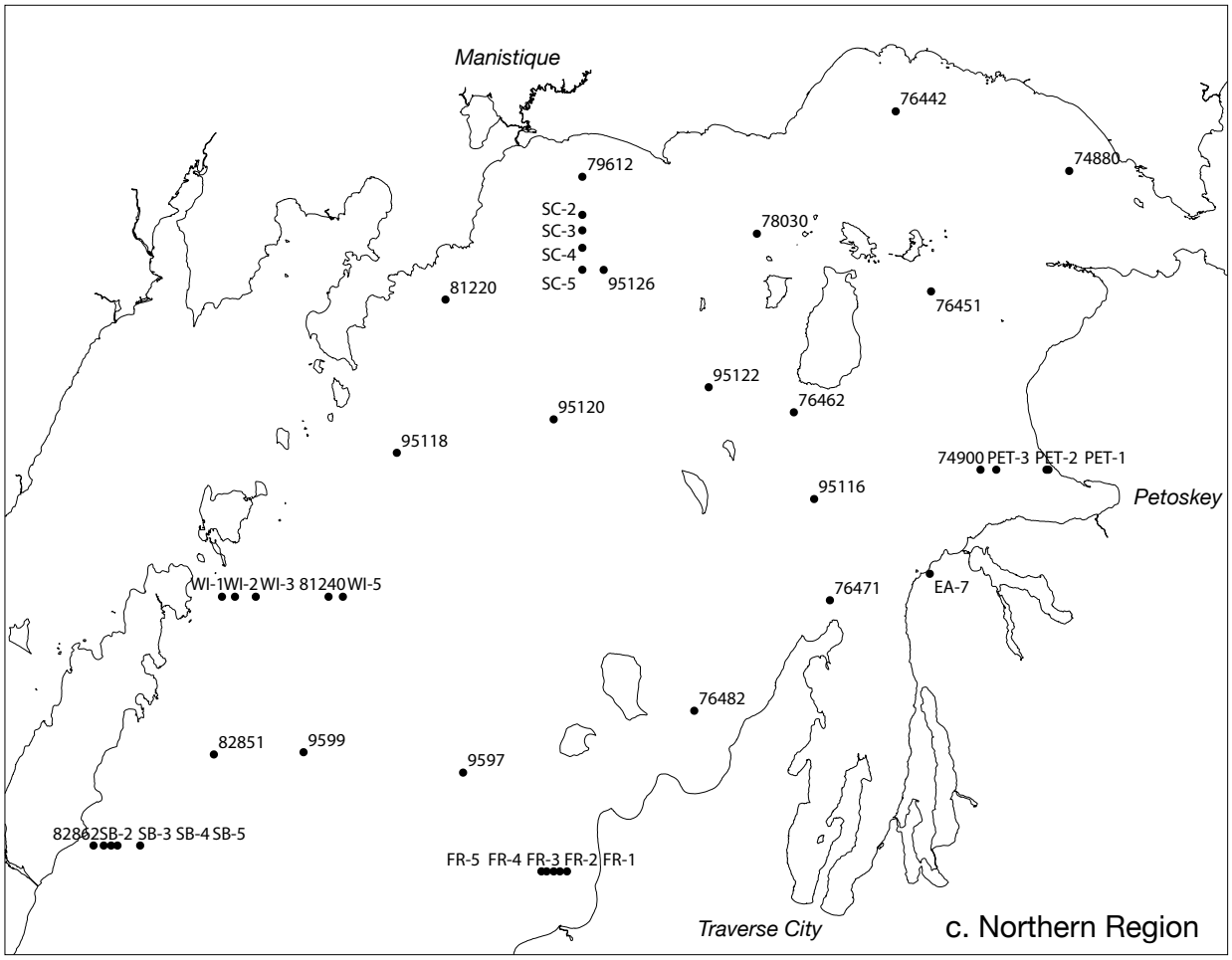

Figure 4. Designation of sites sampled in 1994-1995, 2000, and 2005 that were located in the northern region of Lake Michigan. Site coordinates are given in Table 1.

Figure 5. Designation of sites sampled in 1994-1995, 2000, and 2005 that were located in Green Bay, Lake Michigan. Site coordinates are given in Table 1.

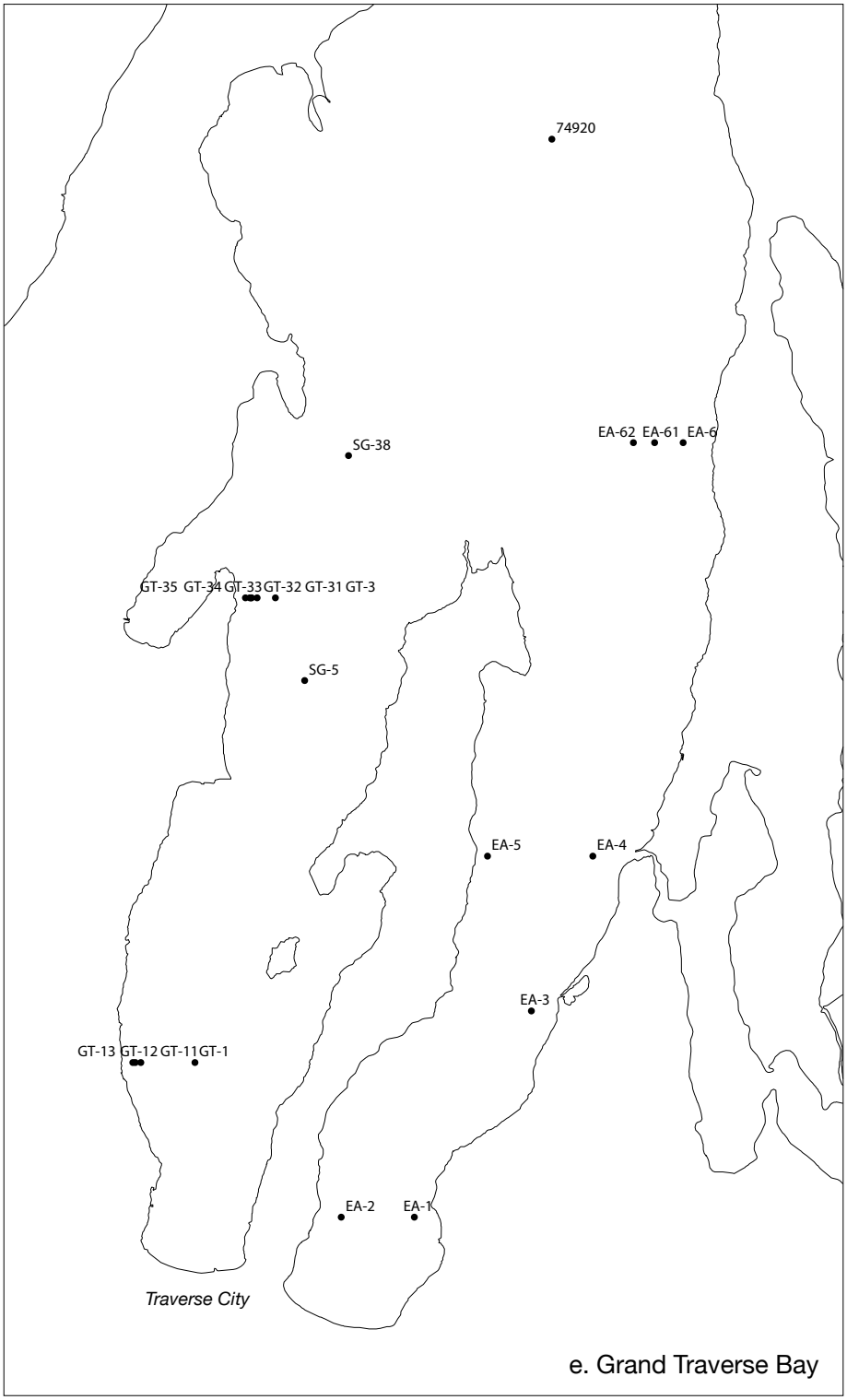

Figure 6. Designation of sites sampled in 1994-1995, 2000, and 2005 that were located in Grand Traverse Bay, Lake Michigan. Site coordinates are given in Table 1.

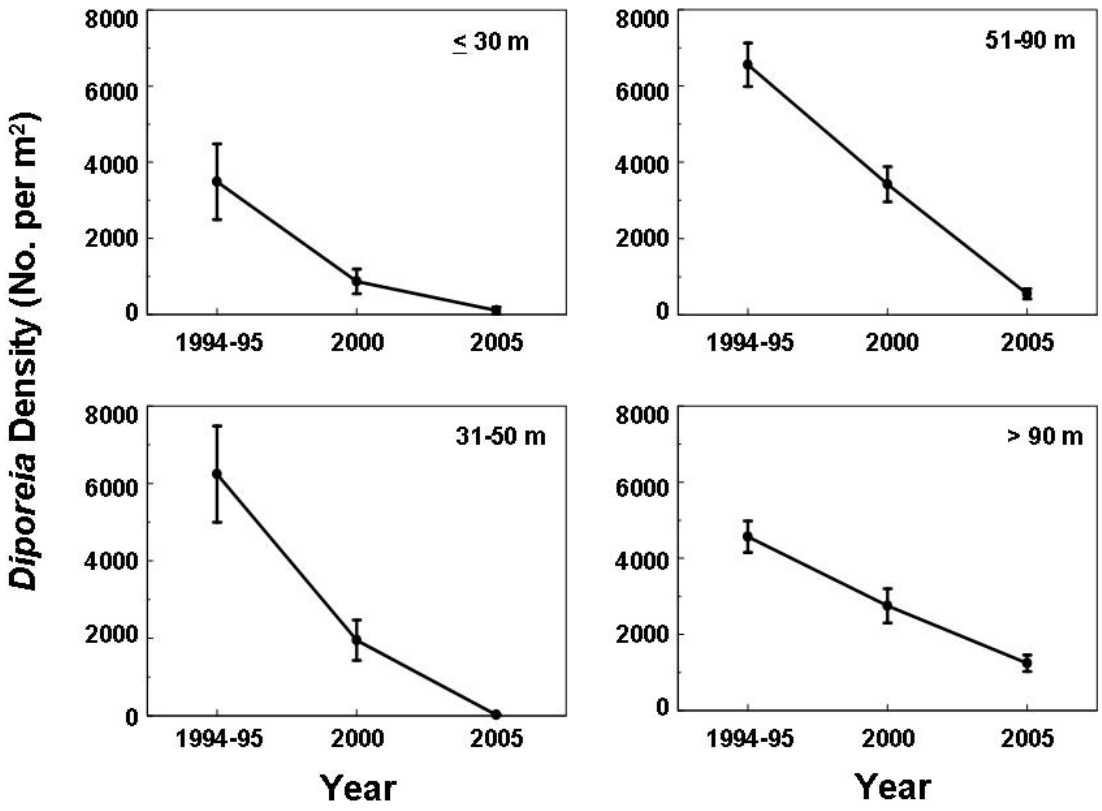

Figure 7. Mean (± SE) density (no. per m^2) of *Diporeia* at each of four depth intervals (≤ 30 m, 31-50 m, 51-90 m, > 90 m) in 1994-1995, 2000, and 2005.

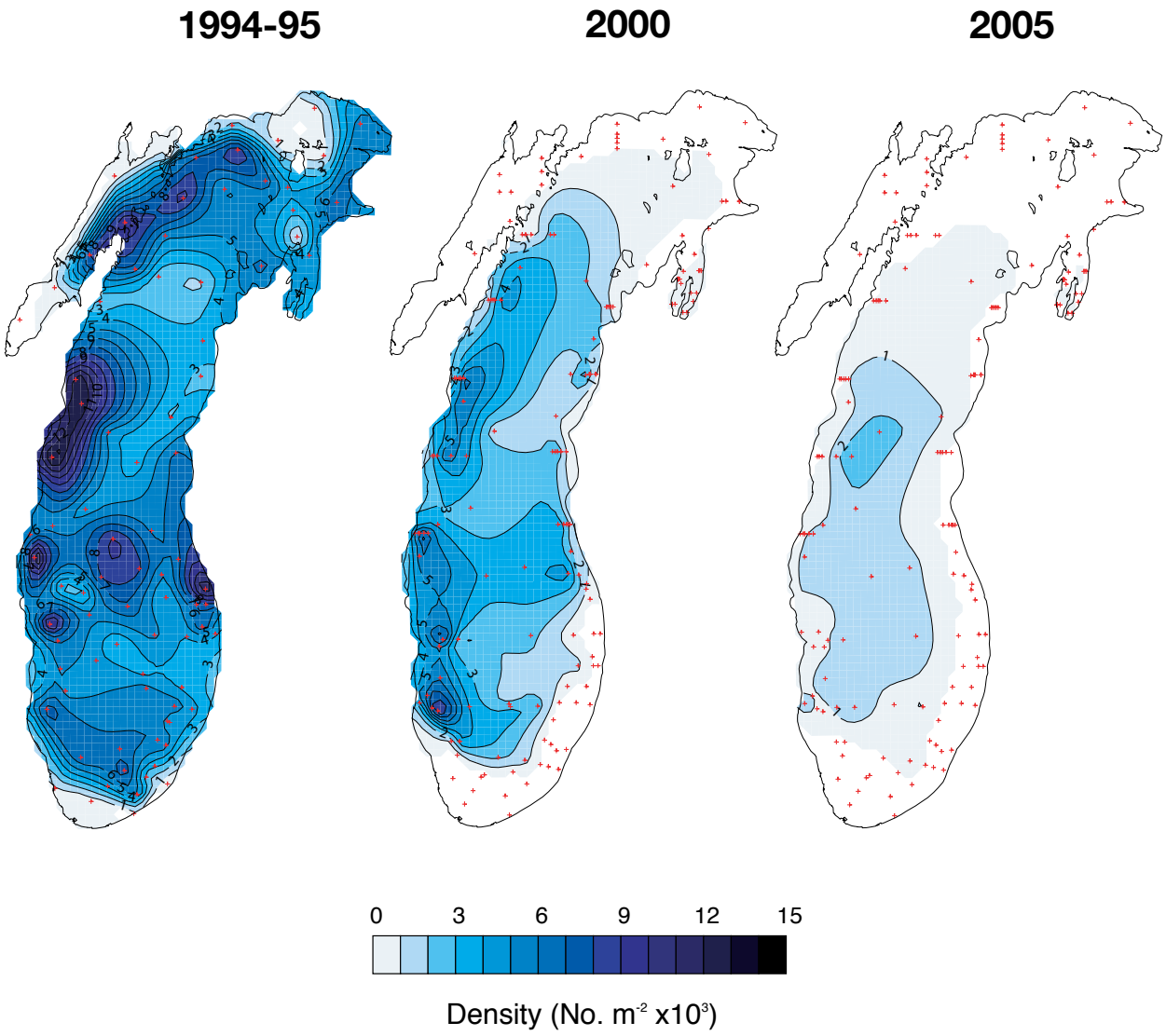

Figure 8. Distribution of *Diporeia* in Lake Michigan in 1994-1995, 2000, and 2005. Values given as mean density (no. per m^2). Small crosses denote sampling sites.

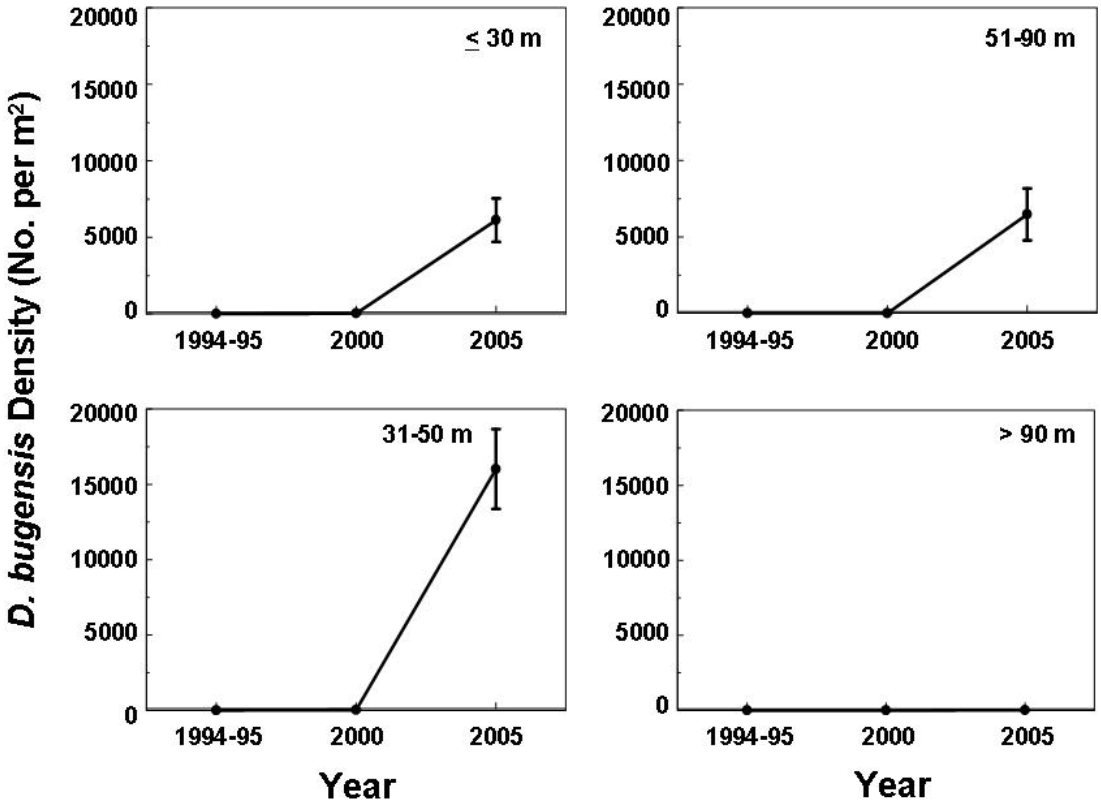

Figure 9. Mean (± SE) density of *Dreissena r. bugensis* at each of four depth intervals (≤ 30 m, 31-50 m, 51-90 m, > 90 m) in 1994-1995, 2000, and 2005.

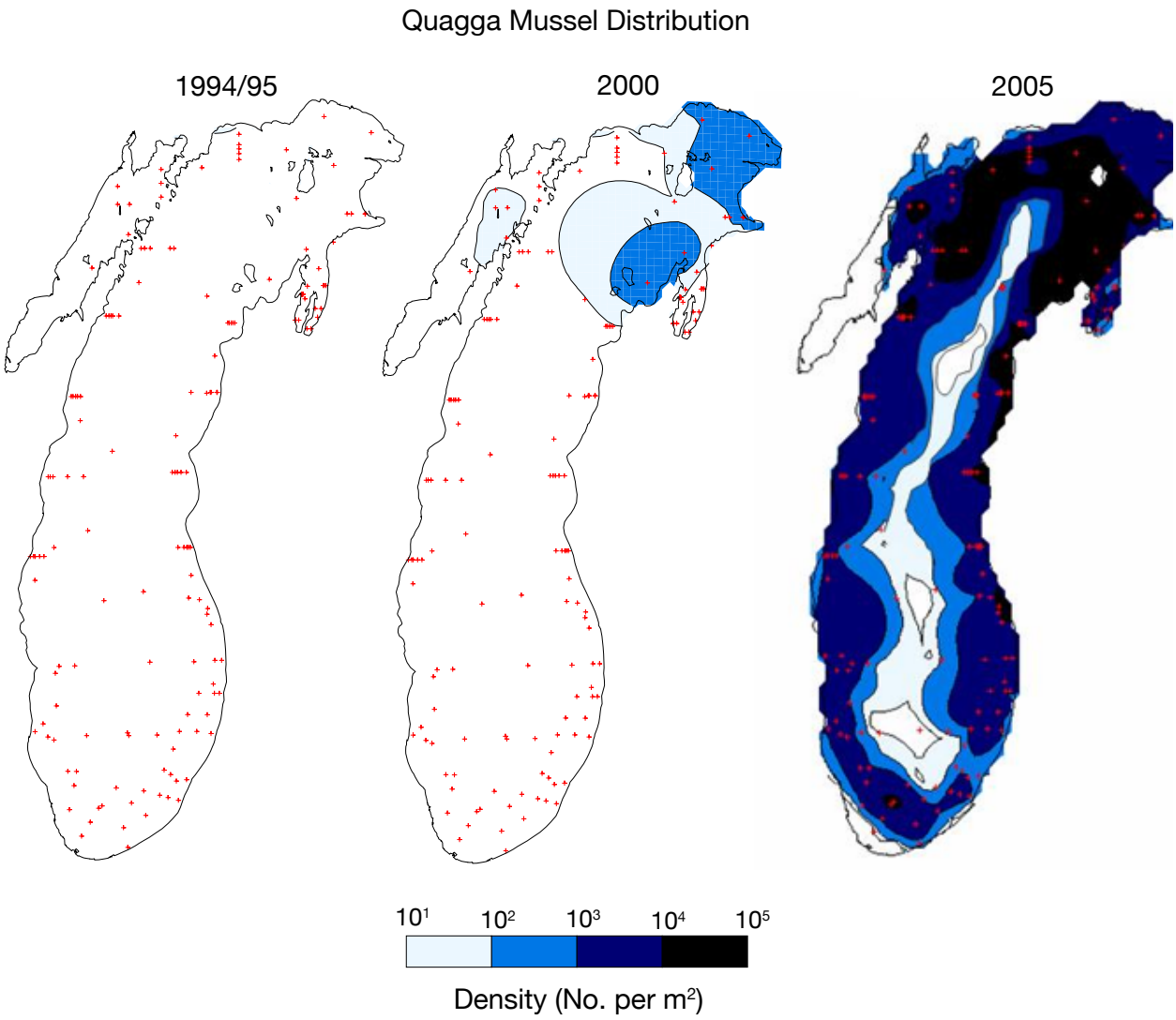

Figure 10. Distribution of *Dreissena r. bugensis* in Lake Michigan in 1994-1995, 2000, and 2005. Values given as mean density (no. per m^2). Small crosses denote sampling sites. For 2005, contours were manipulated slightly in the northern, mid-lake region to reflect more realistic patterns. Although not thoroughly sampled, this region would have few individuals because of extreme depths.

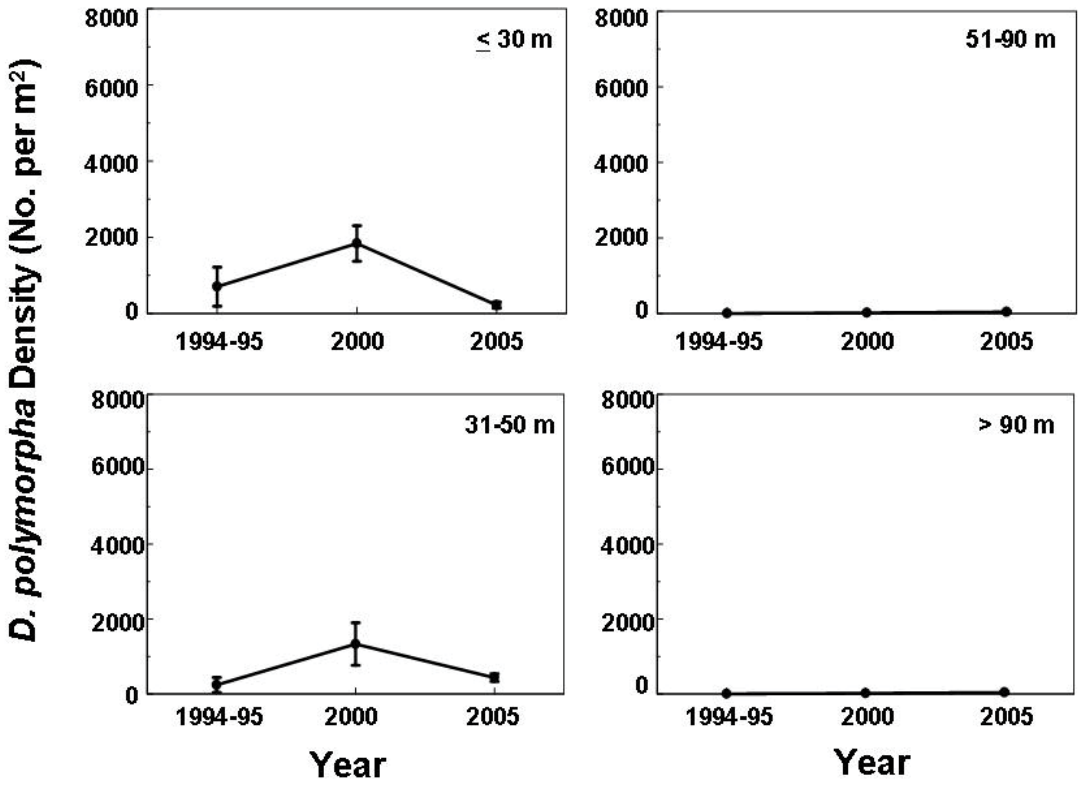

Figure 11. Mean (± SE) density (no. per m^2) of *Dreissena polymorpha* at each of four depth intervals (≤ 30 m, 31-50 m, 51-90 m, > 90 m) in 1994-1995, 2000, and 2005.

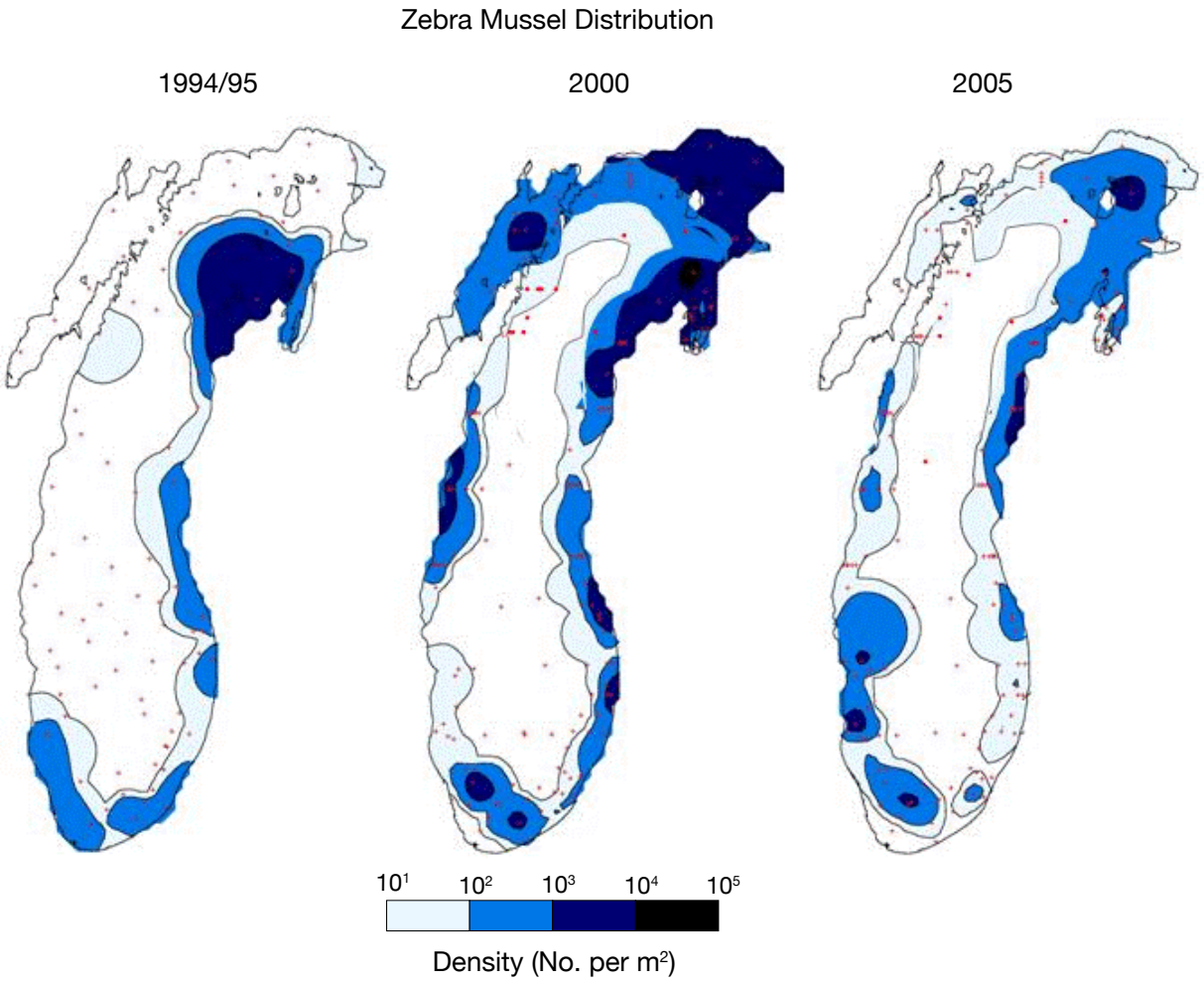

Figure 12. Distribution of *Dreissena polymorpha* in Lake Michigan in 1994-1995, 2000, and 2005. Values given as mean density (no. per m^2). Small crosses denote sampling sites. For 2000 and 2005, contours were manipulated slightly in the northern, mid-lake region to reflect more realistic patterns. Although not thoroughly sampled, this region would have few to no individuals because of extreme depths.