The Status of *Diporeia* spp. in Lake Ontario, 1994-1997

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Abstract

Surveys of benthic macroinvertebrates conducted in Lake Ontario between 1994 and 1997 revealed a recent decline in *Diporeia* spp. (Amphipoda) abundance. The lowest population densities and summer biomass are in the eastern basin of the lake at all depths. Densities and biomass declined in the shallowest (10-50 m) depth zone between 1994 and 1997. Mean *Diporeia* spp. densities declined from 1412 m^{-2} to 1 m^{-2}, and the total mean biomass declined from 0.66-g DW m^{-2} to 0.001 g-DW m^{-2}. The latter represents an overall loss of about 5100 mt of biomass in the shallowest depth zone. In contrast, biomass at the deepest zone (>90 m) did not change from 1994 to 1997 and has actually increased over twofold since 1972. This shift of total biomass from shallow to deeper sediments will have a profound effect on organisms that depend upon *Diporeia* spp. for food. Because of the importance of benthic macroinvertebrates, and particularly *Diporeia* spp. in fish diets, changes in the status of

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Diporeia spp. could have dramatic effects on fish production in Lake Ontario.

Introduction

The abundance of the deep-water amphipod, *Diporeia* spp. (hereafter, diporeia as a common name), in Lake Ontario has undergone dramatic changes since the early 1990s. Prior to 1990, diporeia (formerly *Pontoporeia hoyi*) was the most abundant macroinvertebrate in the lake (Mozley and Howmiller 1977; Nalepa 1991). In deeper habitats, it accounted for 40-70% of the total density of benthic organisms (Nalepa 1991), reaching the greatest densities at depths below the summer thermocline in waters 30-60-m deep. After 1994, benthic-macroinvertebrate populations declined in many areas of Lake Ontario (Lozano et al. 2001; Dermott 2001). In the eastern basin, the densities of diporeia averaged 8200 m^{-2} between 1982 and 1993. After 1995, no amphipods were found at three stations in the eastern basin. At a mid-lake station, diporeia increased from 1100 to 5200 m^{-2} (Dermott 2001). Lake-wide surveys in 1994 and 1997 showed that densities of diporeia were highest at depths >42 m but that diporeia was absent at shallower depths (Lozano et al. 2001). At depths between 41 and 100 m, densities of diporeia averaged 5200 m^2 in 1994 and 2400 m^{-2} in 1997. At depths <40 m, the percentage of stations where very few or no diporeia (<6 m^{-2}) were found doubled from 40% in 1994 to 84% in 1997. A zone of very low diporeia density (<6 m^{-2}) extended in 1997 as far as 26-km offshore and as deep as 200 m, encompassing over 29% of the total surface area of Lake Ontario (Lozano et al. 2001).

In this paper, we examined the status of diporeia from 1994 to 1997 and compared our findings to earlier research studies conducted prior to the invasion of dreissenids. We present evidence that, although the total biomass of amphipods did not decline between 1972 and 1997, the current distributional patterns of diporeia biomass may have a major impact on nearshore trophic dynamics.

Methods

Benthic-macroinvertebrate data were obtained from two sources. The benthic invertebrate data from Nalepa and Thomas (1976) were used to describe densities and biomass of diporeia in Lake Ontario in 1972 prior to the invasion by *Dreissena polymorpha* and *D. bugensis.* They collected triplicate sediment samples with a Ponar grab at 55 stations throughout the lake. Sampling depths ranged from 14 to 223 m.

The second source was the 1994 and 1997 data from Lozano et al. (2001) and Dermott (2001) whose work followed the invasion of dreissenids. Benthic samples were collected at 51 stations in 1994 and 68 stations in 1997. Sampling depths ranged from 10 to 213 m. Methods in Nalepa and Thomas (1976) were similar to those of Lozano et al. (2001) with one exception. To estimate site densities, Nalepa and Thomas (1976) averaged individual grab samples; Lozano et al. (2001) pooled three grab samples.

Sampling sites for diporeia were divided into a western, central, and eastern basin based on Thomas et al. (1972). Sites were also divided into three depth intervals (10-50 m, 51-90 m, and >90 m) similar to prior characterizations of depth-macroinvertebrate associations in Lake Ontario (Nalepa and Thomas 1976; Lozano et al. 2001). These depth intervals also approximate sediment depositional areas within the lake (Thomas et al. 1972) and sediment types (Lozano et al. 2001).

The main effects of year and/or basin were tested with a one- or two-way ANOVA for mean population densities within each depth zone (numbers of individuals m^{-2}). Tukey's pairwise comparison test ($P < 0.05$) was used to test for differences between mean densities (Wilkinson 1996). A log transformation was used to stabilize the variance prior to data analysis. Diporeia densities were converted to dry biomass using average weight (1.3 mg) reported by Cavaletto et al. (1996) for diporeia collected in Lake Ontario. Total biomass of diporeia was calculated for each depth interval within each of the three basins. Bathymetry measurements for calculation of sediment surface area were taken from Schwab and Sellers (1996).

Results

The spatial distribution of diporeia differed between 1994 and 1997, especially in the 10- to 50-m zone. In 1994, the highest population densities were found at stations located along the north shore and at the eastern end of the lake (Fig. 1). Along the north shore, there was only a single site (42-m deep) with density equal to zero. At the other nine locations along the north shore, densities reached levels between 5900 and 7900 m^{-2} at depths ranging from 48 to 82 m. A contiguous zone with stations with population densities of <6 individuals m^{-2} was found along the southeastern shore between the Genesee River outlet and Mexico Bay (Fig.1). The number of stations with population densities of <6 individuals m^{-2} increased to 30 of 68 in 1997 compared to 8 of 51 in 1994, and these stations extended all around the lake. The depauperate zone in 1997 extended as far as 26-km offshore to a depth of 160 m and encompassed more than 29% of the total lake area. The most-severe decline in diporeia was found along the southern and eastern shores from the outlet of the Niagara River to Point Petre (Fig. 1) where diporeia was completely absent from samples collected in waters ≤140-m deep.

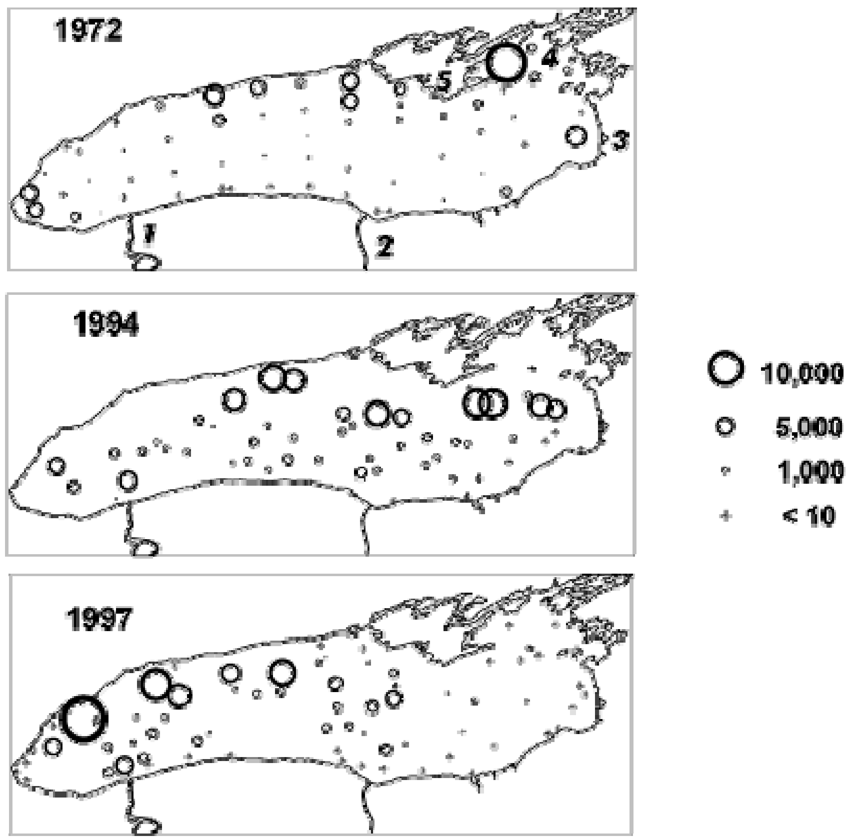

Fig. 1. Distribution and density (no.m^{-2}) of diporeia in 1972, 1994, and 1997. Kingston basin was not sample in 1994. A cross marks sites with very-low densities (<6 m^{-2}). Geographical locations mentioned in text are given in the top panel, where 1 = Niagara River, 2 = Rochester (mouth of the Genessee River), 3 = Mexico Bay, 4 = Kingston Basin, and 5 = Point Petre.

Table 1. Mean density and standard error (#/m^2) of diporeia at three depth intervals for three basins of Lake Ontario, 1972-1997.

		1972			1994			1997		
Depth interval (m)		West	Central	East	West	Central	East	West	Central	East
10-50	Mean	1,701	1,932	3,226	203	2,131	2[a]	34[a]	1[a]	0[a]
	SE	816	671	1,621	–	2,131	2	33	1	0
	N	7	11	6	1	2	3	6	6	9
51-90	Mean	986	2,427	2,536	3,266	6,575	5,581	5,725	1,791	11[b]
	SE	564	2,060	837	–	573	1,263	1,853	845	5
	N	3	2	5	1	4	6	6	10	3
>90	Mean	773	938	521	2,388	2,064	1,811	2,524	2,279	596
	SE	188	246	202	756	200	572	605	306	232
	N	5	10	5	6	20	8	8	14	6

[a] Represents mean densities within the depth interval 10-50 m that were significantly smaller compared to densities in 1972.

[b] Represents mean densities within the depth interval 51-90 m that were significantly smaller compared to 1972.

The patterns of diporeia distribution shifted away from the eastern basin and away from shallower waters from 1972 to 1997. In the shallowest depth interval (10-50 m), densities of diporeia in 1994 and 1997 were significantly lower compared to densities found in 1972 within the eastern basin of the lake (Table 1). At depths of 10-50 m in the central and western basins, densities of diporeia in 1997 were significantly lower compared to densities found in 1972. In the shallowest depth interval, lake-wide mean density of *Diporeia* in 1972 was 2188 m^{-2} compared to lake-wide mean densities of 1412 and 10 m^{-2} in 1994 and 1997, respectively. Both values were significantly lower than the density in 1972. At depths of 51-90 m, densities of diporeia were significantly lower in the eastern basin in 1997 (11 m^{-2}) compared to densities there in 1972 and 1994 (2536 and 5581 m^{-2}, respectively). In the mid-depth (51-90 m) interval, lake-wide mean density of diporeia in 1972 was 2049 m^{-2} compared to lake-wide mean densities of 6167 and 3266 m^{-2} in 1994 and 1997, respectively. There were no statistical differences between lake-wide densities between years. In the >90-m depth interval, the densities of diporeia in 1972 ranged between 521 and 938 m^{-2} and were generally lower compared to densities in 1994 and 1997 (combined range of 596 to 2524 m^{-2}). Lake-wide mean densities at depths >90 m were 793, 2060, and 1920 m^{-2} for 1972, 1994, and 1997, respectively.

The biomass of diporeia also shifted away from the eastern basin and from shallower waters from 1972 to 1997 (Fig. 2). Within the 10- to 50-m-depth zone, total biomass in 1972 was 17.1 kilotons (1 kiloton = 1000 metric tonnes). At similar depths, total biomass was 0.04 kilotons in 1997. This biomass represents a substantial loss (99.8%) of benthic biomass that could have been available for fish consumption. In 1997, total biomass was reduced in the 51- to 90-m-depth interval compared to biomass in 1994 but was generally similar to biomass in 1972. From 1994 to 1997, there were no losses or increases in total biomass at depths >90 m, but values then were greater than those found in 1972.

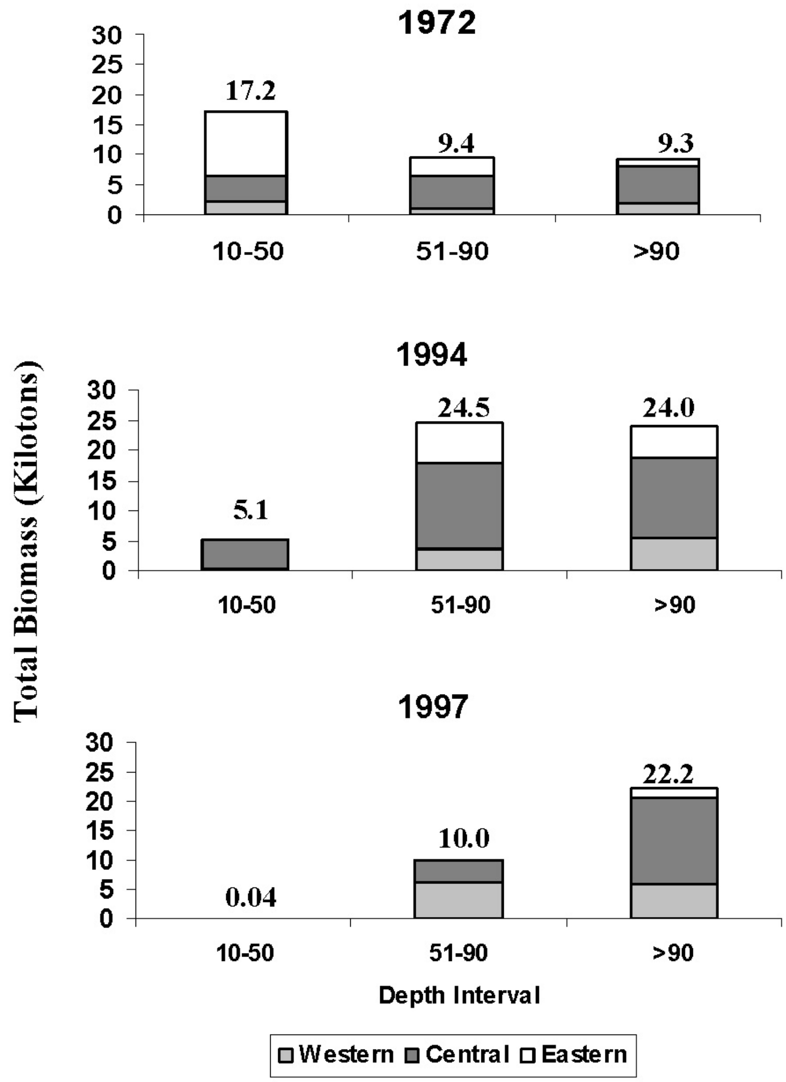

Fig. 2. Total biomass (kilotons) of diporeia in 1972, 1994, and 1997 within three depth intervals and three basins of Lake Ontario. The total biomass for each depth interval is displayed above the bar.

Discussion

Our data indicate a major decline in diporeia densities at depths <50 m from 1972 to 1994-1997 with the greatest decline in the eastern and central basins (Table 1). At depths between 51 and 90 m, the densities of diporeia also declined over the same years but only in the eastern basin of the lake. There were no trends in the densities of diporeia at depths >90 m.

Diporeia populations at deeper sites in Lake Ontario were either stable and/or increased during the past decade and appear unaffected by the causes of the declines at shallower depths. Dermott (2001) reported an increase from 1050 to 5239 m^{-2} at a mid-lake station (110-m deep) between 1992 and 1995. Nalepa (1991) reported diporeia densities of 1400 to 2400 m^{-2} between 1964 and 1987 at the same mid-lake station. At a similar location, we found diporeia density to be 4730 m^{-2} in 1997.

The area where diporeia was collected in very low numbers ($<6\ m^{-2}$) was smallest in 1972 and greatest in 1997. In 1972, diporeia was absent in an area extending along the south shore from the Niagara River eastward to Rochester, New York (Nalepa and Thomas 1976). The loss of diporeia in Lake Ontario sediments has accelerated since 1994. In 1997, the area at depths between 10 and 50 m where diporeia was absent expanded all around the lake. The loss was greatest in the eastern basin. Diporeia was found at only nine of 40 stations in 1997 and all of these stations were deeper than 75 m.

At three sites where diporeia was sampled in the eastern basin between 1982 and 1996 (Dermott 2001), diporeia populations declined from $>6000\ m^{-2}$ to zero. Dermott (2001) suggested that with the elimination of diporeia between the 10- to 60-m contours, 29% of the lake-wide amphipod production was lost. Our calculations did not support this conclusion because total biomass in 1997 was around 32 kilotons, similar to the 36 kilotons found in 1972. Our data, however, did show a shift of production from shallow to deep water.

Prior to the invasion of dreissenids, 48% of the total biomass was found in shallow depths (<50 m). In 1997 the production of diporeia in shallow waters approached zero, but, in the same year, 69% of the total biomass of diporeia was produced in waters deeper than 90 m (Fig. 2).

The shift of production from shallow to deeper sediments will have a profound effect on diporeia consumers. Great Lakes benthic-community biomass, especially in deeper waters, is driven by pelagic primary production. An important food source for diporeia arrives in the spring and fall when water conditions favor diatom blooms and subsequent settling of diatoms (Gardner et al. 1990; Scavia et al. 1986). Diporeia requires these algae for growth and reproduction, storing the assimilated energy as lipid. Lipid levels of diporeia are high and can account for up to 50% of amphipod dry weight after the spring diatom bloom (Gardner et al. 1985). Flint (1986) estimated that 23% of the total annual carbon production from pelagic phytoplankton is consumed by diporeia. A large portion of diporeia biomass is transferred up the food chain to forage fish. Diporeia is the dominant food organism of the slimy sculpin (*Cottus cognatus*) in Lake Ontario (Owens and Weber 1995), and many fish species feed on diporeia at some stage in their life cycle (Mozley and Howmiller 1977). Therefore, changes in the status of diporeia could have dramatic effects on fish production in Lake Ontario. For example, slimy sculpin populations began to increase from 1984 to 1991, abruptly declined in 1992, and remained low through 1998 (Mills et al. 2003). Owens et al. (2003) suggest that reductions in populations of diporeia, an important food item for slimy sculpin, were the cause of the decline.

In Lake Ontario, the loss of diporeia coincided with the appearance of dreissenid mussels, *Dreissena polymorpha* and *D. bugensis*. Since their invasion, dreissenids have been collected from sand/silt substrates to depths of 140 m (Lozano et al. 2001; Mills et al. 1993). Densities reached 37,000 m^{-2} at depths between 10 and 27 m (Lozano et al. 2001). High densities, widespread distribution, and high filtering rates enable *Dreissena* populations to filter large volumes of water and thereby decrease algal biomass (Holland 1993; Fahnenstiel et al. 1995). The diversion of algal production into dreissenid tissue and biodeposits may deprive diporeia of food settling from the water column (Dermott 2001), but competition for food does not fully explain the complete collapse of diporeia populations in eastern Lake Ontario.

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