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NOTE

Lake-wide Distribution of *Dreissena* in Lake Michigan, 1999

Guy W. Fleischer*, Timothy J. DeSorcie, and Jeffrey D. Holuszko

U. S. Geological Survey
Great Lakes Science Center
1451 Green Road
Ann Arbor, Michigan 48105

*ABSTRACT. The Great Lakes Science Center has conducted lake-wide bottom trawl surveys of the fish community in Lake Michigan each fall since 1973. These systematic surveys are performed at depths of 9 to 110 m at each of seven index sites around Lake Michigan. Zebra mussel (*Dreissena polymorpha*) populations have expanded to all survey locations and at a level to sufficiently contribute to the bottom trawl catches. The quagga (*Dreissena bugensis*), recently reported in Lake Michigan, was likely in the catches though not recognized.* Dreissena *spp. biomass ranged from about 0.6 to 15 kg/ha at the various sites in 1999. Dreissenid mussels were found at depths of 9 to 82 m, with their peak biomass at 27 to 46 m. The colonization of these exotic mussels has ecological implications as well as potential ramifications on the ability to sample fish consistently and effectively with bottom trawls in Lake Michigan.*

INDEX WORDS: Zebra mussels, Dreissena, *Lake Michigan, population status, geographic distribution, depth distribution.*

INTRODUCTION

The first evidence of the imminent encroachment of zebra mussels (*Dreissena polymorpha*) into Lake Michigan occurred with the recovery of dreissenid shells in May 1988 in Indiana Harbor at Gary, Indiana (Kevin Cummings, Illinois Natural History Survey, Champaign, Illinois, personnel communication; INHS Catalog #9566). Confirmation of the establishment of zebra mussels in Lake Michigan proper, where living *Dreissena* were collected, was in 1989 near Whiting, Indiana (USGS Nonindigenous Aquatic Species Database, Florida Caribbean Science Center). By 1990, adult zebra mussels had been found at multiple sites in southern Lake Michigan waters of Illinois, Indiana, and Michigan (Kraft 1993), and by 1992 were reported to range along the eastern and western shoreline in the southern two-thirds of the lake, as well as in Green Bay and Grand Traverse Bay (Marsden 1992). Since 1973, the Great Lakes Science Center has conducted daytime bottom trawl surveys in Lake Michigan during the fall. From these surveys, the relative abundance of important prey fish populations are measured for comparison over time, and estimates of lake wide biomass available to the bottom trawls can be generated (Hatch *et al.* 1981). The colonization and expansion of zebra mussels in Lake Michigan has gone largely unnoticed in the annual surveys as this bivalve was observed infrequently in the bottom trawls prior to 1999. However, in 1999, zebra mussels had become a significant portion of the catches. In this note, the geographical and bathymetric distributions of zebra mussels in the 1999 trawl survey are documented. These results represent the first lake-wide assessment of dreissenid abundance and distribution in Lake Michigan.

METHODS

The unit of sampling effort in the surveys was a 10-minute tow using a ¼ Yankee Standard number 35 bottom trawl (12-m headrope, 15.5-m footrope, and 13-mm mesh in the cod end) dragged on contour as described by Hatch *et al.* (1981). Tows were conducted at 9-m (5-fathom) depth increments ranging 9 to 110 m off established index locations

*Corresponding author: E-mail: guy_fleischer@usgs.gov

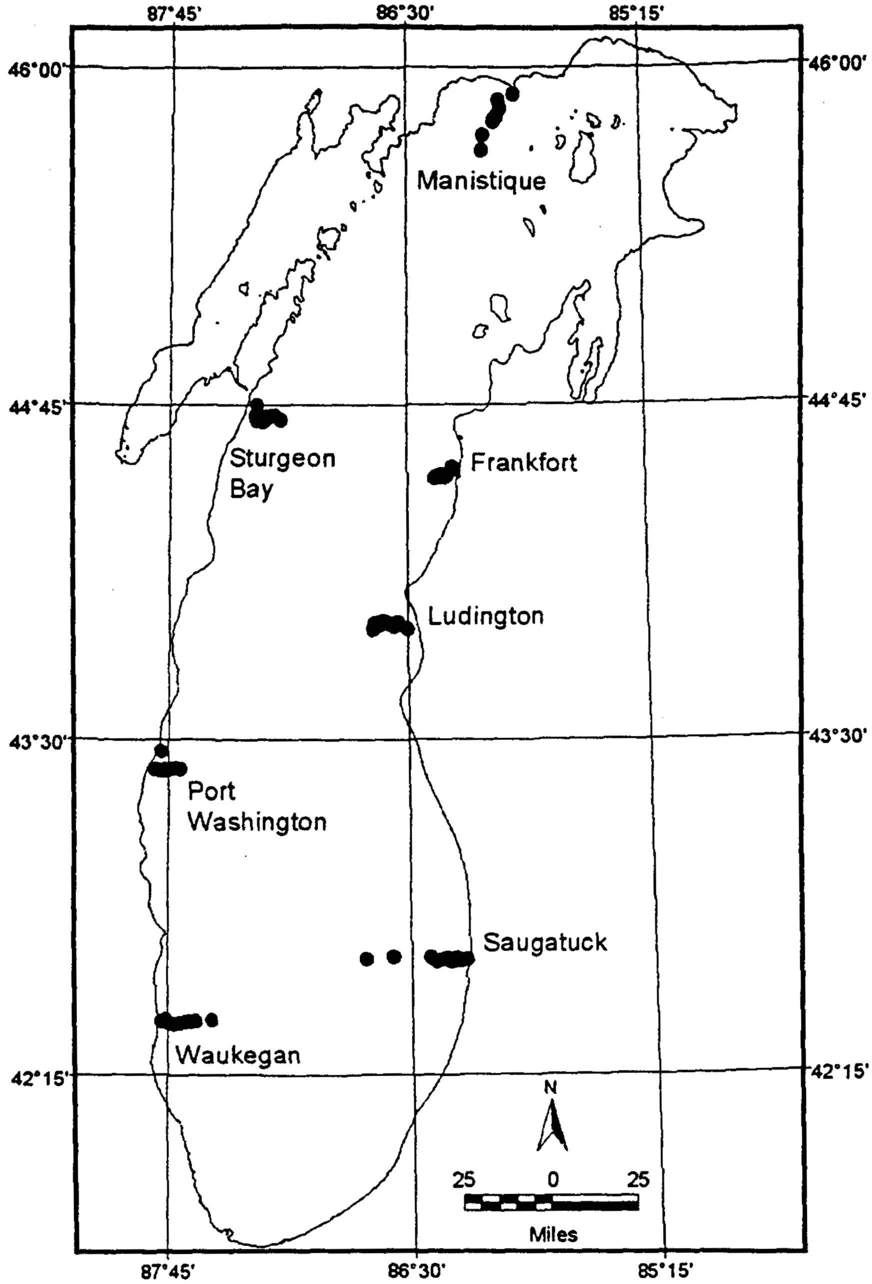

FIG. 1. Locations sampled with bottom trawls in fall 1999 on Lake Michigan by USGS Great Lakes Science Center. Each trawl site is indicted by a filled circle.

near Manistique, Frankfort, Ludington, and Saugatuck, Michigan; Waukegan, Illinois; and Port Washington and Sturgeon Bay, Wisconsin (Fig. 1).

Each trawl catch was sorted by species and weighed to the nearest gram—mass of all organisms was measured as wet weight and included shell and living tissue weight for the mussels. Large catches (> 20 kg) were subsampled, and total weight of the remainder of the large catch was apportioned by the weights of each species (both fish and mussels) in the subsample to estimate total weight caught for each species. All catch data were

TABLE 1. Biomass (kg/ha) of zebra mussels collected by location and depth from bottom trawl surveys conducted in Lake Michigan by USGS Great Lakes Science Center, 1999. Blanks indicate no sample.

	Sampling location						
Depth (m)	Frankfort	Waukegan	Manistique	Ludington	Port Washington	Saugatuck	Sturgeon Bay
9		0.00	0.00	0.52		0.00	
18	5.97	9.00	0.65	3.94	0.00	0.00	0.00
27	44.97	49.72	8.20	5.36	11.09	7.47	0.70
37	27.15	8.61	36.56	12.61	12.86	9.27	5.02
46	47.35	3.41	12.98	10.72	3.93	4.36	0.13
55	22.61	0.79	5.43	0.97	0.00	0.00	0.00
64	1.01	0.00	13.45	0.00	0.00	0.00	0.00
73	1.68	0.00	4.10	0.00	0.00		0.00
82	0.56		0.00			0.00	0.00
91	0.00	0.00	0.00	0.00	0.00	0.00	0.00
110	0.00		0.00	0.00	0.00	0.00	0.00
Location mean (pooled)	15.13	7.95	7.40	3.41	3.10	2.11	0.59

entered into an on-board electronic database. The estimates of biomass of organisms collected (weight of catch per unit area swept by trawl) included adjustments for greater net wingspread and difference in towing time (additional time net was on bottom) with depth (Fleischer *et al.* 1999).

The observed spatial patterns of *Dreissena* biomass were analyzed by application of a general linear model for analysis of variance and post hoc pair-wise (Tukey) comparisons, where the log-transformed biomass values were related to both depth and location. The observations reported here should be considered provisional in that it was assumed that zebra mussels were the only dreissenid present in fall 1999. More recently, the quagga (*Dreissena bugensis*) has been reported and confirmed in Lake Michigan (T. Nalepa 2000, Great Lakes Environmental Research Lab, Ann Arbor, MI, personal communication). It is likely that quaggas were present in the samples but were not recognized given their relatively low abundance, though the quagga can be distinguished from the zebra mussel by external morphology (Spidel *et al.* 1994). As such, this report is based principally on the status of zebra mussels, but recognizing that quagga mussels were probably present in the collections.

RESULTS AND DISCUSSION

Zebra mussels were found at all locations surveyed in 1999 (Table 1). Those catches, as well as the previously reported presence in Grand Traverse Bay and Green Bay (Marsden 1992), confirm that zebra mussels are distributed lake-wide in Lake Michigan, as forecast by Strayer (1991) and Ramcharan *et al.* (1992). Pooled mean biomass (kg/ha) of *Dreissena* was greatest off Frankfort, Manistique, and Waukegan (Table 1), though the pooled biomass off Waukegan was influenced by the very large catch at 27 m at this location (Table 1). Although originally established in southern Lake Michigan (Marsden 1992), it appears zebra mussels are now in greatest abundance in the northern and eastern-most portions of the lake. The analysis of variance model indicated a significant overall spatial and depth effect ($P < 0.001$, F = 12.15, df = 68) and a significant location effect ($P < 0.001$, F = 6.71, df = 6), where post hoc pairwise comparisons show that biomass at Frankfort was greater than biomass at all sites except Manistique, Waukegan, and Ludington ($P \leq .05$). Further, biomass at Manistique was greater than biomass at Sturgeon Bay, Saugatuck, and Port Washington ($P \leq .05$). These emerging geographic differences in population abundance may indicate conditions that are generally more favorable for zebra mussels in the northern and eastern portions of the lake, a pattern likely a reflection of their preference for hard or coarser substrate types (Berkman *et al.* 1998). Besides bathymetric or substrate features, the lake-wide density differences may also include effects of greater diatom availability in the north (Nalepa *et al.* 2000), an important food item of zebra mussels (Ten Winkel and Davids 1982). However, zebra

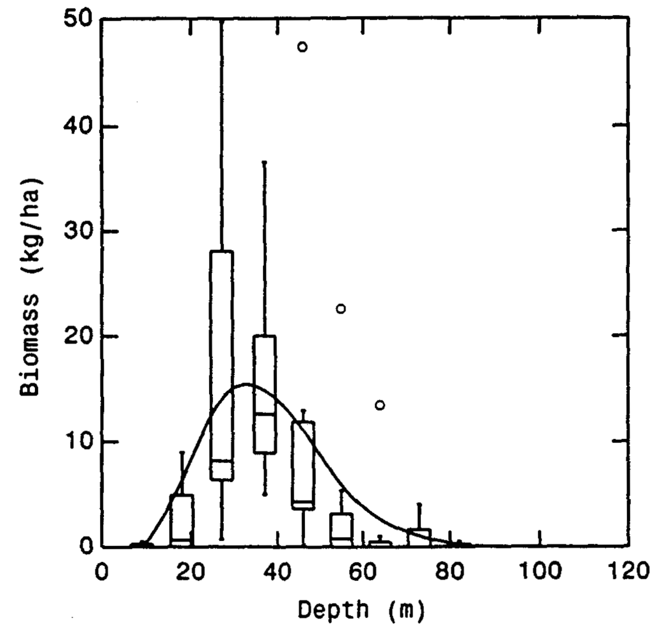

FIG. 2. Depth distribution of zebra mussels in Lake Michigan. Boxes indicate 25 and 75 percentiles, whiskers indicate 10 and 90 percentiles, and crossbars within boxes indicate medians for biomass (kg/ha) at each survey depth (outliers shown by individual circles). Line indicates plot (fit by least-squares smoothing) of mean biomass by depth.

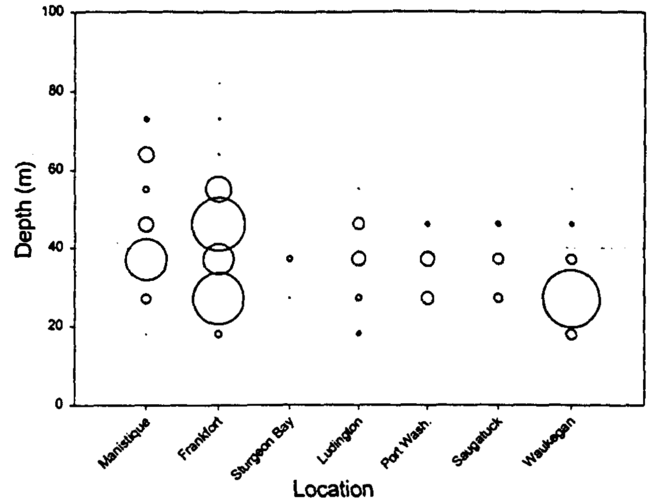

FIG. 3. Bubble plot of zebra mussel abundance by location and depth in Lake Michigan, 1999. Bubble diameter represents relative biomass for each sample.

mussel populations are dynamic and subject to wide variations in abundance (Strayer 1991) and measurements for any single year, especially in an incipient stage of colonization, may not necessarily be indicative of the long-term average density.

Zebra mussels in Lake Michigan were collected at 9 to 82 m, with their greatest concentrations at 27 to 46 m (Fig. 2). In Lake Ontario, zebra mussels were found to range to depths greater than 50 m (Mills *et al.* 1993), but were most abundant at 15 to 25 m (Mills *et al.* 1999). The greater depth range exhibited by dreissenids in Lake Michigan was most obvious at some of the northern locations (Fig. 3), where the general bathymetry is generally more pronounced and the lakebed is characterized by a predominance of coarse or hard bedrock outcrops (Dawson *et al.* 1997). Surficial geology and the slope of the lakebed in the immediate vicinity of the trawl sites undoubtedly affected the observed bathymetric distribution of dreissenids. However, substrate and bathymetry do not fully explain distributions at all depths and locations (e.g., low near shore abundances and the low overall abundance at Sturgeon Bay). The importance of these and additional factors will be easier to assess as dreissenid populations in Lake Michigan develop further. The bathymetric distribution of zebra mussels in Lake Ontario has also been affected by a subsequent establishment of the quagga mussel, which now dominates deeper areas (Mills *et al.* 1999). This same difference in depth distribution for the two dreissenids may develop in Lake Michigan.

The zebra mussel biomass estimates presented herein are reasonable for assessing regional- and depth-related patterns in abundance. However, these values are undoubtedly biased low when considered on an absolute basis due to gear inefficiency, resulting from the large mesh (8.9 cm) in the body of the trawl, and the avoidance of rocky bottom features, which are almost certainly more heavily colonized by zebra mussels. Nonetheless, the prevalence of zebra mussels in Lake Michigan is noteworthy in that they ranked fourth in weight by species in the 1999 bottom trawl catches and represented nearly 11% of the combined weight of all organisms caught. Direct comparison of zebra mussel biomass with fish biomass, however, may be misleading because of the relatively small portion of soft tissue weight in dreissenids (5 to 15 percent total weight) (Dermott *et al.* 1993).

Anticipated impacts of the zebra mussel population in Lake Michigan may be substantial and include those on primary productivity due to energetic demands (Madenjian 1995, Stoeckmann and Garton 1997), changes in the benthic macroinvertebrate populations (Ricciardi *et al.* 1997, Haynes *et al.* 2000) and trophic effects that can cascade along the food web (Hoyle *et al.* 1999, Johannsson *et al.* 2000). Further expansion and colonization by these mussels may also affect the ability to sample fish effectively in Lake Michigan. Large bycatches of zebra mussels in our bottom trawls may ultimately require conversion to a different design trawl, which would necessitate gear comparison studies to quantify any changes in fish catchability between the new and the previously established trawl gear (O'Gorman *et al.* 1999). Owing to the increased prevalence and potential ecological impacts, *Dreissena* biomass will be recorded annually as a regular component of the trawl fish survey.

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