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## Distribution of Zebra Mussels on Canadian navigation buoys on the Great Lakes, December 1993

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DISTRIBUTION OF ZEBRA MUSSELS ON  
CANADIAN NAVIGATION BUOYS ON THE  
GREAT LAKES, DECEMBER 1993

by

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## ABSTRACT

Wormington, A., C.A. Timmins, H. Johnston, and R.M. Dermott. 1995. Distribution of Zebra Mussels on Canadian navigation buoys on the Great Lakes, December 1993. Can. Manuscr. Rep. Fish. Aquat. Sci. 2281: 36 p.

During November and December 1993, navigational buoys ( $n = 252$ ) retrieved from Canadian waters (Lake Superior downstream to the outlet of Lake Ontario) were examined for the presence of attached Zebra Mussels (*Dreissena polymorpha*) and Quagga Mussels (*D. bugensis*). Attached mussels were found on 136 buoys, or 54.0% of the total. Mussels were absent from all buoys examined on Lake Superior and the North Channel of Georgian Bay. Mussels were attached to 16% of buoys in Georgian Bay and 40% in Lake Huron. Mussels were attached to most buoys from Lake St. Clair, the Detroit River, and Lake Erie. All of the buoys from Lake Ontario had attached mussels in 1993, as compared to only three buoys in December 1992. As in 1992, Quagga Mussels were present only on buoys east of Point Pelee in Lake Erie. They were present on all buoys with attached mussels from the central and eastern basins of Lake Erie. Quagga Mussels represented up to 100% of the attached mussels on buoys near Nanticoke, eastern Lake Erie. Quagga Mussels were present on 75% of the buoys from Lake Ontario; however, no Quagga Mussels were present on buoys in the Bay of Quinte during 1993.

## RÉSUMÉ

Wormington, A., C.A. Timmins, H. Johnston, and R.M. Dermott. 1995. Distribution of Zebra Mussels on Canadian navigation buoys on the Great Lakes, December 1993. Can. Manuscr. Rep. Fish. Aquat. Sci. 2281: 36 p.

En novembre et décembre 1993, on a examiné des bouées de navigation (n = 252) retirées des eaux territoriales canadiennes du lac Supérieur en aval jusqu'au d'egorgeoir du lac Ontario pour voir si des moules zébrées (*Dreissena polymorpha*) et des moules quagga (*D. bugensis*) étaient présentes. Des moules ont été trouvés sur 136 bouées, soit 54% du total. Toutes les bouées retirées du lac Supérieur et du chenal nord de la baie Georgienne étaient exemptes de moules. Des moules étaient présentes sur 16% des bouées de la baie Georgienne et 40% des bouées du lac Huron. Des moules étaient présentes sur la majorité des bouées du lac Sainte-Claire, de la rivière Detroit et du lac Érié. Toutes les bouées retirées du lac Ontario avaient des moules en 1993, en comparaison avec seulement trois bouées qui avaient des moules en décembre 1992. Comme en 1992, les moules quagga étaient plus abondantes dans la partie est du lac Érié. Ils étaient présentes sur toutes les bouées (avec des moules) retirées du bassin central et du bassin est du lac Érié. Les moules quagga représentaient jusqu'à 100% des moules fixées aux bouées près de Nanticoke, du lac Érié est. Les moules quagga étaient présentes sur 75% des bouées du lac Ontario, mais il n'y avait pas de moules quagga présentes sur les bouées de la baie Quinte pendant 1993.



## INTRODUCTION

The Zebra Mussel (*Dreissena polymorpha*) is now well established in the Great Lakes region of North America as a result of an accidental introduction in 1985 or 1986, likely by the discharge of ballast water into Lake St. Clair (Hebert et al. 1989; Griffiths et al. 1991a). With the continuing spread of the Zebra Mussel and the recent appearance in the Great Lakes of the genetically distinct *D. bugensis*, the Quagga Mussel (May & Marsden 1992; Rosenberg & Ludyanskiy 1994), various methods have been devised to monitor their spread and distribution patterns. On the Great Lakes, navigational buoys are placed and removed from shipping channels by various agencies on an annual basis. This procedure coincidentally provides a standard substrate available for mussel colonization over the growing season from known locations. The object of the present study was to document the distribution, relative abundance, and lengths of Zebra and Quagga mussels in the Canadian waters of the Great Lakes by examining these buoys. This was the last monitoring program by the Great Lakes Laboratory for Fisheries and Aquatic Sciences, Department of Fisheries and Oceans (DFO) in Burlington, which had been ongoing since the fall of 1989 for Lake Ontario and the upper St. Lawrence River (MacEachen et al. 1992; Wormington et al. 1993). Similar studies have also been conducted on the U.S. side of the Great Lakes (Hall 1991), the U.S. waters of the St. Lawrence River (Conn 1991), and the Canadian waters of the St. Lawrence River (Hendrick et al. 1993). The distribution of Zebra Mussels on navigational buoys from the lower St. Lawrence had been examined by the Centre Saint-Laurent in Montréal (Mongeau & Jacquaz 1991).

## METHODS

Navigation buoys were examined by one or more of the authors at Canada Coast Guard stations (and other storage facilities) after they were removed from the water at the end of the shipping season (November to December 1993). The buoys are normally placed in the shipping channels in early April. Buoys as far east (downstream) as the outlet from Lake Ontario into the St. Lawrence River were examined. Generally, Lake Superior and most of the Lake Huron buoys were examined at Parry Sound; Lake Erie buoys at Amherstburg and Nanticoke; and Lake Ontario and Bay of Quinte buoys at Prescott. At the various docking facilities, the distinctive number on each buoy and the buoy type were recorded. Using the distinctive numbers on each buoy, their exact position in the lakes could be determined from information supplied by the Canadian Coast Guard (Anonymous 1992). Buoys were carefully examined for the presence of either Zebra Mussels or Quagga Mussels. Particular attention was directed at weld seams and surface junctions, as this is where mussels preferably attach. If buoys were placed on their sides, and were of a type with hollow interiors, the presence of mussels on the inside was noted. Where the density of mussels was low, the total number of mussels-per-buoy was determined by counting all mussels that were present on the buoy. Where the number of mussels was excessive, sub-sampling, using quadrates of known areas was completed. The densities of the

mussels and their sizes were not measured on many of the buoys from Lake St. Clair, the Detroit River, or Lake Erie.

If the mussels were abundant, about 100 would be randomly collected for later analysis of mussel lengths and/or ratio of Zebra Mussels to Quagga Mussels. Otherwise, all attached mussels on the buoys were collected. Shell lengths were measured to the nearest mm. Mussels collected from each buoy were separated into small (<4 mm), medium, and large (>12 mm) size classes. For Lake Erie, where populations of mussels were extremely dense, only animals retained on a 2 mm mesh screen were counted and measured.

Most buoys in this study were of four distinct types (see Figures 7 to 10): 2-foot spar; 4-foot can (cone); 6-foot can (cylinder); and 9-foot buoy (saucer or bell). Some uncommon buoys were also examined for the presence of mussels. An estimate of the wet surface area of each buoy type (area below the water line) was calculated with measurements taken while the buoys were on the docks. Density estimates were determined as abundance per m<sup>2</sup>. Only the 6-foot and 9-foot type buoys had hollow, ballast interiors. During this survey, the external wetted area of the buoys (area below the water line) was calculated as 6.098 m<sup>2</sup> (4-foot can); 10.968 m<sup>2</sup> (6-foot can); and 7.221 m<sup>2</sup> (9-foot buoy). The external wetted area of the smaller spar, styrene, and Quinte buoys was not measured.

During 1994, only buoys from the Bay of Quinte in eastern Lake Ontario, and Georgian Bay, near Midland were examined. These results are also included in this report, as the distribution of *Dreissena* is still expanding in these areas.

Results of the study were compared to similar surveys that have been conducted in previous years covering Canadian waters (Dermott et al. 1991; Mongeau & Jacquaz 1991; MacEachen et al. 1992; and Wormington et al. 1993).

## RESULTS

### REGIONWIDE

Across the entire survey area, 252 buoys of various types were examined for the presence of either Zebra or Quagga mussels during November and December 1993. Of this total, 136 (54.0%) had mussels of either species. Of the buoys that had mussels, Zebra Mussels were on 132 (97.1%), while 49 buoys (36.0%) had attached Quagga Mussels. Of the buoys that had mussels, only four buoys from Lake Erie had attached Quagga Mussels but not Zebra Mussels. The percentage of Quagga Mussels on any single buoy, compared to Zebra Mussels, ranged from under 1% on nine buoys (all in Lake Ontario including Kingston Harbour) to 100% on the four buoys in eastern Lake Erie.

During 1993, Zebra Mussels were found as far upstream in the Great Lakes as Stokes Bay Entrance (VK) in Lake Huron. The densities of Zebra Mussels reached 80 600 m<sup>-2</sup> on buoy E9 (Pelee Passage) in western Lake Erie, where Zebra Mussels have been present since 1988. However, the recently colonized Kingston Harbour (which had no mussels at all in 1992) had up to 76 350 m<sup>-2</sup> (buoy K1 at Myles Shoal). Mussels were found on buoys in the Bay of Quinte for the first time in 1993. By November 1994, mussel populations in the Bay of Quinte increased such that all buoys examined in 1994 had attached mussels.

Quagga Mussels were found only on buoys from Port Stanley in central Lake Erie, downstream to include all of Lake Ontario (including Kingston Harbour). Since 1992, Quagga Mussels have become common in the central basin as far west as Wheatley (near Point Pelee). No Quagga Mussels were found on the buoys from the Bay of Quinte. Relatively high percentages of Quagga Mussels (compared to Zebra Mussels) were found on buoys in central and eastern Lake Erie. For example, in this area 11 of the 15 buoys analyzed for comparative percentages had greater than 40% Quaggas, while eight of 15 (53.3% of buoys) had greater than 60% Quaggas. In 1993, the highest proportion of Quagga Mussels on Great Lakes buoys (100%) was found on four buoys from eastern Lake Erie.

#### Lake Superior

A total of four buoys were examined, with no mussels found (Table 1). The buoy J8 at Holden Shoal is located in the north-central portion of the lake (Nipigon Bay area) and buoy JC at Barwis Rock is located in the Simpson Channel. The location of the Weather buoys AES-3D07Z and AES-3D09Z is unknown. The buoys from Thunder Bay were not examined in 1993.

#### North Channel/St. Marys River

No mussels were found on the 15 buoys examined from the North Channel/St. Marys River area (Table 1).

#### Georgian Bay

A total of 50 buoys from Georgian Bay were examined in 1993 (Fig. 1) and of these, eight (16.0%) had attached Zebra Mussels (Table 2). The density of mussels on the buoys was very low, with the maximum being 5.4 m<sup>-2</sup> on buoy MM8 (Port McNicoll). The mean length of Zebra Mussels from Georgian Bay in 1993 was 11.5 mm (n = 147), with a range of 3-16 mm. Data from the limited number of buoys examined in November 1994 indicated the mussels had spread northeast to attach to buoys MN6 at the east side of Beausoleil Island and C75 and C78 at Honey Harbour. When examined in late November 1994, these spar buoys had remained in the water for two years. The average mussel length ranged between 13.6 mm and 19.0 mm. A maximum of only five Zebra Mussels per buoy was found on these buoys in November 1994.

Also, while mussel colonies are present at Collingwood Harbour, no mussels were found on the buoys from the harbour (TN21).

### Lake Huron

Of the 10 buoys examined, four (40%) had Zebra Mussels (Fig. 1). The density of mussels on the buoys was very low, with a maximum of 5.0 m<sup>-2</sup> on buoy VJ2 (Southampton). For the Lake Huron buoys, the mean length of Zebra Mussels was 4.2 mm (n = 70), with a range of 1-17 mm (Table 3).

### St. Clair River

Of the 15 buoys examined from the St. Clair River, only three buoys (20.0%) had attached Zebra Mussels (Fig. 2). The three buoys with mussels on the St. Clair River had only one or two mussels each (Table 4).

### Lake St. Clair

Sixteen of the 20 buoys (80%) examined from Lake St. Clair had Zebra Mussels (Fig. 2). Relative densities of mussels on these buoys ranged from "one only" to "heavy" (Table 4).

### Detroit River

A total of 41 buoys were examined, of which 28 (68.3%) had Zebra Mussels (Fig. 2). Densities ranged from "one only" to "moderate" (Table 4).

### Western Lake Erie

Of the nine buoys examined (all from Pelee Passage), all had attached Zebra Mussels (Fig. 3). Of the six buoys which were quantitatively analyzed, all had very high densities of attached Zebra Mussels. The densities of mussels on the buoys ranged from a minimum of 8250 m<sup>-2</sup> to a maximum of 80 600 m<sup>-2</sup>. On the western Lake Erie buoys, the mean length of the Zebra Mussels was 7.2 mm (n = 978), with a range of 1-15 mm (Table 5).

### Central Lake Erie

Only a single buoy located "two miles off" Port Stanley (meteorological) was examined (Fig. 3). This buoy had both Zebra Mussels (61%) and Quagga Mussels (39%). The mean length of the Zebra Mussels was 5.2 mm (n = 126), with a range of 1-12 mm. The mean length of the Quagga Mussels was 10.1 mm (n = 79), with a range of 2-14 mm (Table 6). No other large buoys were retrieved from the Canadian side of the central basin.

### Eastern Lake Erie

All 24 buoys in eastern Lake Erie had attached mussels (Fig. 3). All buoys had attached Quagga Mussels (100%), but only 20 buoys (83.3%) had Zebra Mussels. The percentage of Quagga Mussels on the buoys (as a proportion of total mussels) ranged from 8% to 100%. However, excluding the one buoy (E at Port Colborne) on which only 8% of the mussels were Quagga, the minimum percentage of Quagga Mussels on the buoys increased to 30% (Table 6). The mean length of Zebra Mussels was 3.1 mm ( $n = 878$ ), with a range of 1-12 mm. The mean length of Quagga Mussels was 3.4 mm ( $n = 1433$ ), with a range of 1-12 mm (Table 6).

### Lake Ontario (including Kingston Harbour)

A total of 32 buoys from Lake Ontario were examined of which all had attached mussels (Fig. 4). All buoys had Zebra Mussels, while 24 buoys (75%) also had attached Quagga Mussels. Included in these statistics are the three buoys at Kingston Harbour, all of which also had both Zebra and Quagga mussels (Table 7). The greatest density of mussels in Lake Ontario (excluding Kingston Harbour) was 52 867  $m^{-2}$  on buoy KN3 (Salmon Island) and the highest density found in Kingston Harbour (buoy K1 at Myles Shoal) was 76 350  $m^{-2}$  (Table 7). The percentage of Quagga Mussels found on Lake Ontario buoys ranged from 0% (six different buoys) from the area near Toronto and the area near Main Duck Island, to 33% (MV4) at Oshawa Harbour. The highest percentages of Quagga Mussels on the Lake Ontario buoys were found on the buoys from the north shore, 33% at Oshawa and 28% on buoy P at Presqu'île.

The mean length of Zebra Mussels on the Lake Ontario buoys (not including Kingston Harbour) was 6.8 mm ( $n = 2703$ ), with a range of 1-15 mm; the mean length of Quagga Mussels was 8.3 mm ( $n = 188$ ), with a range of 2-13 mm. At Kingston Harbour, the mean length of mussels was slightly higher: the mean length of Zebra Mussels was 7.5 mm ( $n = 402$ ), with a range of 1-12 mm, and the mean length of Quagga Mussels was 8.4 mm ( $n = 22$ ), with a range of 4-14 mm (Table 7).

### Bay of Quinte

In the Bay of Quinte during December 1993, a total of 31 buoys were examined (Fig. 5). Of this total, only 11 buoys (35.5%) had attached mussels, all of which were Zebra Mussels. Densities of attached Zebra Mussels ranged from "one total" (QT at Trent River Entrance) to 125  $m^{-2}$  (Q52 at Minnie Blakely Shoal). The mean length of Zebra Mussels on the Bay of Quinte buoys was 11.2 mm ( $n = 172$ ), with a range of 4-16 mm (Table 8). The distribution of mussels in the Bay of Quinte (Fig. 5) suggests that colonization occurred from populations in the marinas of Trenton or Belleville, or from established populations further upstream in Rice Lake.

During December 1994, all of the buoys from the Bay of Quinte had attached mussels (Fig. 6). Thirteen buoys were picked randomly from the lower to upper bay and examined. Densities increased from "1 total" (Q1 at Adolphus Reach) to 23 250 m<sup>-2</sup> in Belleville Harbour (Q54). The mean length was 9.1 mm and the range was 2-22 mm (Table 9). Although Quagga Mussels were present on buoys from the entrance to the bay (Upper Gap), no Quagga Mussels were found attached to the buoys on the Bay of Quinte.

#### Other Areas

Three buoys were examined from the Muskoka District, but no mussels were found. These buoys are not included in the statistics for the Great Lakes as a whole.

#### Unknown Areas

A total of nine buoys from unknown areas were examined, but no mussels were found. These buoys are not included in the statistics.

### DISCUSSION

The primary distribution of *Dreissena* on the navigational buoys of the Great Lakes continues to reflect the downstream drift of veliger larvae from the initial North American introduction at Lake St. Clair, despite its localized presence at major ports upstream in the Great Lakes. Absence of mussels on the buoys from Lake Superior, northern Lake Huron and most of Georgian Bay is a result of few local populations and poor growth conditions due to the low temperatures, and low algae and calcium levels in these lakes. In spite of the established mussel colonies along southern Lake Huron, near Goderich on the east shore and Saginaw Bay on the west side (Anonymous 1991a), most of the navigational buoys of Lake Huron were not colonized. Therefore, in Lake Huron, the buoys did not provide a good indication of the Zebra Mussel distribution pattern.

The lack of attached mussels on the buoys from the St. Clair River and northern Lake St. Clair reflect the rapid flow rate of Lake Huron water by these sites. Veligers released by mussel colonies in the upper St. Clair River would drift downstream to Lake St. Clair within 21 hours (Griffiths et al. 1991b), well short of the up to four weeks required for transformation into settling mussels (Mackie 1991). However, mussel colonies are present along the riverbanks from Sarnia, downstream to Lake St. Clair.

## HISTORICAL DISTRIBUTION ON THE LOWER GREAT LAKES

Although no navigational buoys from Lake Erie were examined by DFO personnel during 1989, mussels had colonized 100% of the buoys between the Detroit River and Sandusky, Ohio in that year (Lancaster 1990). During 1989, coverage on the American buoys in Lake Erie decreased eastward in the lake with only 20% coverage at Erie, Pennsylvania and 5% coverage at Buffalo, New York. During December 1989, 25 buoys from Lake Ontario and 107 buoys from the St. Lawrence River had been examined. At that time, only three of the buoys between the Niagara River and the Quebec border had attached mussels. Three Zebra Mussels (4.8 to 6 mm) were present on a single buoy (red 2) retrieved from Lake Ontario, offshore from the Niagara River. All other mussels were on two buoys (#16 and #17) immediately downstream from the Snell Locks at Massena, New York, having a size range of 7.2 to 16.7 mm. The maximum number of mussels was 56 on buoy 17 (DFO, unpublished data). This indicates that the population in the locks was a result of a secondary introduction.

During December 1990, all the examined buoys retrieved from Lake Erie by the Canadian Coast Guard had attached mussels; however, no estimates of density were made. In December 1990, the only Canadian buoys from Lake Ontario with attached mussels were from Toronto Harbour and westward (Dermott et al. 1991). No buoys from U.S. territorial waters have been examined by DFO since 1989. The distribution of mussels in Lake Ontario during 1990 reflected the general counter clock-wise circulation in the lake. Veligers, entering Lake Ontario from the Niagara River, drift eastward in the Niagara Plume along the south shore of Lake Ontario toward Rochester and Oswego, New York. Currents then move further along the east side of the lake toward the outlet of the St. Lawrence River. On the north shore of Lake Ontario, currents tend to move from Toronto westward toward Hamilton. The northeast shore of Lake Ontario, lacking major ports as secondary introduction points of mussels, was furthest from the main source of veligers that enter the lake at the Niagara River. By December 1990, Zebra Mussels were present along the south side as far east as Rochester and on many of the buoys in the St. Lawrence River between the Snell Locks at Massena, New York and the tidal-zone reaches of the river below Quebec City (Mongeau & Jacquaz 1991).

By the fall of 1991, Zebra Mussels had colonized most of Lake Ontario except the northeast shore. At that time, densities on Canadian buoys were greatest on W at Port Weller with 8300 m<sup>-2</sup>, and on a meteorological buoy off Hamilton (Grimsby) with 5500 m<sup>-2</sup>. A reproducing population of Zebra Mussels, probably introduced by commercial shipping from Lake Erie, has been present in Hamilton Harbour since the fall of 1990. Most of the buoys in the upper St. Lawrence River had attached mussels during December of 1992. The established population in the Snell Locks at Massena continued to supply veligers to the buoys in Lake St. Francis (MacEachen et al. 1992) and further downstream to Quebec City (Louise Lapierre, Centre Saint Laurent, personal communication).

In both 1991 and 1992, no mussels were observed on any of the buoys from the Bay of Quinte in northeast Lake Ontario. However, Zebra Mussels had been reported in 1990 at cement plants on the Bay of Quinte at both Picton and Bath (Schaner 1991). Mussel colonies were also present at the entrance to the Bay of Quinte and upstream at Rice Lake (Anonymous 1991b). Prior to 1993, reproduction within the Bay of Quinte had been either minor, or the veligers drifted out of the lower bay before transforming into the settling stage.

## PRESENCE OF QUAGGA MUSSELS

The round-shelled Quagga Mussels (*D. bugensis*) were found at the Lake Erie end of the Welland Canal as early as 1989 (Dermott 1993). In 1990, three small mussels, with shell features suggestive of Quagga Mussels, were collected from the meteorological buoy off Port Stanley, Lake Erie, representing 3.5% of the attached mussels. In the same year, the proportion of Quagga Mussels on buoy W at Port Weller, Lake Ontario was 1.2%.

During October 1991, additional meteorological buoys and moorings removed from Lake Erie at Long Point and Rondeau also had large numbers of attached Quagga Mussels. These represented up to 85% of the attached mussels (buoy from the tip of Long Point) and 68% of the larger (>5 mm) mussels in the central basin of Lake Erie (off Rondeau). In 1991, only two specimens of the 118 mussels collected from the Port Weller buoy (W) were Quagga Mussels (1.7%). The only other buoy from the Canadian side of Lake Ontario in 1991 with attached Quagga Mussels was that from outer Toronto Island (buoy TE18) which had one Quagga Mussel out of the 162 attached mussels (0.6%). The buoys from the Toronto area continued to have a relatively high proportion of Quagga Mussels in 1993 as compared to the rest of Lake Ontario. By December 1991, almost all the buoys from the St. Lawrence which had attached *Dreissena polymorpha*, also had attached *D. bugensis*. The proportion of Quagga Mussels ranged between 6% and 72% on individual buoys, with the greatest proportion on buoys west of Wolfe Island at the entrance to the St. Lawrence River. However, total mussels on these buoys from the upper river averaged only six mussels per buoy.

During 1992, the proportion of Quagga Mussels on Lake Erie buoys had increased from 0% in the western basin to 94% on buoy E3 in the eastern basin. This reflected the general increase in proportion of Quagga Mussels among the *Dreissena* populations from west to east, which was especially high in the vicinity of Long Point. The increased proportion of Quagga Mussels on offshore buoys may be due to the apparently lower temperature preference of the Quagga Mussels. Data from both Lake Erie (Dermott 1993) and Lake Ontario (Mills et al. 1993) indicate that the proportion of this dreissenid becomes greater with increased depth. By 1993, the proportion of Quagga Mussels on buoys from the Nanticoke area in eastern Lake Erie was very high, reaching 100% of the total attached mussels. Data from the vicinity near Nanticoke during the fall of 1994, indicated that Zebra Mussels are now rare along the north shore of the eastern basin of Lake Erie (<1 in 100). Downstream in Lake Ontario, the proportion of Quagga Mussels

on the buoys was considerably less, averaging 6.3%. The reasons for the reduction in the abundance of Quagga Mussels at the east end of Lake Ontario during 1993 as compared to 1992 are not known. As of the fall of 1994, Quagga Mussels have yet to be reported further upstream in the Great Lakes than in western Lake Erie off the city of Monroe, Michigan. Specimens have been reported only from Lakes Erie and Ontario, the St. Lawrence River, and the Erie Canal between Buffalo and Syracuse, New York.

In Lake Erie, on most of the buoys where both species of *Dreissena* existed, the average size of the measured Quagga Mussels was slightly larger than the average size of the Zebra Mussels on the same buoy. In both 1992 and 1993, the difference was greatest on the buoy offshore from Port Stanley. There is insufficient evidence to judge if the growth rate of the Quagga Mussels was faster than the Zebra Mussels. Unpublished data (S.J. Nichols, US National Biol. Survey) suggests that Quagga Mussels begin reproduction earlier in the spring, so they would settle on the buoys before the Zebra Mussels.

Populations of Zebra Mussels have only recently increased in the Bay of Quinte. However, high densities (to 52 800 m<sup>-2</sup>) were present on the buoys near the lower end of the bay during 1993, especially on the buoys at the Upper Gap (KM2), Salmon Island, and the Lower Gap (KN3) at the west and east ends of Amherst Island respectively. Zebra and Quagga Mussels have been common in the lower Bay of Quinte only since fall 1993. By the fall of 1994, Zebra Mussels were common throughout the bay on both hard substrates and the navigation buoys. However, Quagga Mussels were present on rock substrates only in the lowermost portion of the Bay of Quinte and the Upper Gap leading into Lake Ontario.

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## REFERENCES

- Anonymous, 1991a. North American range of the Zebra Mussel as of 18 January 1991. *Dreissena polymorpha* Information Review 2(1): 10.
- Anonymous, 1991b. Zebra Mussel Distribution. Ontario Ministry of Natural Resources, Maple, Ontario. Unpublished. 1 Map.
- Anonymous, 1992. Inland Waters: List of Lights, Buoys and Fog Signals. Canadian Coast Guard, Marine Navigation Services, Ottawa. 236 p.
- Conn, B. 1991. Colonization of navigational buoys by Zebra Mussels (*Dreissena polymorpha*) in the St. Lawrence River. *Dreissena polymorpha* Information Review 2(1): 5.
- Dermott, R., C. Timmins, and J. Leslie. 1991. Distribution of Zebra Mussels on navigation buoys from Lake Ontario and upper St. Lawrence River in December 1990. Great Lakes Laboratory for Fisheries and Aquatic Sciences, Burlington, Ontario. Unpublished Report. 5 p.
- Dermott, R. 1993. Distribution and ecological impact of Quagga Mussels in the lower Great Lakes. Paper presented at the Third International Zebra Mussel Conference, February 23-26, 1993. Toronto, Ontario.
- Griffiths, R.W., D.W. Schloesser, J.H. Leach, and W.P. Kovalak. 1991a. Distribution and dispersal of the Zebra Mussel (*Dreissena polymorpha*) in the Great Lakes region. *Can. J. Fish. Aquat. Sci.* 48: 1381-1388.
- Griffiths, R.W., S. Thornley, and T.A. Edsall. 1991b. Limnological aspects of the St. Clair River. *Hydrobiol.* 219: 97-123.
- Hall, W. 1991. Zebra Mussel colonization on Great Lakes buoys. *Dreissena polymorpha* Information Review 2(6): 4.
- Hebert, P.D.N., B.W. Muncaster, and G.L. Mackie. 1989. Ecological and genetic studies on *Dreissena polymorpha* (Pallas): A new mollusc in the Great Lakes. *Can. J. Fish. Aquat. Sci.* 46: 1587-1591.

- Hendrick, A., S.R. LaPan, R. Dermott, and B. Timmins. 1993. 1992 St. Lawrence River Zebra Mussel monitoring program. In 1992 Annual Report, St. Lawrence River sub-committee to the Lake Ontario committee and the Great Lakes Fishery Commission.
- Lancaster, C.T. 1990. Buoy survey of the United States Coast Guard, 1989. Report to T.F. Nalepa, NOAA, dated 10 January. 1 p.
- MacEachen, C., C. Timmins, and R. Dermott. 1992. Distribution of Zebra Mussels on navigation buoys from Lake Ontario and upper St. Lawrence River in December 1991. Great Lakes Laboratory for Fisheries and Aquatic Sciences, Burlington, Ontario. Unpublished Report. 16 p.
- Mackie, G.L. 1991. Biology of the exotic Zebra Mussel, *Dreissena polymorpha*, in relation to native bivalves and its potential impact in Lake St. Clair. *Hydrobiol.* 219: 251-268.
- May, B., and J.E. Marsden. 1992. Genetic identification and implications of another invasive species of dreissenid mussel in the Great Lakes. *Can. J. Fish. Aquat. Sci.* 49: 1501-1506.
- Mills, E.L., R.M. Dermott, E.F. Roseman, D. Dustin, E. Mellina, D.B. Conn, and A.P. Spidle. 1993. Colonization, ecology, and population structure of the "quagga" mussel; (Bivalvia: Dreissenidae) in the lower Great Lakes. *Can. J. Fish. Aquat. Sci.* 50: 2305-2314.
- Mongeau, F. and B. Jacquaz. 1991. Abondance et distribution des moules zebrees (*Dreissena polymorpha*) dans le Fleuve Saint-Laurent. Centre Saint-Laurent, Environnement Canada, Montréal, Québec. Unpublished. 27 p.
- Rosenberg, G. and M.L. Ludyanskiy. 1994. A nomenclature review of *Dreissena* (Bivalvia: Dreissenidae), with identification of the Quagga Mussel as *Dreissena bugensis*. *Can. J. Fish. Aquat. Sci.* 51: 1474-1484.
- Schaner, T. 1991. OMNR's Zebra Mussel monitoring program on Lake Ontario, 1990. Chapter 5. In Lake Ontario Fisheries Unit 1990 Annual Report, Ontario Ministry of Natural Resources.
- Wormington, A., C.A. Timmins, and R.M. Dermott. 1993. Distribution of Zebra Mussels on navigation buoys on the Great Lakes and upper St. Lawrence River, December 1992. *Can. Manuscr. Rep. Fish. Aquat. Sci.* 2186: 35 p.



**TABLE 1. BUOYS EXAMINED WITHOUT ANY INDICATION OF ATTACHED ZEBRA MUSSELS OR QUAGGA MUSSELS, DECEMBER 1993.**

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**Lake Superior**

J8                      Weather AES - 3D07Z  
 JC                      Weather AES - 3D09Z

**North Channel / St. Marys River**

JD14	J31	J66	J74	KE4
J19	J44	J71	KC2	K8
J24	J56	J72	KE3	UV2

**Georgian Bay**

AL	H13	M3	P24	TN2
D	H19	P1	P26	TN11
EA2	H21	P2	P27	TN21
EE5	J12	P7	P28	T5
EE6	J13	P10	P30	T7
E1	J16	P13	P35	T9
E11	J17	P16	P37	
H	MC4	P19	P46	
H12	M2	P22	Parry Sound (private)	

**Muskoka District**

A14	A19	C2		
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**Lake Huron**

JH1	JS5	VC2		
JS2	JS8	2		

**St. Clair River**

AM	A22	A36	A46	A60
AMB	A24	A44	A54	X50
A14	A30			

**Lake St. Clair**

XP1	XP2	XY3	XY6	
-----	-----	-----	-----	--

**Detroit River**

DL1	D35	D44	D50	D63
DL6	D36	D45	D57	D73
D32	D37	D46		

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**TABLE 1: BUOYS WITHOUT MUSSELS (continued)**

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**Western Lake Erie**

- all buoys examined had mussels

**Central and Eastern Lake Erie**

- all buoys examined had mussels

**Lake Ontario (including Kingston Harbour)**

- all buoys examined had mussels

**Bay of Quinte**

JVB	QP9	Q3	Q22	Q74
Q	QP13	Q11	Q40	U11
QP5	QT16	Q13	Q41	U13
QP8	Q1	Q17	Q72	U20

**Locations Not Known**

A12	A118	D70	KA2	TN2
A110	A126	HV2	K3	

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**TABLE 2. SPATIAL DISTRIBUTION OF ZEBRA MUSSELS: GEORGIAN BAY, DECEMBER 1993.**

Buoy Number	Buoy Type	Abundance (m <sup>-2</sup> )	percent of total	# collected			Average / Range (n = total mussels)
				<4S	M	L>12	
<u>Roberts Island</u> MK	"triangle"	2 total	Z = 100 % Q = 0 %	0	1	1	x = 10.5 mm / 8–13 mm (n = 2) -----
<u>Port McNicoll</u> MM8	4' can	5.4 m <sup>-2</sup>	Z = 100 % Q = 0 %	0	8	21	x = 13.1 mm / 6–16 mm (n = 29) -----
<u>Flat Point</u> MM4	4' can	4.9 m <sup>-2</sup>	Z = 100 % Q = 0 %	0	7	23	x = 13.0 mm / 6–16 mm (n = 30) -----
<u>Midland Bay Shoal</u> M20	4' can	2.5 m <sup>-2</sup>	Z = 100 % Q = 0 %	0	10	3	x = 11.3 mm / 7–13 mm (n = 13) -----
<u>Candlemas Shoal</u> M13	6' can	5.0 m <sup>-2</sup>	Z = 100 % Q = 0 %	0	42	13	x = 11.0 mm / 4–15 mm (n = 55) -----
<u>Pinery Point</u> M12	4' can	1.5 m <sup>-2</sup>	Z = 100 % Q = 0 %	0	9	1	x = 9.4 mm / 4–13 mm (n = 10) -----
<u>Brébeuf-McNicol</u> M8	6' can	0.6 m <sup>-2</sup>	Z = 100 % Q = 0 %	2	5	0	x = 7.9 mm / 3–11 mm (n = 7) -----
<u>Sawlog Point</u> M6	6' can	0.1 m <sup>-2</sup>	Z = 100 % Q = 0 %	0	1	0	x = 5.0 mm / 5 mm (n = 1) -----

**TABLE 3. SPATIAL DISTRIBUTION OF ZEBRA MUSSELS: LAKE HURON DECEMBER 1993.**

Buoy Number	Buoy Type	Abundance (m <sup>-2</sup> )	percent of total	# collected			Average / Range (n = total mussels)
				<4S	M	L>12	
<u>Stokes Bay Entrance</u> VK	6' can	1.1 m <sup>-2</sup>	Z = 100 % Q = 0 %	8	4	0	x = 3.3 mm / 1–5 mm (n = 12) -----
<u>Southampton</u> VJ2	9' saucer	5.0 m <sup>-2</sup>	Z = 100 % Q = 0 %	17	19	0	x = 3.5 mm / 1–11 mm (n = 36) -----
<u>Saugeen River</u> VJ3	4' can	4.3 m <sup>-2</sup>	Z = 100 % Q = 0 %	10	8	4	x = 5.9 mm / 1–17 mm (n = 22) -----
<u>Kettle Point Reef</u> V4	6' can	not counted	Z = 100 % Q = 0 %	all < 1 mm			not measured -----

**TABLE 4. SPATIAL DISTRIBUTION OF ZEBRA MUSSELS: ST. CLAIR RIVER, LAKE ST. CLAIR AND DETROIT RIVER, DECEMBER 1993.**

<u>Buoy #</u>	<u>Buoy Type</u>	<u>Abundance</u>	<u>% Zebra</u>
<u>Bay Point</u> (St. Clair River)			
A66	6' can	1 only	100 %
A68	6' can	1 only	100 %
A70	6' can	2 only	100 %
<u>Martin Island</u> (Lake St. Clair)			
XE2	4½' light buoy	heavy	100 %
<u>St. Clair Cutoff</u> (Lake St. Clair)			
X32	6' can	moderate (253)	100 %
<u>Thames River mouth</u> (Lake St. Clair)			
T	4½' light buoy	heavy	100 %
<u>Ruscom River</u> (Lake St. Clair)			
XK1	small styrene	light	100 %
XK3	small styrene	moderate	100 %
XK4	small styrene	light	100 %
XK5	small styrene	light	100 %
XK6	small styrene	trace	100 %
XK7	small styrene	moderate	100 %
<u>Puce River</u> (Lake St. Clair)			
XY1	small styrene	light	100 %
XY2	small styrene	trace	100 %
XY4	small styrene	trace	100 %
XY5	small styrene	light	100 %
<u>Pike Creek</u> (Lake St. Clair)			
XP3	small styrene	1 only	100 %
XP5	small styrene	trace	100 %
XP6	small styrene	22	100 %
<u>Peche Island</u> (Detroit River)			
DP7	4' can	trace	100 %
DP5	4' can	light	100 %
DP2	4' can	light	100 %
DPB	6' can	moderate	100 %
D110	6' can	moderate	100 %
<u>N of Fighting Island</u> (Detroit River)			
DL5	6' can	5 only	100 %
D108	6' can	moderate	100 %
DQ	4' can	light (74)	100 %
D104	6' can	light	100 %
D102	4' can	trace	100 %

**TABLE 4: ST. CLAIR RIVER, LAKE ST. CLAIR AND DETROIT RIVER  
(continued)**

<u>Buoy #</u>	<u>Buoy Type</u>	<u>Abundance</u>	<u>% Zebra</u>
<u>Grosse Ile (Detroit River)</u>			
D6B	6' can	light (32)	100 %
D84	4' can	2 only	100 %
D78	6' can	10 only	100 %
D76	6' can	light	100 %
D74	6' can	light (67)	100 %
D72	6' can	light (119)	100 %
D68	6' can	light (86)	100 %
<u>Amhersburg Channel (Detroit River)</u>			
D67	6' can	1 only	100 %
D64	6' can	7 only	100 %
D60	6' can	1 only	100 %
D59	6' can	a few only	100 %
D56	6' can	1 only	100 %
D55	4' can	7 only	100 %
D52	6' can	4 only	100 %
D43	6' can	5 only	100 %
D38	6' can	a few only	100 %
D31	6' can	1 only	100 %
D24	6' can	2 only	100 %

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**TABLE 5. SPATIAL DISTRIBUTION OF ZEBRA MUSSELS:  
WESTERN LAKE ERIE, DECEMBER 1993.**

Buoy Number	Buoy Type	Abundance (m <sup>-2</sup> )	percent of total	# collected			Average / Range (n = total mussels)
				<4S	M	L>12	
<u>Pelee Passage</u>							
E6	6' can	34250 m <sup>-2</sup>	Z = 100 % Q = 0 %	26	102	9	x = 6.6 mm / 2-15 mm (n = 137) -----
E8	6' can	"heavy"	Z = 100 % Q = 0 %	not measured			not measured -----
E9	6' can	80600 m <sup>-2</sup>	Z = 100 % Q = 0 %	19	100	10	x = 7.9 mm / 2-14 mm (n = 129) -----
E10	6' can	39250 m <sup>-2</sup>	Z = 100 % Q = 0 %	85	110	5	x = 5.3 mm / 1-15 mm (n = 200) -----
E12	4' can	8250 m <sup>-2</sup>	Z = 100 % Q = 0 %	0	164	1	x = 8.9 mm / 4-13 mm (n = 165) -----
E13	6' can	"heavy"	Z = 100 % Q = 0 %	not measured			not measured -----
P	9' saucer	49600 m <sup>-2</sup>	Z = 100 % Q = 0 %	12	157	18	x = 8.0 mm / 2-15 mm (n = 187) -----
EP2	6' can	"heavy"	Z = 100 % Q = 0 %	not measured			not measured -----
X	9' saucer	35650 m <sup>-2</sup>	Z = 100 % Q = 0 %	32	112	16	x = 6.6 mm / 2-15 mm (n = 160) -----

**TABLE 6. SPATIAL DISTRIBUTION OF ZEBRA MUSSELS AND QUAGGA MUSSELS: CENTRAL AND EASTERN LAKE ERIE, DECEMBER 1993.**

Buoy Number	Buoy Type	percent of total	# collected			Average / Range (n = total mussels)
			<4S	M	L>12	
<u>Port Stanley (central Lake Erie)</u>						
"2 miles off"	meteorological	Z = 61 %	32	94	0	x = 5.2 mm / 1-12 mm (n = 126)
		Q = 39 %	6	57	16	x = 10.1 mm / 2-14 mm (n = 79)
<u>Long Point Bay (eastern Lake Erie)</u>						
N	6' can	Z = 42 %	89	42	0	x = 2.8 mm / 1-9 mm (n = 131)
		Q = 58 %	115	69	0	x = 3.2 mm / 1-10 mm (n = 184)
<u>Nanticoke Shoal (eastern Lake Erie)</u>						
EA8	6' can	Z = 70 %	45	47	0	x = 3.6 mm / 1-8 mm (n = 92)
		Q = 30 %	29	98	0	x = 6.2 mm / 1-10 mm (n = 127)
<u>Stelco Wharf Approach (eastern Lake Erie)</u>						
ET1	6' can	Z = ✓ Q = ✓	not measured			not measured
ET11	6' can	Z = ✓ Q = ✓	not measured			not measured
ET14	6' can	Z = 0 % Q = 100 %	—	—	—	----- x = 2.1 mm / 1-6 mm (n = 164)
NTB	6' can	Z = 0 % Q = 100 %	not measured			not measured
<u>Nanticoke Generating Station (eastern Lake Erie)</u>						
EN1	6' can	Z = ✓ Q = ✓	not measured			not measured
EN2	6' can	Z = 36 %	32	29	0	x = 3.4 mm / 1-8 mm (n = 61)
		Q = 64 %	58	50	0	x = 3.8 mm / 1-11 mm (n = 108)
EN5	6' can	Z = ✓ Q = ✓	not measured			not measured
EN7	6' can	Z = ✓ Q = ✓	not measured			not measured
EN8	6' can	Z = 8 %	11	2	0	x = 2.5 mm / 1-6 mm (n = 13)
		Q = 92 %	60	81	0	x = 4.1 mm / 1-10 mm (n = 141)
EN9	6' can	Z = ✓ Q = ✓	not measured			not measured
EN10	6' can	Z = ✓ Q = ✓	not measured			not measured
EN11	6' can	Z = ✓ Q = ✓	not measured			not measured
EN12	6' can	Z = ✓ Q = ✓	not measured			not measured

✓ = mussels collected but not counted

**TABLE 6. CENTRAL AND EASTERN LAKE ERIE, DECEMBER 1993.**  
(continued)

Buoy Number	Buoy Type	percent of total	# collected			Average / Range (n = total mussels)
			<4S	M	L>12	
<u>Nanticoke Generating Station</u> (continued)						
EN14	6' can	Z = ✓ Q = ✓	not measured			not measured
EN15	6' can	Z = 0 % Q = 100 %	—	—	—	----- x = 2.4 mm / 1-7 mm (n = 184)
EN16	6' can	Z = 0 % Q = 100 %	not measured			not measured
<u>Tecumseh Reef</u> (eastern Lake Erie)						
EA6	6' can	Z = 57 % Q = 43 %	91 126	38 16	0 0	x = 2.7 mm / 1-7 mm (n = 129) x = 2.2 mm / 1-11 mm (n = 142)
<u>Mohawk Island</u> (eastern Lake Erie)						
EA4	6' can	Z = 66 % Q = 34 %	111 54	37 23	0 0	x = 2.8 mm / 1-11 mm (n = 148) x = 3.0 mm / 1-10 mm (n = 77)
<u>Port Colborne</u> (eastern Lake Erie)						
E	9' saucer	Z = 92 % Q = 8 %	106 12	69 16	0 0	x = 3.5 mm / 1-12 mm (n = 175) x = 5.6 mm / 1-12 mm (n = 28)
E3	6' can	Z = 11 % Q = 89 %	19 55	6 40	0 0	x = 2.8 mm / 1-6 mm (n = 25) x = 4.0 mm / 2-9 mm (n = 95)
<u>Cassady Point</u> (eastern Lake Erie)						
EA2	6' can	Z = 46 % Q = 54 %	49 91	28 20	0 0	x = 3.4 mm / 1-9 mm (n = 77) x = 2.6 mm / 1-12 mm (n = 111)
<u>Middle Reefs</u> (eastern Lake Erie)						
EU4	6' can	Z = 16 % Q = 84 %	25 25	2 47	0 0	x = 2.4 mm / 2-4 mm (n = 27) x = 4.2 mm / 1-7 mm (n = 72)

✓ = mussels collected but not counted

**TABLE 7. SPATIAL DISTRIBUTION OF ZEBRA MUSSELS AND QUAGGA MUSSELS: LAKE ONTARIO (including KINGSTON HARBOUR), DECEMBER 1993.**

Buoy Number	Buoy Type	Abundance (m <sup>-2</sup> )	percent of total	# collected			Average / Range (n = total mussels)
				<4S	M	L>12	
<u>Port Weller Light</u>							
W	9' saucer	6823 m <sup>-2</sup>	Z = 98 % Q = 2 %	1 1	134 8	0 0	x = 8.0 mm / 3-11 mm (n = 135) x = 9.1 mm / 3-11 mm (n = 9)
<u>Burlington Canal entrance</u>							
H	9' saucer	650 m <sup>-2</sup>	Z = 99 % Q = 1 %	26 2	93 3	0 0	x = 4.8 mm / 2-8 mm (n = 119) x = 7.4 mm / 2-12 mm (n = 5)
<u>West Entrance north side (Toronto Harbour)</u>							
TT3	6' can	8 m <sup>-2</sup>	Z = 93 % Q = 7 %	0 0	80 6	0 0	x = 8.2 mm / 4-10 mm (n = 80) x = 7.5 mm / 5-9 mm (n = 6)
<u>West Entrance west side (Toronto Harbour)</u>							
T	9' saucer	100 m <sup>-2</sup>	Z = --- Q = ---	not measured not measured			not measured not measured
<u>Gibraltar Point (Toronto Harbour)</u>							
TE18	9' saucer	167 m <sup>-2</sup>	Z = --- Q = ---	not measured not measured			not measured not measured
<u>Outer Harbour (Toronto Harbour)</u>							
T7	4' can	700 m <sup>-2</sup>	Z = 99.2 % Q = 0.8 %	86 0	42 3	0 0	x = 3.6 mm / 1-12 mm (n = 128) x = 7.7 mm / 6-10 mm (n = 3)
<u>Toronto Harbour</u>							
T8	4' can	1567 m <sup>-2</sup>	Z = 100 % Q = 0 %	75 —	45 —	1 —	x = 3.9 mm / 1-13 mm (n = 121) -----
<u>Main Harbour Channel (Toronto Harbour)</u>							
T4	4' can	533 m <sup>-2</sup>	Z = 100 % Q = 0 %	59 —	71 —	0 —	x = 5.0 mm / 1-12 mm (n = 130) -----
<u>Outer Approach east (Toronto Harbour)</u>							
T2	9' saucer	69 m <sup>-2</sup>	Z = 95 % Q = 5 %	19 0	97 6	0 0	x = 7.7 mm / 1-11 mm (n = 116) x = 9.2 mm / 7-12 mm (n = 6)
<u>Outer Approach west (Toronto Harbour)</u>							
T1	6' can	350 m <sup>-2</sup>	Z = 99.3 % Q = 0.7 %	67 0	77 1	0 0	x = 5.8 mm / 1-11 mm (n = 144) x = 8.0 mm / 8 mm (n = 1)
<u>Frenchman Bay Approach</u>							
F	6' can	0.8 m <sup>-2</sup>	Z = 100 % Q = 0 %	3 —	6 —	0 —	x = 3.9 mm / 3-5 mm (n = 9) -----
<u>Oshawa Harbour</u>							
MV4	6' can	2.7 m <sup>-2</sup>	Z = 67 % Q = 33 %	3 0	17 10	0 0	x = 5.6 mm / 2-10 mm (n = 20) x = 7.2 mm / 6-9 mm (n = 10)
<u>Presqu'île Point</u>							
P	6' can	13 m <sup>-2</sup>	Z = 72 % Q = 28 %	0 0	93 37	0 0	x = 6.2 mm / 4-9 mm (n = 93) x = 9.4 mm / 6-12 mm (n = 37)
<u>Upper Gap</u>							
KM5	6' can	7367 m <sup>-2</sup>	Z = 97.7 % Q = 2.3 %	2 2	96 11	0 0	x = 7.0 mm / 2-10 mm (n = 98) x = 7.5 mm / 2-11 mm (n = 13)

TABLE 7: LAKE ONTARIO (continued)

Buoy Number	Buoy Type	Abundance (m <sup>-2</sup> )	percent of total	# collected			Average / Range (n = total mussels)
				<4S	M	L>12	
<u>Bluff Point</u>							
KM4	6' can	13300 m <sup>-2</sup>	Z = 99.3 % Q = 0.7 %	4 0	104 3	0 0	x = 7.0 mm / 1–12 mm (n = 108) x = 9.3 mm / 6–11 mm (n = 3)
<u>Upper Gap south</u>							
KM2	9' saucer	17759 m <sup>-2</sup>	Z = 96 % Q = 4 %	0 0	107 20	0 0	x = 7.2 mm / 4–11 mm (n = 107) x = 7.2 mm / 4–9 mm (n = 20)
<u>Bath Point (North Channel)</u>							
KN8	4' can	7344 m <sup>-2</sup>	Z = 99.1 % Q = 0.9 %	1 0	129 5	0 0	x = 7.9 mm / 3–11 mm (n = 130) x = 8.4 mm / 7–9 mm (n = 5)
<u>Traverse Shoal</u>							
K14	6' can	480 m <sup>-2</sup>	Z = 97 % Q = 3 %	2 0	77 6	1 1	x = 8.6 mm / 2–14 mm (n = 80) x = 10.3 mm / 9–13 mm (n = 7)
<u>False Ducks Bank</u>							
K12	6' can	1533 m <sup>-2</sup>	Z = 95.4 % Q = 4.6 %	0 0	115 14	0 0	x = 8.5 mm / 4–12 mm (n = 115) x = 9.4 mm / 7–12 mm (n = 14)
<u>William Shoal</u>							
K11	6' can	533 m <sup>-2</sup>	Z = 96.8 % Q = 3.2 %	2 0	79 14	0 0	x = 7.7 mm / 3–12 mm (n = 81) x = 8.4 mm / 5–12 mm (n = 14)
<u>Main Duck Island</u>							
M9	6' can	400 m <sup>-2</sup>	Z = 100 % Q = 0 %	0 —	42 —	13 —	x = 10.9 mm / 4–15 mm (n = 55) -----
<u>The Ducks</u>							
MM2	6' can	433 m <sup>-2</sup>	Z = 99.1 % Q = 0.9 %	1 0	47 2	12 0	x = 10.8 mm / 6–14 mm (n = 60) x = 12.0 mm / 12 mm (n = 2)
<u>South Charity Shoal</u>							
M7	6' can	600 m <sup>-2</sup>	Z = 98.8 % Q = 1.2 %	0 0	57 1	9 0	x = 9.8 mm / 4–15 mm (n = 66) x = 4.0 mm / 4 mm (n = 1)
M6	6' can	867 m <sup>-2</sup>	Z = 99.2 % Q = 0.8 %	1 not measured	46 not measured	9 not measured	x = 10.2 mm / 3–14 mm (n = 56) not measured
<u>Emeric Point</u>							
K10	6' can	6767 m <sup>-2</sup>	Z = 97 % Q = 3 %	6 0	76 6	0 0	x = 6.5 mm / 2–10 mm (n = 82) x = 6.7 mm / 5–8 mm (n = 6)
<u>Salmon Island</u>							
KN3	6' can	52867 m <sup>-2</sup>	Z = 98.7 % Q = 1.3 %	30 0	87 20	0 0	x = 5.2 mm / 1–10 mm (n = 117) x = 8.2 mm / 4–11 mm (n = 20)
<u>Melville Shoal</u>							
K9	9' saucer	14367 m <sup>-2</sup>	Z = 100 % Q = 0 %	4 —	137 —	0 —	x = 7.4 mm / 3–11 mm (n = 141) -----
<u>Salmon Island South Shoal</u>							
K8	6' can	19967 m <sup>-2</sup>	Z = 100 % Q = 0 %	5 —	119 —	0 —	x = 6.7 mm / 2–11 mm (n = 124) -----
<u>Snake Island</u>							
K5	6' can	45967 m <sup>-2</sup>	Z = 99.4 % Q = 0.6 %	38 1	150 5	0 0	x = 5.1 mm / 1–10 mm (n = 188) x = 5.7 mm / 3–8 mm (n = 6)

TABLE 7: LAKE ONTARIO (continued)

Buoy Number	Buoy Type	Abundance (m <sup>-2</sup> )	percent of total	# collected			Average / Range (n = total mussels)
				<4S	M	L>12	
<u>Penitentiary Shoal</u> (Kingston Harbour)							
K3	6' can	24500 m <sup>-2</sup>	Z = 99.4 %	8	106	0	x = 7.9 mm / 3-12 mm (n = 114)
			Q = 0.6 %	0	3	0	x = 7.0 mm / 4-11 mm (n = 3)
<u>Myles Shoal</u> (Kingston Harbour)							
K1	6' can	76350 m <sup>-2</sup>	Z = 99 %	20	148	0	x = 6.7 mm / 1-12 mm (n = 168)
			Q = 1 %	0	17	0	x = 8.1 mm / 4-11 mm (n = 17)
<u>Point Frederick</u> (Kingston Harbour)							
KH2	6' can	3367 m <sup>-2</sup>	Z = 99.3 %	3	117	0	x = 8.1 mm / 1-12 mm (n = 120)
			Q = 0.7 %	0	1	1	x = 13.0 mm / 12-14 mm (n = 2)

**TABLE 8. SPATIAL DISTRIBUTION OF ZEBRA MUSSELS AND QUAGGA MUSSELS: BAY OF QUINTE, DECEMBER 1993.**

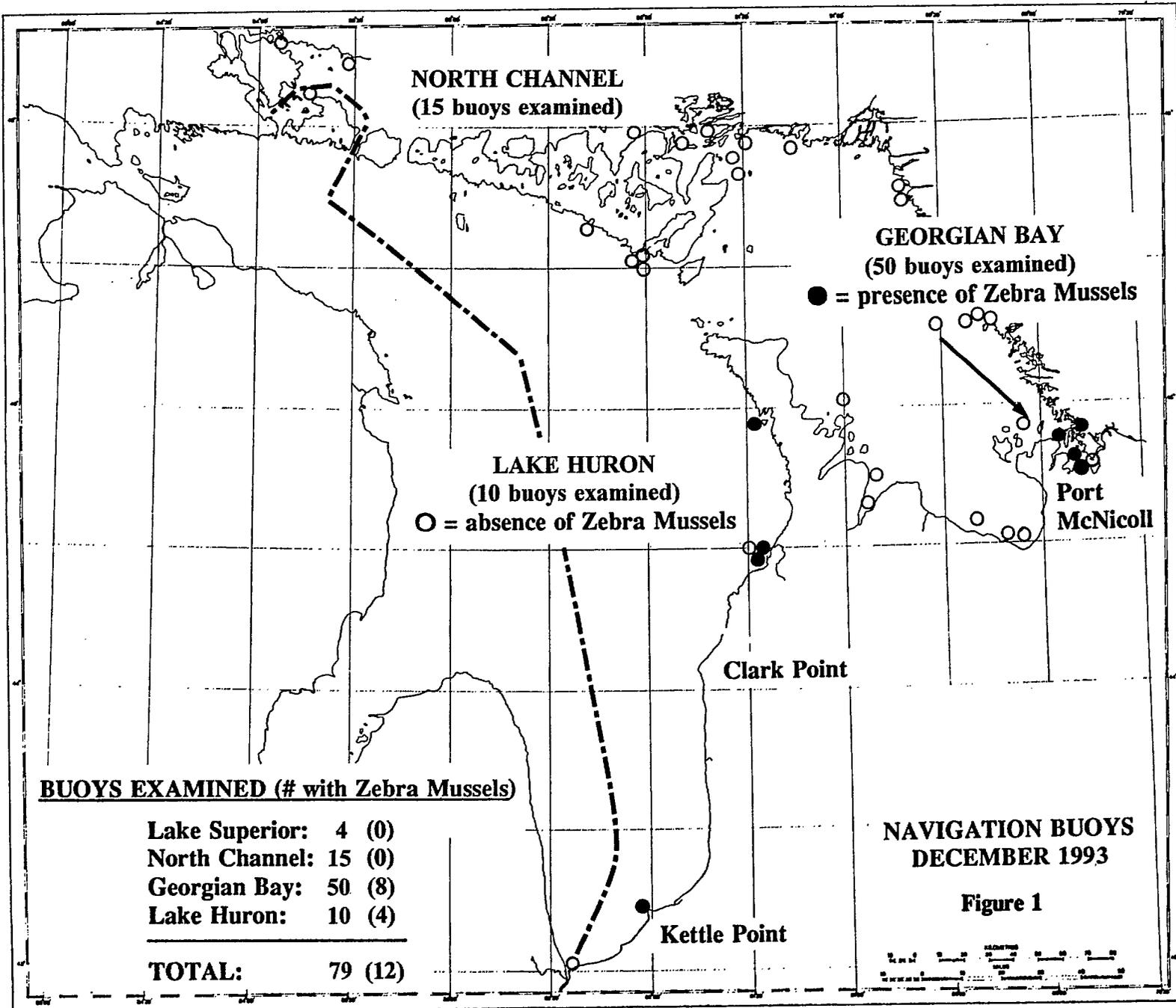
Buoy Number	Buoy Type	Abundance (m <sup>-2</sup> )	percent of total	# collected			Average / Range (n = total mussels)
			Z = 100 % Q = 0 %	<4S	M	L>12	
<u>Trent River Entrance</u> QT	"Quinte"	(1 total)	Z = 100 % Q = 0 %	0	1	0	x = 11.0 mm / 11 mm (n = 1) -----
<u>Trenton East</u> QTB	"Quinte"	(3 total)	Z = 100 % Q = 0 %	0	1	2	x = 12.7 mm / 10-14 mm (n = 3) -----
<u>Narrows Shoal west</u> Q61	"Quinte"	(29 total)	Z = 100 % Q = 0 %	0	10	12	x = 12.4 mm / 9-15 mm (n = 22) -----
<u>Narrows Shoal east</u> Q59	"Quinte"	(29 total)	Z = 100 % Q = 0 %	0	14	14	x = 12.4 mm / 10-15 mm (n = 28) -----
<u>Belleville Harbour</u> Q54	"Quinte"	(8 total)	Z = 100 % Q = 0 %	0	8	0	x = 10.1 mm / 8-12 mm (n = 8) -----
<u>Massasauga Point</u> Q53	"Quinte"	(5 total)	Z = 100 % Q = 0 %	0	4	1	x = 12.2 mm / 12-13 mm (n = 5) -----
<u>Minnie Blakely Shoal</u> Q52	4' can	125 m <sup>-2</sup>	Z = 100 % Q = 0 %	0	25	27	x = 12.3 mm / 4-16 mm (n = 52) -----
<u>Trident Point</u> Q46	4' can	3 m <sup>-2</sup>	Z = 100 % Q = 0 %	0	17	1	x = 9.9 mm / 6-13 mm (n = 18) -----
<u>North Port Shoal</u> Q43	4' can	3 m <sup>-2</sup>	Z = 100 % Q = 0 %	0	18	0	x = 9.0 mm / 6-12 mm (n = 18) -----
<u>Sucker Creek</u> Q42	4' can	3 m <sup>-2</sup>	Z = 100 % Q = 0 %	0	15	0	x = 7.7 mm / 5-12 mm (n = 15) -----
<u>East Entrance (Telegraph Narrows)</u> Q21	"Quinte"	(2 total)	Z = 100 % Q = 0 %	0	2	0	x = 9.5 mm / 9-10 mm (n = 2) -----

**TABLE 9. SPATIAL DISTRIBUTION OF ZEBRA MUSSELS AND QUAGGA MUSSELS: BAY OF QUINTE, DECEMBER 1994.**

Buoy Number	Buoy Type	Abundance (m <sup>-2</sup> )	percent of total	# collected			Average / Range (n = total mussels)
				<4S	M	L>12	
<u>Adolphus Reach</u> Q1	"Quinte"	(1 total)	Z = 100 % Q = 0 %	0	0	1	x = 13.0 mm / 13.0 mm (n = 1) -----
<u>Glenora</u> Q3	"Quinte"	(4 total)	Z = 100 % Q = 0 %	0	3	1	x = 10.8 mm / 8-13 mm (n = 4) -----
<u>Picton</u> QP5	"Quinte"	(3 total)	Z = 100 % Q = 0 %	0	1	2	x = 12.0 mm / 6-16 mm (n = 3) -----
<u>Long Reach</u> Q11	"Quinte"	10 385 m <sup>-2</sup>	Z = 100 % Q = 0 %	1	22	4	x = 8.4 mm / 3-19 mm (n = 27) -----
<u>Mohawk Bay</u> Q13	"Quinte"	3161 m <sup>-2</sup>	Z = 100 % Q = 0 %	0	7	0	x = 7.6 mm / 6-10 mm (n = 7) -----
<u>Telegraph Narrows (W)</u> Q41	"Quinte"	(18 total)	Z = 100 % Q = 0 %	0	13	3	x = 8.5 mm / 5-18 mm (n = 16) -----
<u>North Port Shoal</u> Q43	4' can	16 053 m <sup>-2</sup>	Z = 100 % Q = 0 %	0	33	6	x = 10.1 mm / 5-22 mm (n = 39) -----
<u>Trident Point</u> Q46	4' can	13 846 m <sup>-2</sup>	Z = 100 % Q = 0 %	0	28	3	x = 8.9 mm / 5-16 mm (n = 31) -----
<u>Massasauga Point</u> Q53	"Quinte"	12 450 m <sup>-2</sup>	Z = 100 % Q = 0 %	15	58	2	x = 5.5 mm / 2-15 mm (n = 75) -----
<u>Belleville Harbour</u> Q54	"Quinte"	23 250 m <sup>-2</sup>	Z = 100 % Q = 0 %	7	37	4	x = 7.0 mm / 3-18 mm (n = 48) -----
<u>Narrows Shoal east</u> Q59	"Quinte"	11 300 m <sup>-2</sup>	Z = 100 % Q = 0 %	15	47	10	x = 7.0 mm / 2-17 mm (n = 72) -----
<u>Trenton</u> Q72	"Quinte"	(133 total)	Z = 100 % Q = 0 %	13	83	27	x = 8.5 mm / 2-16 mm (n = 123) -----
<u>Trent River Entrance</u> QT	"Quinte"	(4 total)	Z = 100 % Q = 0 %	0	3	1	x = 11.0 mm / 7-18 mm (n = 4) -----

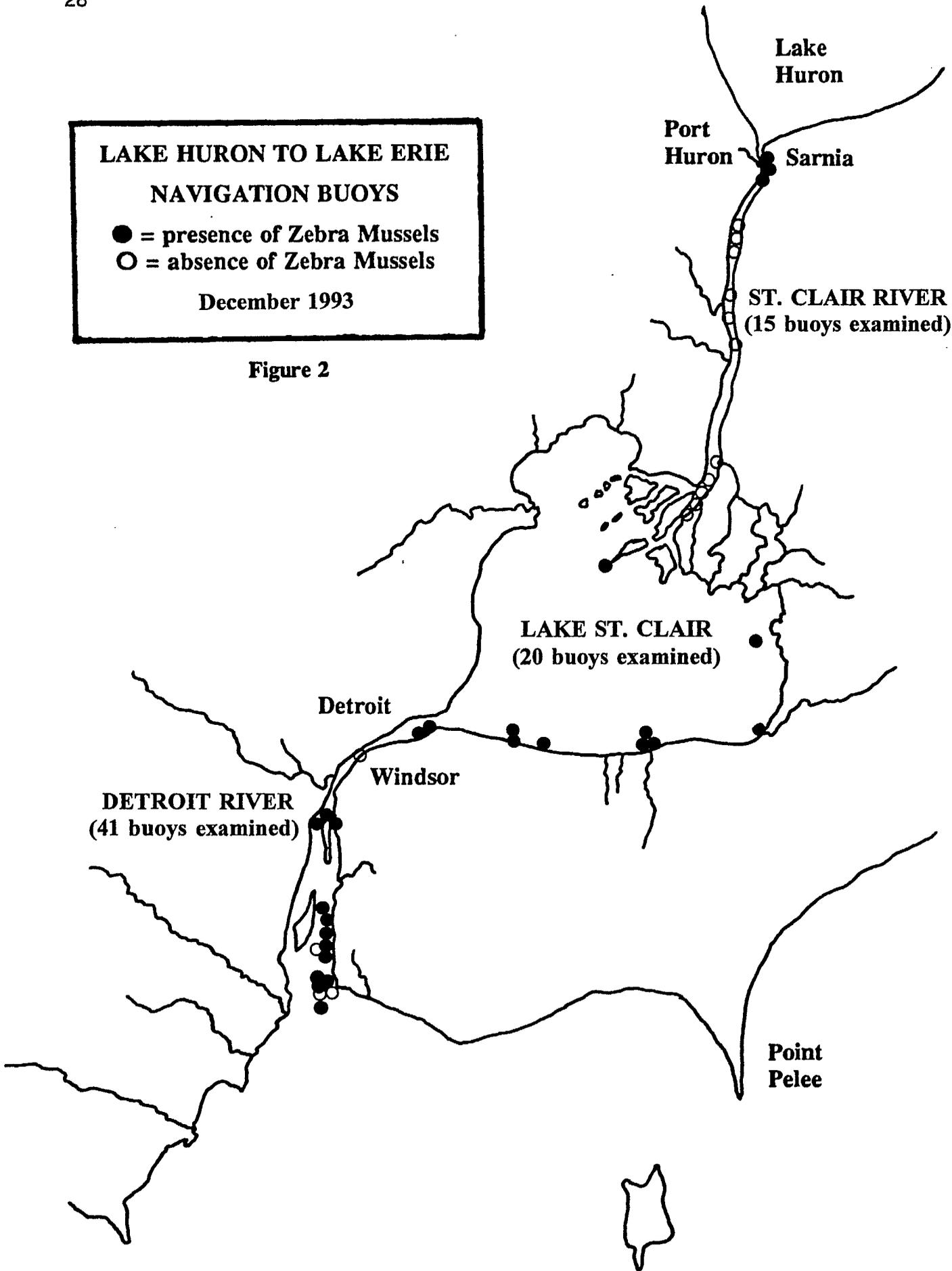
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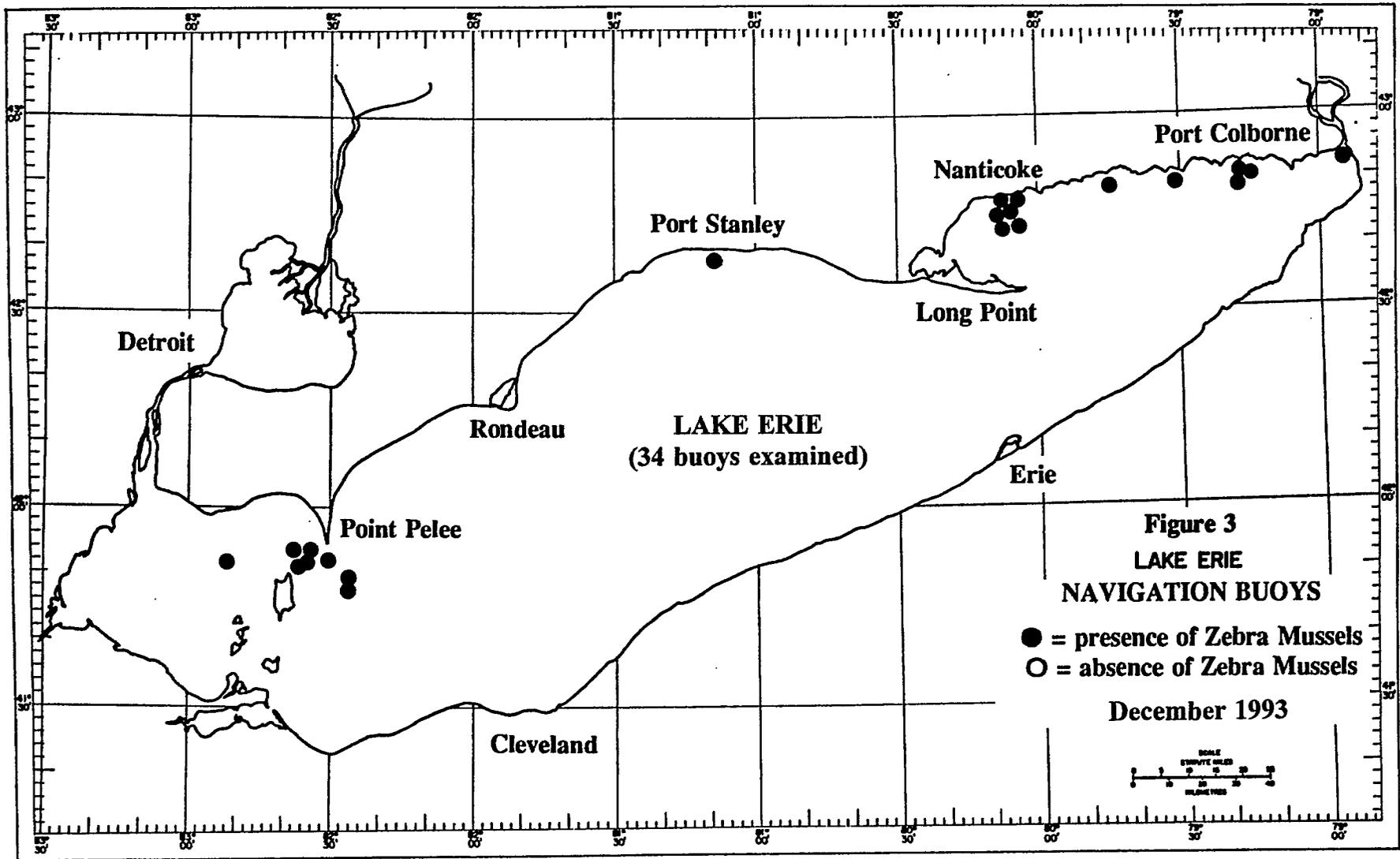
- Figure 1. Presence and absence of mussels on navigation buoys in the North Channel, Georgian Bay, and Lake Huron, December 1993.
- Figure 2. Presence and absence of mussels on navigation buoys in the St. Clair River, Lake St. Clair, and the Detroit River, December 1993.
- Figure 3. Presence and absence of mussels on navigation buoys in Lake Erie, December 1993.
- Figure 4. Presence and absence of mussels on navigation buoys in Lake Ontario, December 1993.
- Figure 5. Presence and absence of mussels on navigation buoys in the Bay of Quinte, December 1993.
- Figure 6. Presence of mussels on navigation buoys in the Bay of Quinte, December 1994.
- Figure 7. A pile of 2-foot spar type buoys at Parry Sound, Ontario, November 1992.
- Figure 8. A typical 4-foot can or cone at Parry Sound, Ontario, November 1992.
- Figure 9. A typical 6-foot can or cylinder buoy at Parry Sound, Ontario, November 1992.
- Figure 10. A typical 9-foot saucer or bell buoy, November 1992.

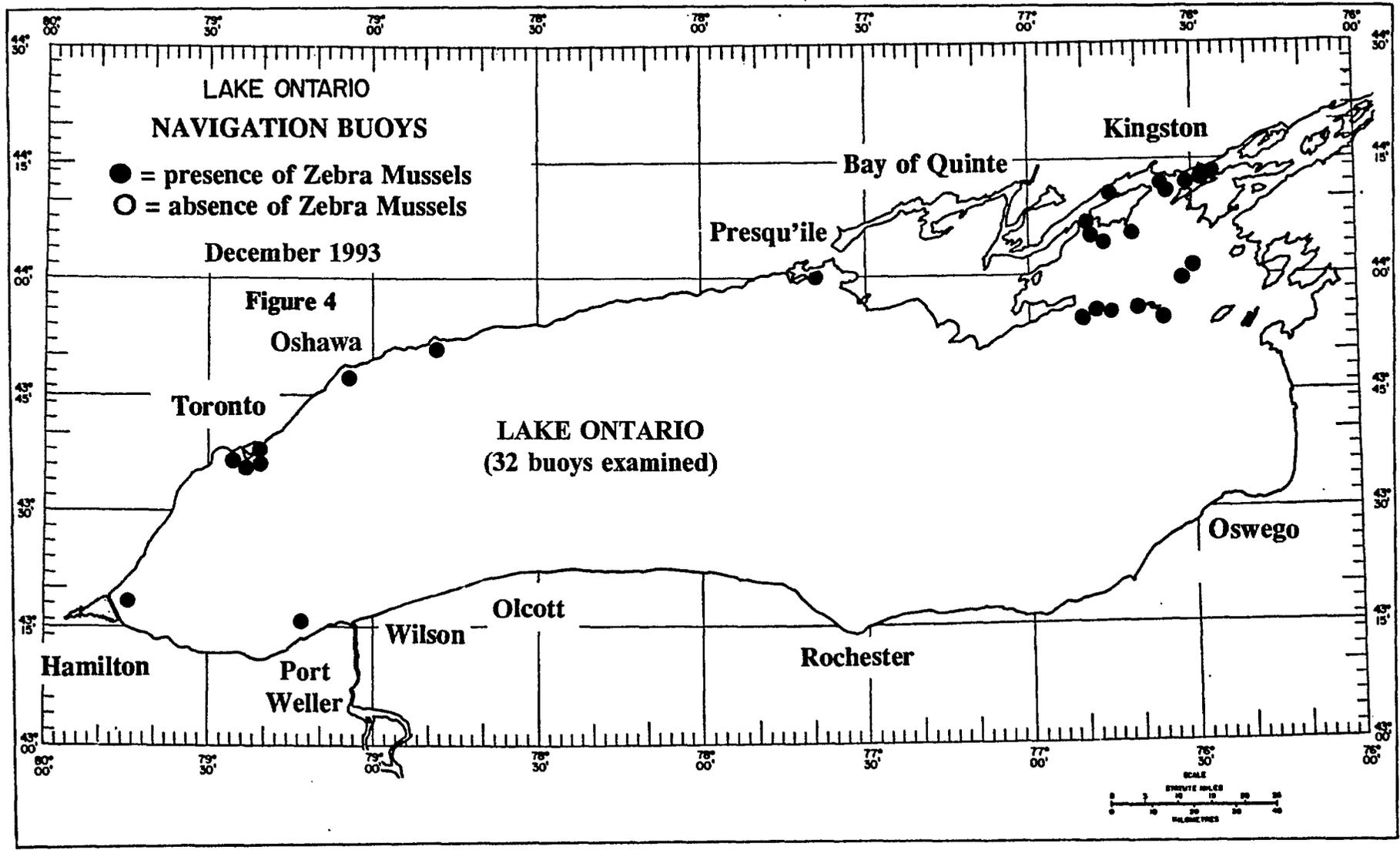


**LAKE HURON TO LAKE ERIE  
NAVIGATION BUOYS**  
● = presence of Zebra Mussels  
○ = absence of Zebra Mussels  
December 1993

Figure 2







# Bay of Quinte

## NAVIGATION BUOYS

- = presence of Zebra Mussels
- = absence of Zebra Mussels

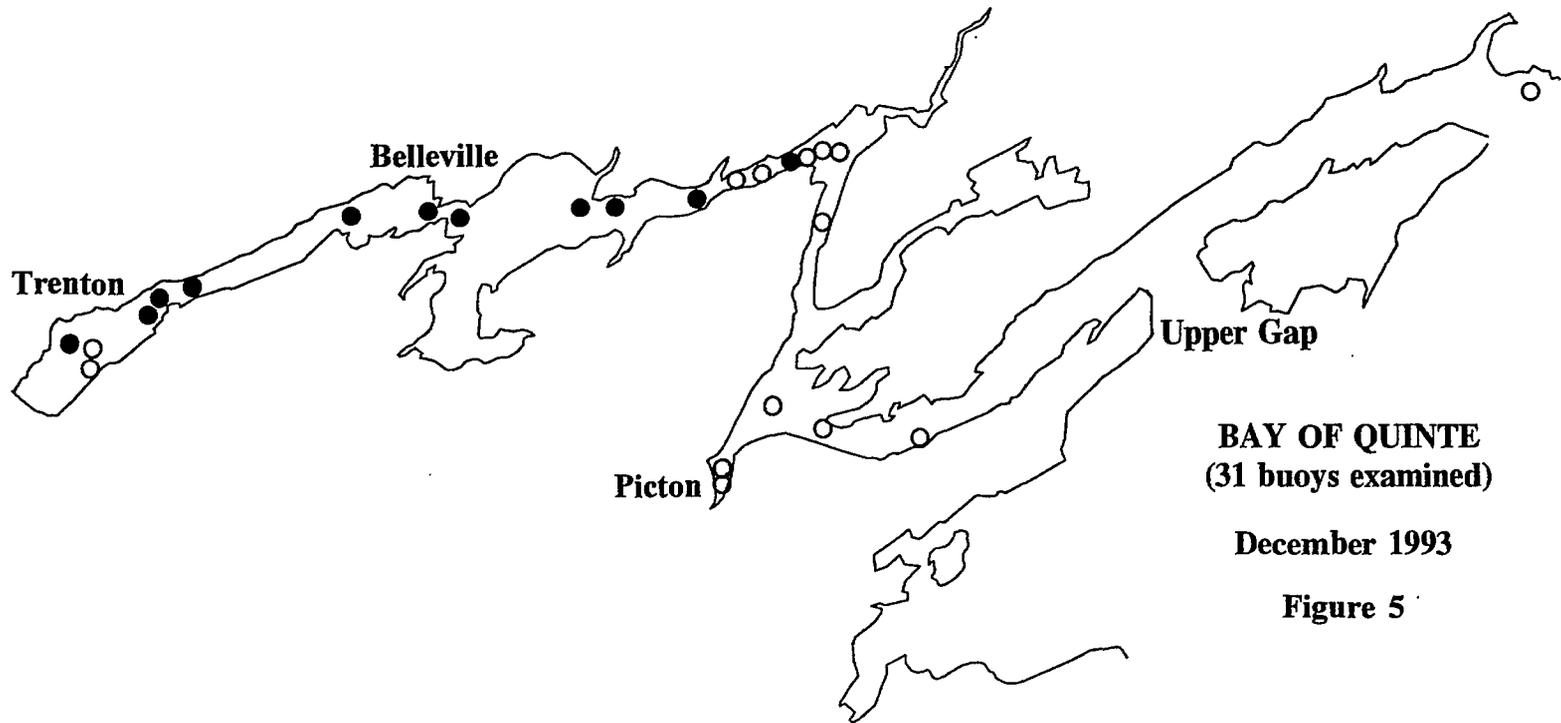


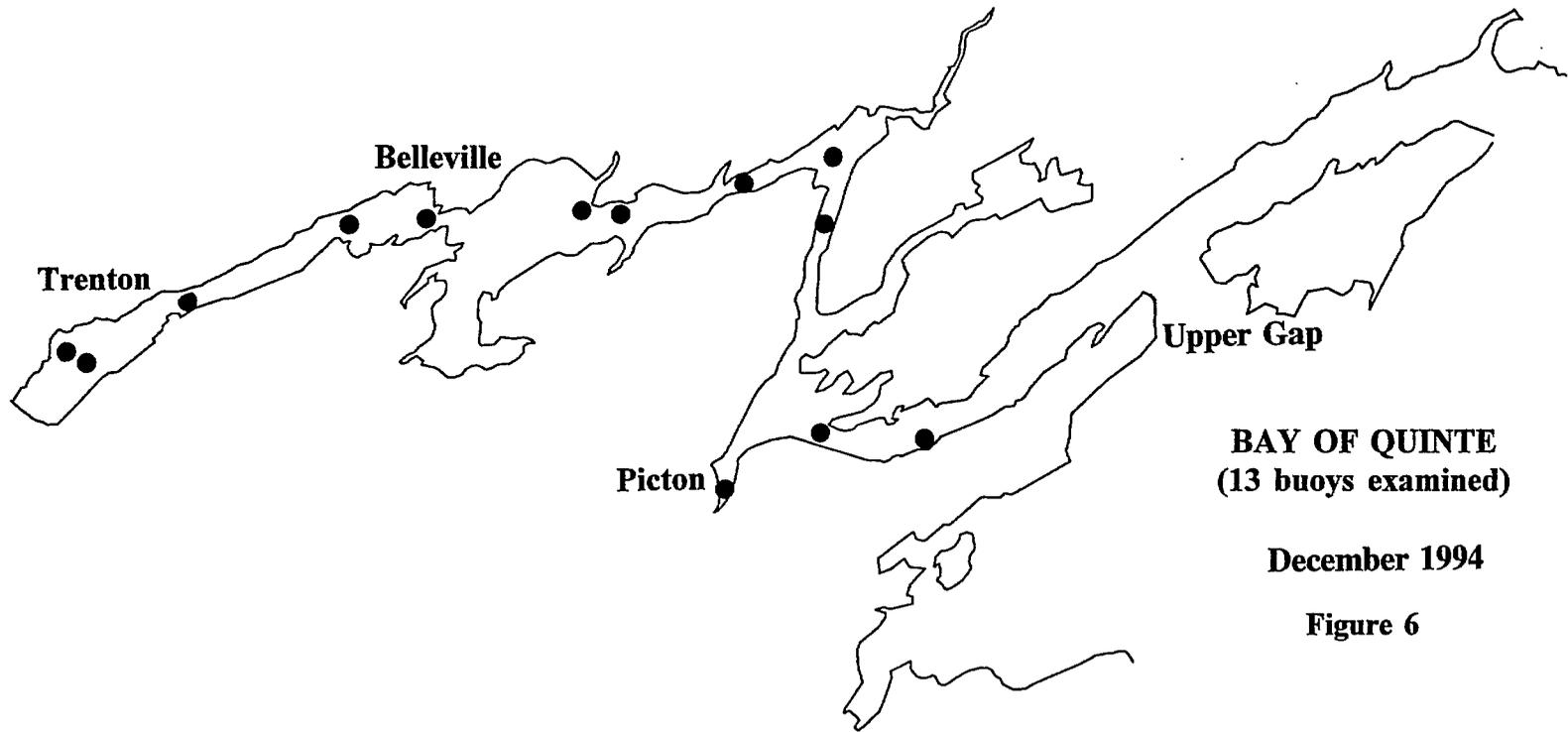
Figure 5

Unknown Scale

# Bay of Quinte

## NAVIGATION BUOYS

- = presence of Zebra Mussels
- = absence of Zebra Mussels



Unknown Scale

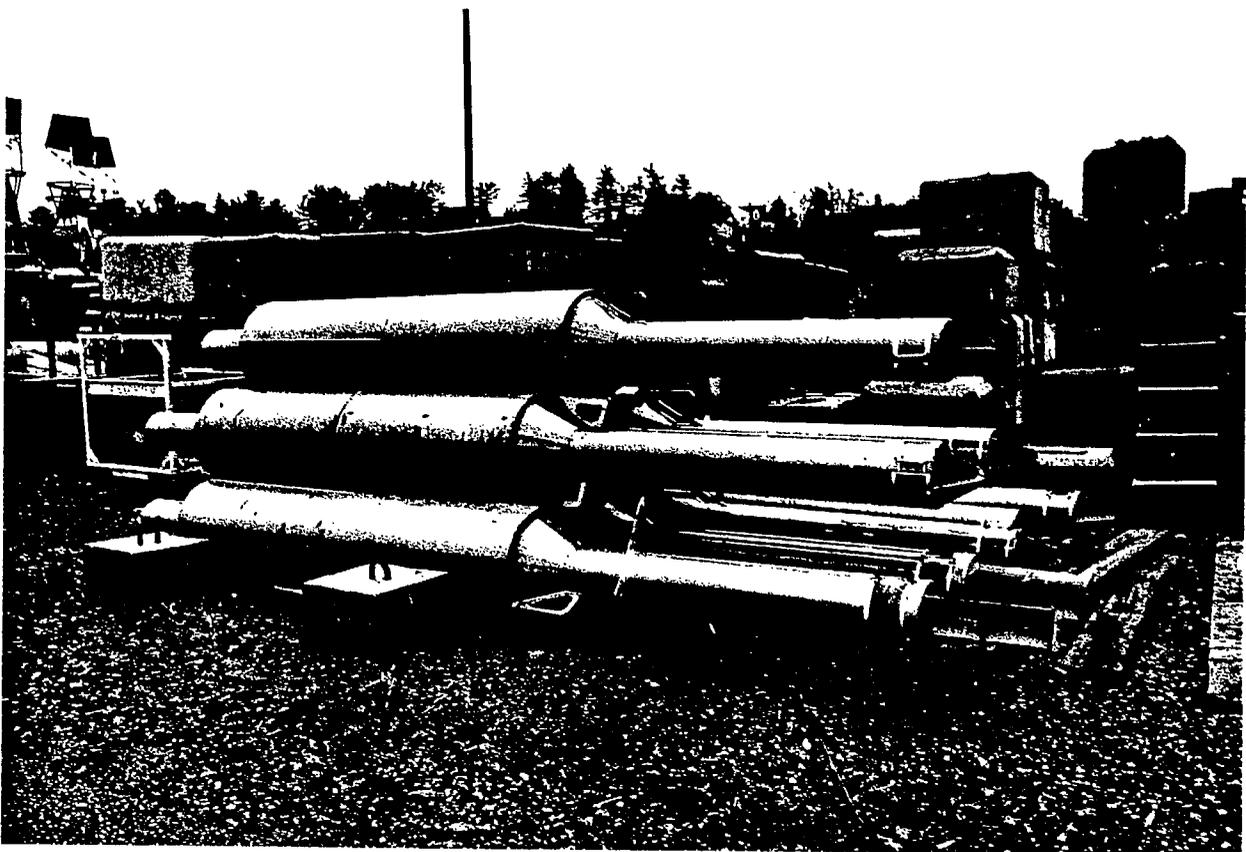


Figure 7. A pile of 2-foot spar type buoys at Parry Sound, Ontario, on November 30, 1992.  
Photo by Alan Wormington.



Figure 8. A typical 4-foot can or "cone" buoy at Parry Sound, Ontario, on November 30, 1992. Photo by Alan Wormington.



Figure 9. A typical 6-foot can or "cylinder" buoy at Parry Sound, Ontario, on November 30, 1992. Photo by Alan Wormington.



Figure 10. A typical 9-foot or "saucer" buoy, sometimes referred to as a bell buoy. Photographed on November 30, 1992, at Parry Sound, Ontario, by Alan Wormington.