

Return and Increase in Abundance of Aquatic Flowering Plants in Put-In-Bay Harbor, Lake Erie, Ohio¹

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ABSTRACT. The initial survey of aquatic flowering plants in Put-in-Bay Harbor, South Bass Island, OH, by Pieters (1901), and a follow-up study by Stuckey (1971), documented an overall loss of 50% of the species, and 61% of the submersed species. In the past 25 years, and moreover in the past five years, dramatic new changes in the species composition have occurred in the flora: 1) nine species have returned or appeared for the first time, 2) fourteen species have continued to survive or have increased in abundance, and 3) five species have declined in overall abundance. The return of species requiring clear water for seed germination and growth and the reduction in abundance of species tolerant of turbid water may be related to the invasions and spread of *Dreissena polymorpha* (Zebra Mussel) and *Dreissena bugensis* (Quagga Mussel) which have resulted in increasing water clarity. *Vallisneria americana* continues to be the dominant submersed species of Put-in-Bay Harbor.

OHIO J. SCI. 95 (3): 261-266, 1995

INTRODUCTION

Changes in the species composition and abundance of aquatic flowering plants continue to occur at Put-in-Bay Harbor in Western Lake Erie, OH, since 1967 (Stuckey 1971, 1978, 1979, 1989; Schneider and Stuckey 1991). In the initial plant survey of the Harbor in 1898, Pieters (1901) reported 40 species, of which only 20 (50%) persisted after 70 years (Stuckey 1971). With the invasion in the summer of 1988 by *Dreissena polymorpha* (Zebra Mussel) and in 1991 by *Dreissena bugensis* (Quagga Mussel), water clarity has increased fourfold (Table 1), and certain species of aquatic plants have returned or increased in abundance (Mills et al. 1993, Snyder et al. 1994). The present paper elaborates on the changes in Put-in-Bay Harbor which has traditionally been divided into four areas: the main Harbor of Put-in-Bay, Squaw Harbor, Fishery Bay, and an inlet, Terwilliger's Pond (Fig. 1).

MATERIALS AND METHODS

The Franz Theodore Stone Laboratory of The Ohio State University is located on Gibraltar Island in Put-in-Bay Harbor, and serves as the site where these investigations have been headquartered. The sampling of submersed aquatics followed the same methods reported in Stuckey (1971), mostly by dredging the bottom with a grappling hook from a rowboat. The second author has augmented this sampling method by snorkeling and scuba along four transects (Fig. 2), as well as by use of a Remote Observation Vehicle (ROV) on loan from the U.S. Fish and Wildlife Service, Ann Arbor, MI. The ROV was equipped with a video camera to record observations of the substrate and vegetation in natural light along transect B and D in the Harbor (Fig. 2). During the course of the study the entire Harbor was inventoried for species composition and relative abundance of

submersed macrophytes. These sampling techniques allowed for documentation of plant zonation from the open lake water into the Harbor (Fig. 3).

RESULTS

The changes in the aquatic and wetland flora that have occurred during the past 30 years are evident in three respects: 1) species that have returned or have appeared for the first time, 2) species previously present that continue to survive or have increased in abundance, and 3) species that have declined in abundance (Table 2).

Eight species noted by Pieters (1901) have not been seen since, as recorded by Stuckey (1971): *Potamogeton amplifolius* Tuckerm., *P. freisii* Rupr., *P. praelongus* Wulf., *P. perfoliatus* L., *P. filiformis* Pers., *P. gramineus* L., *Megaladonta beckii* (Torr.) Greene, and *Scirpus expansus* Fern.

Species that have returned or have appeared for the first time (Appendix).

Najas guadalupensis (Spreng.) Magnus was rediscovered in 1978 by M. Glorioso, and has been seen there nearly every year since (Stuckey 1989). This species is now considered occasional in water 2-3 m deep along the southeast shore of Gibraltar Island and in Fishery Bay near Peach Point. Submersed species that have reappeared along with the increased water clarity since the late 1980s are *Potamogeton pusillus* var. *pusillus* L. and *P. foliosus* Raf., both of which were last reported by Core (1949), and *Najas flexilis* (Willd.) Rostk. & Schmidt (Table 2) last recorded by Stansbery (1961). When the water began to clear dramatically in the late 1980s (Table 1) and the bottom of the Bay could be seen in the vicinity of the docks in Fishery Bay at Stone Laboratory, numerous plants of *P. pusillus* var. *pusillus* appeared, and have appeared every year since. Specimens of *P. foliosus* and *Najas flexilis* were first obtained in 1991. Since then, *N. flexilis*, has become more extensive each year and in 1994 grew throughout the Bay. One extremely large colony grew in 3.5-4.5 m of water near the southwest tip

¹Manuscript received 14 November 1994 and in revised form 4 April 1995 (#94-24).

Table 1

Mean secchi disk values (m) for the western basin of Lake Erie and Put-in-Bay Harbor, OH.

Month	Year							
	1967-1982 ¹	1988 ²	1988-1990 ³	1990 ⁴	1991	1992	1993	1994
March	-	-	-	-	1.29	2.56	2.02	1.90
April	-	-	-	1.00	0.90	3.69	1.55	1.83
May	-	-	-	1.82	2.65	3.92	2.06	2.14
June	-	-	-	2.11	2.80	3.17	2.92	3.40
July	-	-	-	2.79	3.32	3.18	3.14	3.58
August	-	-	-	3.44	3.42	3.05	3.70	3.93
September	-	-	-	3.90	3.33	3.29	3.94	3.76
October	-	-	-	2.87	3.59	2.83	2.55	3.61
November	-	-	-	1.37	2.47	-	-	-
Annual	0.80	*	2.10	2.42	2.64	3.21	2.74	3.02

¹Data for 1967-1982 from Boisenga and Herdendorf (1993).

²Year of Zebra Mussel introduction.

³Data for 1988-1990 (May-November each year) from Leach (1993).

⁴Data for 1990-1994 (unpublished) from J. Hageman, Manager of F. T. Stone Laboratory, Put-in-Bay, OH.

of Gibraltar Island. In 1994, *Najas minor* All., an European species, was obtained near the docks on Gibraltar Island. This specimen, represented by one small plant with three mature fruits, is the first collection for Put-in-Bay Harbor and the islands in western Lake Erie, and adds to the records of Wentz and Stuckey (1971).

Among the emersed (emergent) species, *Nelumbo lutea* (Willd.) Pers. was last reported as rare by Stuckey (1971) from Squaw Harbor, and was not seen during

the high water years of the 1970s. It first reappeared in 1980, and maintains a stable colony at the west end of Terwilliger's Pond. *Nuphar advena* Ait., last recorded by Core in 1940 (Core 1949), reappeared in 1994. *Elodea canadensis* Michx., a submersed, perennial species that overwinters as living plants (Stuckey et al. 1978), has also reappeared. It is most prevalent in water near the Stone Laboratory docks in Fishery Bay on South Bass Island.

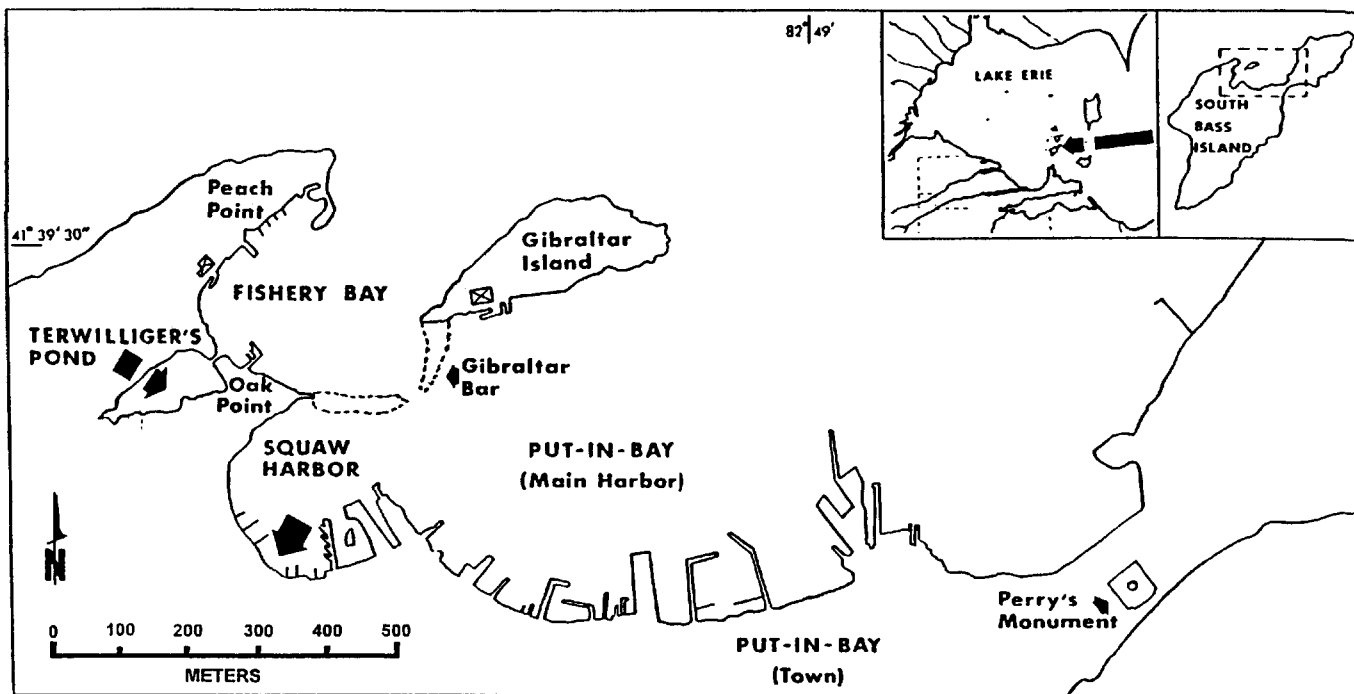


FIGURE 1. Outline map of Put-in-Bay Harbor (modified from Stuckey 1971), showing the sub-inlets: Main Harbor of Put-in-Bay, Squaw Harbor, Fishery Bay, and Terwilliger's Pond, along the north shore of South Bass Island, western Lake Erie, OH. The location of the laboratory buildings at Stone Laboratory on Gibraltar Island and Peach Point are marked with an X.

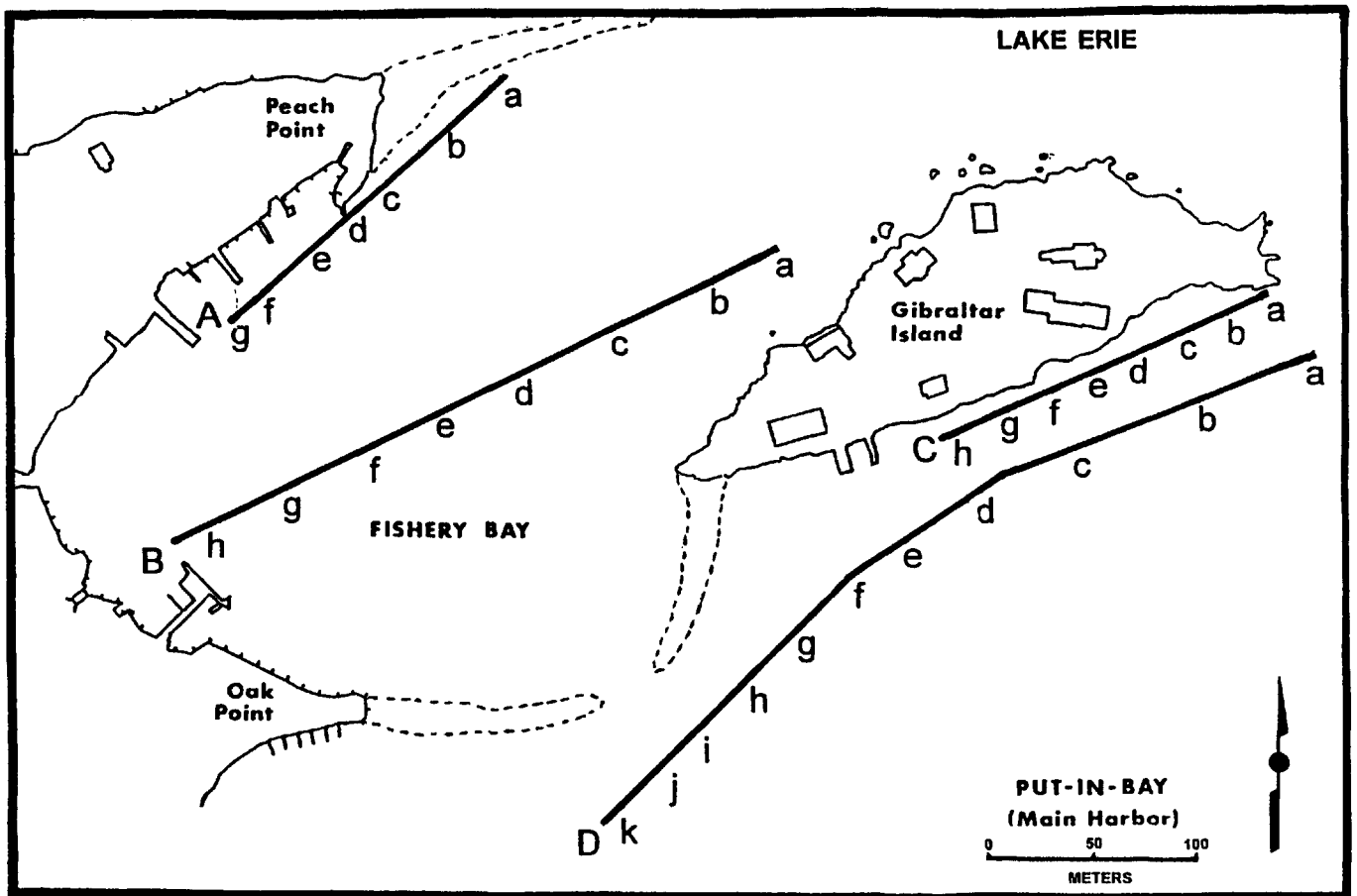


FIGURE 2. Put-in Bay Harbor transects A-D.

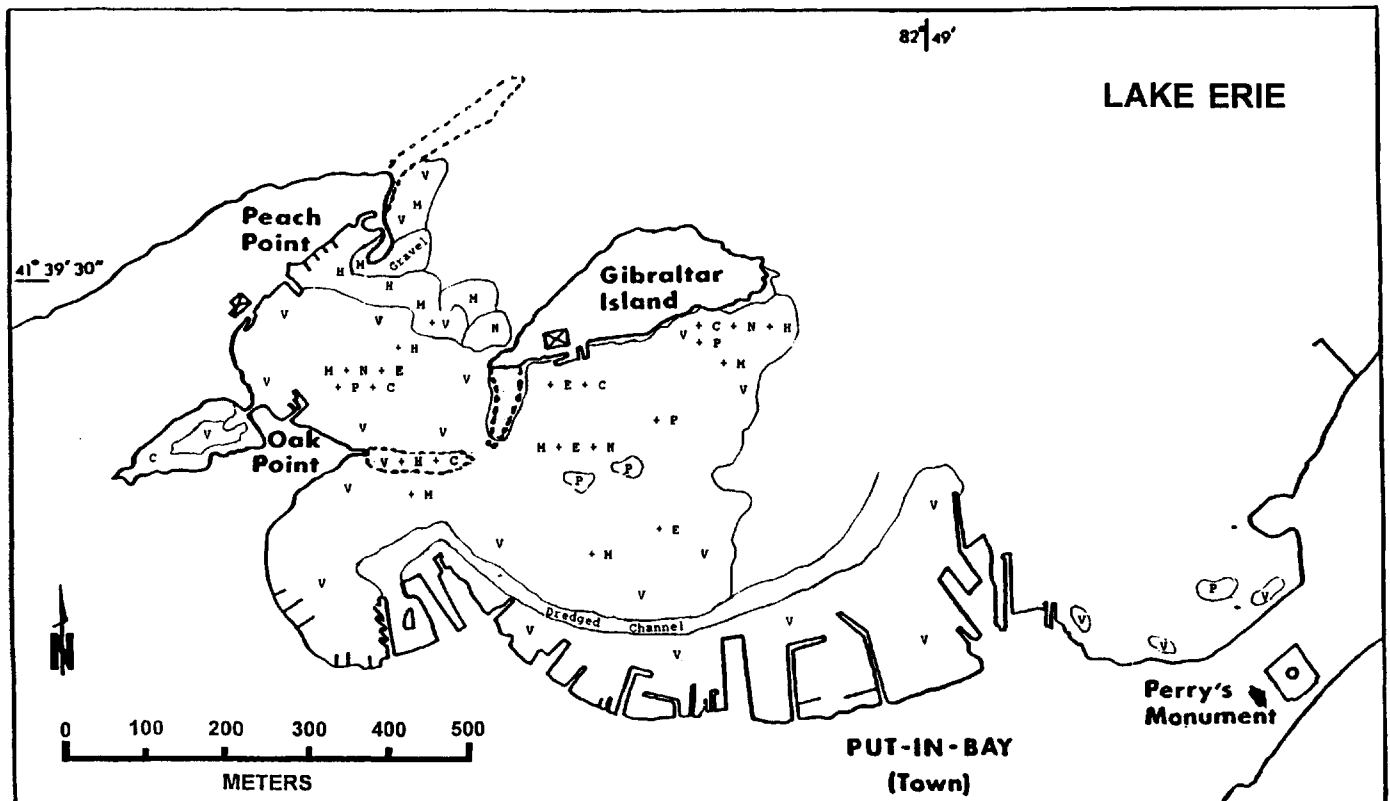


FIGURE 3. Generalized vegetational composition and extent of submersed macrophyte beds in Put-in-Bay Harbor indicating dominant species (V = *Vallisneria americana*, M = *Myriophyllum spicatum*, H = *Heteranthera dubia*, E = *Elodea nuttallii*, N = *Najas flexilis*, P = *Potamogeton richardsonii*). Individual letters indicate species growing in continuous beds, while a + preceding a letter indicates small colonies or scattered individuals of a species.

Species that continue to survive.

Those species that have continued to survive in Put-in-Bay Harbor may also be discussed as two groups. The submersed species, *Heteranthera dubia* (Jacq.) MacM. (Fig. 3), *Ceratophyllum demersum* L., and *Elodea nuttallii* (Planch.) St. John (Fig. 3) continue to be occasional. On the other hand, *Vallisneria americana* Michx. occurs in such luxuriance as to cover nearly the entire bottom of the Bay (Fig. 3). Its abundance has increased dramatically since 1985, when the second author first qualitatively surveyed the Harbor, and may now be considered "superabundant," certainly the dominant submersed macrophyte species in the Bay, although it is interrupted by occasional colonies of the above three species. The northern pondweed, *Potamogeton richardsonii* (Benn.) Rydb. is now more plentiful than reported by Stuckey (1971), and considered occasional throughout the Bay with small, persistent colonies near either shore of Perry's Victory Monument and two large, fruiting colonies in 2.5 m of water in the middle of the main harbor, each occupying 10 m² (Fig. 3). *Zannichellia palustris* L. remains rare. The occurrence of this species, seldom noticed during the warm summer months is probably more evident during the spring months of May or June.

The emersed (emergent) or shoreline species showing some increase in abundance during the past 30 years are *Justicia americana* (L.) Vahl, *Carex comosa* Boot., *Scirpus pungens* Vahl (*S. americanus* Pers.), and *S. validus* Vahl. Other species evidently not changed in abundance are *Scirpus acutus* Muhl., *S. atrovirens* Willd., *S. fluviatilis* (Torr.) Gray, *Juncus torreyi* Cov., *Rumex verticillatus* L., *Sparganium eurycarpum* Engelm., *Asclepias incarnata* L., and *Sagittaria latifolia* Willd.

Species that have decreased in abundance.

With the exception of the emersed species *Typha latifolia* L., only submersed species have shown a noticeable decline in abundance. The native species *Potamogeton*

pectinatus L. is now considered rare, where previously it was much more common throughout the Bay during the 1970s and 1980s. *Potamogeton pusillus* var. *tenuissimus* Mert. & Koch (*P. berchtoldii* Fieber in Stuckey 1971, based on the nomenclatural revision by Haynes 1974), has remained occasional. Nonindigenous, submersed species have also declined in abundance compared to the 1970s and 1980s, when they were more common, including *Myriophyllum spicatum* L., *Potamogeton crispus* L., and the submersed form of *Butomus umbellatus* L. (clustered in an area 3 m² near Peach Point in 0.5 m of water). *Hibiscus palustris* L. was planted in Terwilliger's Pond in 1986, but has declined elsewhere in the Harbor.

The native *Myriophyllum exalbescens* Fern. was last known for Put-in-Bay Harbor in 1946, based on specimens in the F. T. Stone Laboratory Herbarium. The report of *M. exalbescens* by Stuckey (1971) is in error. *Myriophyllum spicatum*, the foreign species, was first collected from Put-in-Bay Harbor in June 1952, as represented by specimens in the F. T. Stone Laboratory Herbarium (Stuckey 1989; Mills et al. 1993). This record predates the 1961 report for Lake Erie at Rondeau Provincial Park, Ontario, Canada (Aiken et al. 1979).

DISCUSSION

As discussed in detail by Stuckey (1971, 1989), increased turbidity of the water was believed to be the major factor in the loss of submersed species of aquatic vascular plants in the bays, marshes, and ponds of western Lake Erie. The most convincing evidence for the loss of submersed species was in Put-in-Bay Harbor, where of the 22 species noted in the survey by Pieters (1901), 15 (61%) of them had disappeared by 1967. If the turbidity were reduced, one then might logically expect that certain changes would occur in the floristic species composition. Some improvement in water clarity was becoming evident by 1985, but with the invasion and subsequent colonization of substrate by the Zebra (1988) and Quagga mussels (1991), the water has now become remarkably clear in both the Bay and the Lake, with 1994 secchi disk readings at times exceeding 4.5 m. This loss of turbidity has allowed two trends to become evident in species composition and abundance.

First, the submersed, perennial species, *Najas guadalupensis* and *Elodea canadensis*, and the submersed annuals, *Potamogeton foliosus*, *P. pusillus* var. *pusillus*, and *Najas flexilis*, have returned to the Bay. The northern pondweed *Potamogeton richardsonii* was rare in 1985, occurring as single, isolated plants, but now occurs as several large colonies. Other native species that have continued to live in the Bay since 1900 have also increased, but to a lesser extent.

Second, those species that thrived when the waters were much more turbid are now exhibiting a decrease in abundance, including the native *Potamogeton pectinatus*, and the non-indigenous ones, *Myriophyllum spicatum*, *Potamogeton crispus*, and the submersed form of *Butomus umbellatus*. The invasion of these non-indigenous species into Lake Erie is documented in Mills et al. (1993).

Another factor that may allow for the return or increase in abundance of the native *Najas flexilis*,

TABLE 2 (Continued)

¹Publication with author and year in parentheses are cited in Stuckey (1971) and not cited here.

²Years not in parentheses refer to the year of the study and/or collections.

³Growth Habit:

S = Submersed aquatic species

E = Emersed (or large, floating-leaved) aquatic species

⁴Geographical Distribution:

N = Northern

S = Southern

W = Widespread

⁵Abundance values as determined by Stuckey (1971), or inferred from the literature for the data between 1890-1994, or observations by the authors.

SA = Superabundant

A = Abundant

C = Common

O = Occasional

R = Rare

+ = Present (used when abundance values are not known)

• = Herbarium specimen record (Known herbarium specimens cited in Table 2 are available for most of the 1898 records of Pieters (1901), the 1930-1941 records of Core (1949), the 1967-1970 records of Stuckey (1971), and the recent reappearance of the species noted above.)

Potamogeton foliosus, and *P. pusillus* var. *pusillus* and the new, non-native invader *Najas minor*, is that these species are all functionally annuals, dependent upon buried seeds for long-term survival and subsequent germination. This germination occurs under those environmental conditions favorable for each species. Germination evidently can occur if these seeds receive a sufficient amount of light, as well as the proper red wavelengths (Wesson and Wareing 1969a,b; Stuckey 1989). Seeds of many species, and especially seeds of submersed aquatic plants, can survive buried in bottom sediments for many years, and then germinate when the required parameters become available to the seeds (Crocker 1938; Muenscher 1936a,b; Leck and Graveline 1979; Siegley 1986; Siegley et al. 1988; van der Valk 1981; van der Valk and Davis 1976, 1978). To date, no report of seed bank analysis is available for the Harbor.

Fluctuations in abundance of some species and in species composition have occurred since Pieters' initial study in 1901, although the total number of species has essentially remained constant at 40. Future monitoring of the changes in the aquatic flora of Put-in-Bay Harbor may provide additional insight into the long-term effect of *Dreissena* spp. (Zebra Mussels) on the submersed macrophyte species.

ACKNOWLEDGEMENTS. The authors gratefully acknowledge Linda Breier, Tracy L. Engle, John R. Hageman, Jr., Gregg Kennedy, Valerie Kowalski, Lisa Main-Reedy, Donna Pitts, Marvin L. Roberts, Scott Roush, Gregory J. Schneider, Carol E. Sigley, and students in the 1993 aquatic plants course.

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APPENDIX

Put-in-Bay Harbor, Ottawa County specimens examined.*

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- Potamogeton foliosus* Raf.: Put-in-Bay Harbor, August 1991, T. L. Engle (OS).
- Potamogeton richardsonii* (Benn.) Rydb.: Monument Bay, [Put-in-Bay Harbor], 3 August 1963, P. M. Daniel (OS).
- Potamogeton pusillus* L. var. *pusillus*: growing in deep water, Put-in Bay [Harbor], 6 August 1989 C. J. Lee 43 (OS).
- Potamogeton pusillus* var. *tenuissimus* Mert. & Koch [= *P. berchtoldii* Fieber]: Squaw Harbor, Put-in-Bay, 22 July 1963, P. M. Daniel (OS).
- Najas flexilis* (Willd.) Rostk. & Schmidt: Put-in-Bay Harbor, August 1991, T. L. Engle (OS).
- Najas minor* Allioni: South of Gibraltar Island, Put-in-Bay, 9 August 1994, G. Martin (OS).
- Elodea nuttallii* (Planchon) St. John: Quite [Quiet] water 4-5 feet deep, Squaw Harbor, South Bass Island, 7 August 1957, R. Cruden 225 (OS).
- Nuphar advena* Ait.: Put-in-Bay, Terwilliger's Pond, 19 August 1994, R. Chittum (OS).
- Nymphaea tuberosa* Paine: NW corner of Terwilliger's Pond, 13 August 1989, D. L. Burgess (OS).
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*These specimens represent the earliest collections for native species which have reappeared in Put-in-Bay Harbor after an absence, or non-indigenous species which have recently appeared (Table 2).