Flora of the Erie Islands: A Review of Floristic, Ecological and Historical Research and Conservation Activities, 1976 – 2010

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Abstract. The purpose of this review is to survey the floristic, ecological and historical research about the Erie Islands and its flora since 1976 and to describe efforts to conserve Erie Island habitats. Island location records, surveys and multi-island inventories reveal that over 1,000 vascular plant taxa are known from the Erie Islands and new records continue to be found. Alvar habitats, rare globally, occur on the Erie Islands and are a focus of conservation efforts. Forest composition is primarily related to island elevation above lake level and moisture availability. Patterns of succession in abandoned vineyards and orchards are not the same due to differing agricultural practices prior to abandonment that favored different suites of invading species. Applying island biogeographic theory and methods to analyze the flora of the Erie Islands demonstrated that the indigenous flora on individual islands varies in relation to the size of an island in accordance with biogeographic theory whereas the non-indigenous flora on smaller islands is a constantly changing random subset of the non-indigenous flora of larger islands. Geological and palynological research about pre-settlement forests support the historic descriptions of these forests by early European settlers. Governmental and private efforts to preserve Erie Island habitats and the flora therein expanded significantly in the past 35 years. Efforts by the State of Ohio, the Province of Ontario, non-governmental organizations and island communities to acquire and conserve unique island habitats resulted in the preservation of important alvar, wetland and woodland habitat on large islands and the acquisition of Green Island, Middle Island and West Sister Island.

OHIO J SCI 110 (2): 3-12, 2011

INTRODUCTION

In 1966, Ronald L. Stuckey began a project to inventory the flora of the Erie Islands (Figure 1) continuing the studies of Moseley (1899), Pieters (1901), Dodge (1914) and Core (1948). Thomas Duncan joined the project in 1969 and became co-investigator and co-author in 1970. Preliminary results were reported to the Ohio Academy of Sciences Annual Meeting (Stuckey and Duncan 1971) and completion of the project was reported in the same venue (Stuckey and Duncan 1977). The manuscript describing the results of their investigations and containing a catalogue of the flora was submitted for publication (Stuckey and Duncan 1976). After review and preliminary copy editing the manuscript was scheduled for publication in 1979. Due to the authors' professional commitments, the manuscript did not undergo a final editing and was not published. Xerographic copies of the manuscript were deposited in The Ohio State University Library and at The Franz Theodore Stone Laboratory. Additional copies were made available to investigators conducting floristic and ecological research on the Erie Islands. From 1977 to 1988, Stuckey incorporated elements of the manuscript into various publications related to his larger research program on the aquatic plants of northern Ohio near the Lake Erie shoreline (Cooper and Herdendorf 1977; Herdendorf and Stuckey 1979a, b; Stuckey 1979, 1988; Stuckey and Carr 1979). In 1999 and 2000, Stuckey transferred the 1976 manuscript and reviews, notes and copy editing from 1979 to Duncan who created a digital version of the manuscript. No decision about the distribution of the digital version of the manuscript was made. In 2009, the authors were contacted by The Lake Erie Islands Chapter of The Black Swamp Conservancy (LEIC-BSC) and asked if the manuscript could be published for use in their conservation activities. The 1999 digital version of the 1976 manuscript was edited and published (Stuckey and Duncan 2010). The purpose of this review is to survey the floristic, ecological and historical research since 1976 about the Erie Islands and its flora and describe ongoing efforts to conserve Erie Island habitats and the flora they contain to complement and update the results presented in Stuckey and Duncan (2010).

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FLORISTIC RESEARCH

United States Islands

Schneider (1996) surveyed the status of Ohio rare plants on the Lake Erie coast and on the United States Erie Islands. He concluded that Kelleys Island is one of the most significant locations for rare vascular plants in Ohio. On Kelleys, these rare plants occur in abandoned quarries, on the North Shore Alvar and in the North Pond State Nature Preserve (Carp Pond of Stuckey and Duncan 2010). Rare plants in the quarries are Limestone Wild Basil (*Clinopodium arkansanum*), Elk Sedge (*Carex garberi*), Capitate Spike-Rush (*Eleocharis geniculata*), Flat-Stem Spike-Rush (*E. compressa*), Pacific Wormwood (*Artemisia campestris* ssp. *caudata*), Balsam Groundsel (*Packera paupercula*) and Rock Elm (*Ulmus thomasii*). The Division of Natural Areas and Preserves introduced Eastern Four-Nerve Daisy (*Tetraneuris herbacea*) on Kelleys from the Marblehead Peninsula on the Ohio mainland in 1989 as part of a federal recovery plan for the species. New records for the United States Erie Islands on Kelleys Island are Midland Sedge (*Carex mesochorea*), Capitate Spike-Rush (*Eleocharis geniculata*), Blunt Spike-Rush (*E. obtusa*), Philadelphia Panic Grass (*Panicum philadelphicum*) and Narrow-Leaf Blue-Eyed-Grass (*Sisyrinchium angustifolium*). The last three are also known from the Canadian Erie Islands on Pelee Island (Oldham 2001). Of the species noted on Kelleys by Schneider (1996), Stuckey and Duncan (1976, 2010) reported Limestone Wild Basil from Hanck's Pond, Pacific Wormwood from Fishing Point on Pelee and Balsam Groundsel on South Bass and Pelee, as well as reporting each from Kelleys Island. At the North Pond State Nature Reserve, Arum-Leaf Arrowhead (*Sagittaria cuneata*) was not seen in 1998, a high-water year, but

may return during years of lower lake levels. Stuckey and Duncan (1976, 2010) reported Arum-Leaf Arrowhead (*Sagittaria cuneata*) for South Bass Island, North Bass Island and Pelee Island as well as Kelleys Island. Drummond's American-Aster (*Symphyotrichum drummondii*) and Slender Goldentop (*Euthamia caroliniana*), new records for the Erie Islands, were seen on West Sister in 1981 but not seen by Schneider in 1996. Other rare species, tracked by the State of Ohio, are Bluebell-of-Scotland (*Campanula rotundifolia*) and Northern Bog Violet (*Viola nephrophylla*). These species occur on the Bass Islands, Pelee Island and some small islands. Woischke (2003a, b) reviewed the status of rare plants of the Erie Islands on Starve Island, Green Island, Rattlesnake Island and Ballast Island. The status of Erie Islands rare plants on South Bass Island continues to be monitored (Woischke 2009b).

A floristic analysis of two abandoned quarries on Kelleys Island was conducted by Reinking (1979) to examine in more detail the relationships of the flora of abandoned quarries on the Erie Islands presented in Stuckey and Duncan (1976) and to offer recommendations for the management of the quarries to preserve its flora. Stuckey's Hybrid Rush (*Juncus* × *stuckeyi)* was described by Reinking (1981) as a natural hybrid between Northern Green Rush (*J. alpinoarticulatus)* and Torrey's Rush (*J. torreyi),* originally discovered by Ronald L. Stuckey in 1967 in abandoned quarries on Kelleys Island and the Marblehead Peninsula on the mainland. By 1981, Stuckey's Hybrid Rush was increasing in abundance in the quarries on Kelleys Island. Arbour and Gardner (2009) examined the current distribution and status of rare plants on state-owned lands discussed in Schneider (1999) on Kelleys Island with recommendations for management of these areas. They listed 354 species in their survey that will be integrated into the digital data set discussed below (see *Digital floristic data for the Erie Islands* section). Their report of Mud Sedge (*Carex limosa*) of acidic habitats but occurring on Kelleys Island in calcareous soil in an abandoned quarry, was a new record for Erie County, Ohio, and the Erie Islands. Another plant not documented previously in Ohio, Cherokee Sedge (*Carex cherokeensis*) (Woischke 2009a), was found on Kelleys. The previous northernmost records for this species are from Albemarle County, Virginia and Madison County, Kentucky (Kartesz 2010). This species is currently treated as a non-indigenous adventive on the island (Woischke 2010). A non-indigenous orchid species widespread in the United States, Helleborine (*Epipactis helleborine*), was recorded for the first time on the United States Erie Islands (Woischke 2009a) and also known from Pelee Island (Oldham 2001).

Pilatowski (1987) conducted a floristic analysis of Fox's Marsh on North Bass Island comparing the current state of Fox's Marsh to earlier studies including Stuckey and Duncan (1976, 2010). His research supported the conclusion of Stuckey and Duncan

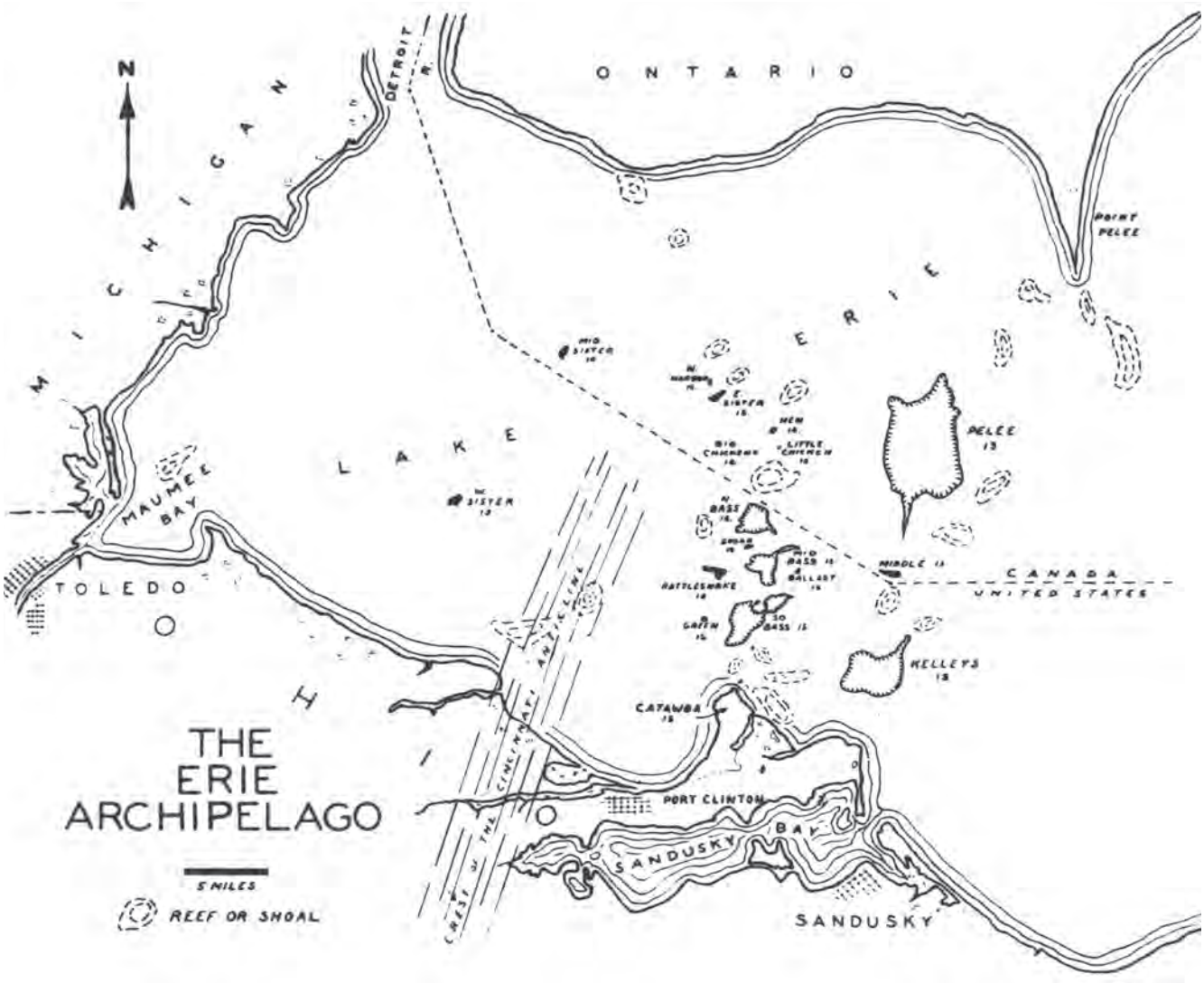

Figure 1. Map of the islands in the western basin of Lake Erie (from Stuckey and Duncan 2010).

(1976, 2010) that Fox's Marsh is floristically diverse, with several species rare or not occurring elsewhere on the islands. With the degradation of Fox's Marsh during the last 20 years due to the invasion of Common Reed (*Phragmites australis* ssp. *australis*) (Schneider 1999; Arbour and Gardner 2008), its diversity is lessened. Common Reed is a serious threat to the native vegetation in all ponds on the Erie Islands. Arbour and Gardner (2008; summary in Woischke 2008a) conducted a vegetation survey of North Bass Island adding approximately 100 new records for that island since Core (1948) and determining the status and distribution of rare plants on the island. A comparison of these lists was not undertaken here but will be part of a project described below (see *Digital floristic data for the Erie Islands* section).

North Pond on Kelleys Island is considered to be one of the best marsh habitats in western Lake Erie (Woischke 2009a) as it was from the late 1960s to the mid-1970s. A detailed comparison of North Pond (Carp Pond) on Kelleys Island, Kuehnle Wildlife Area (Hanck's Pond) on Middle Bass Island, Fox's Marsh on North Bass Island and Fox's Pond on Pelee Island provided in Stuckey and Duncan (1976, 2010) offers a baseline data set for an examination of the changes in these ponds and marshes during the past 35 years.

Hobbs (1992) and Spooner and others (1983) examined the taxonomic status of the Erie Island endemic *Polygonum pensylvanicum* var. *eglandulosum* (now placed in the genus *Persicaria*) and concluded that this endemic variety does not warrant taxonomic recognition. Stuckey and Duncan (1976) recognized the three endemic species of Blackberry (*Rubus*), Erie Blackberry (*R. eriensis*), Core's Blackberry *(R. corei*) and Gordon's Dewberry (*R. gordonii*), described by Liberty Hyde Bailey in Core (1948) and cited in the work of Davis and others (1968 1969a, b) who did not segregate these populations from more widespread species. In Stuckey and Duncan (2010), the endemic species of Blackberry on the Erie Islands are not recognized and are treated as synonyms of Oldfield Blackberry (*R. alumnus* [*R. corei*]), Deam's Dewberry (*R. deamii* [*R. gordonii*]) and Yankee Blackberry (*R. frondosus* [*R. eriensis*]) following Kartesz (2010). No endemic taxa of vascular plants are now known from the Erie Islands.

Gardner (2005) conducted a vegetation survey of West Sister Island reporting 53 species from one of the least studied islands in the western basin of Lake Erie. Vincent and Cusick (1998) reported Erect Brome (*Bromus erectus*), Garden Honeysuckle (*Lonicera ×xylosteoides*), Jetbead (*Rhodotypos scandens*), Nanking Cherry (*Prunus tomentosa*), Simons' Cotoneaster (*Cotoneaster simonsii*), Siberian Crabapple (*Malus baccata*), Spring Speedwell (*Veronica verna*), Thimbleweed (*Anemone blanda*) and Youth-and-Old-Age (*Zinnia violacea*) as non-indigenous species new to Ohio and the Erie Islands. Curve-seed Butterwort (*Ceratocephala testiculata*) was reported for South Bass Island (Cusick 1989).

Canadian Islands

Stuckey (1986) described the first botanical collecting trip by botanists from the United States, William A. Kellerman and his student Harlan H. York, undertaken in 1904 to Pelee Island. York's botanical collections are deposited at The Ohio State University Herbarium, including the only Canadian record of Halberd-Leaf Rose Mallow (*Hibiscus laevis*) (Oldham 1983a). Bernard Boivin (1953) added 56 species to the flora of Pelee Island based mainly on the collections of Wilfred Botham who resided on the island in 1937 and 1938 and wrote a flora of Essex County that contains the Canadian Erie Islands (Botham 1981; update by Oldham 1983c). Many of Botham's collections are cited in Stuckey and Duncan (2010).

A collecting trip to Pelee Island in 1971 by Thomas Duncan resulted in the addition of three species to the Canadian flora (Duncan 1973) from what later became known as the Stone Road Alvar. Craig Campbell and Anton Reznicek made several trips to Pelee and East Sister Islands in the 1970s and added another seven species to the Canadian flora (Campbell and Reznicek 1977). The Canadian Erie Islands continue to produce additions to the Ontario and Canadian flora, such as Glomerate Sedge (*Carex aggregata*) on Middle Island (Oldham and Crins 1988) and Rock Muhly (*Muhlenbergia sobolifera*) on Pelee Island (Oldham and others 1995).

Eighty-three species, rare in Ontario and occurring on the Canadian Erie Islands, are listed in Oldham (1988). Several vascular plants officially listed as species at risk either federally (under the Canadian Species At Risk Act, SARA) or provincially (under the Ontario Endangered Species Act 2007) occur on the Canadian Erie Islands, including Grand Redstem (*Ammannia robusta*), Atlantic Camas (*Camassia scilloides*), Dwarf Hackberry (*Celtis tenuifolia*), Blue Ash (*Fraxinus quadrangulata*), Kentucky Coffeetree (*Gymnocladus dioicus*), Crimson-Eyed Rose-Mallow (*Hibiscus moscheutos*), American Water-Willow (*Justicia americana*), Brown Wide-Lip Orchid (*Liparis liliifolia*), Red Mulberry (*Morus rubra*), Eastern Prickly-Pear (*Opuntia humifusa*), Common Hoptree (*Ptelea trifoliata*) and Climbing Rose (*Rosa setigera*) (COSEWIC 2009; Ontario Ministry of Natural Resources 2009).

The most recently published checklist of the vascular plant flora of the Canadian Erie Islands (Oldham 2001) is included in Celestino (2002). This checklist includes 845 vascular plant taxa for the Canadian Erie Islands, with individual island totals of 823 for Pelee Island, 262 for Middle Island, 215 for East Sister Island, 112 for Hen Island, 108 for Middle Sister Island and 59 for North Harbour Island. Stuckey and Duncan (2010) report 595 for Pelee Island, 153 for Middle Island, 128 for East Sister Island, 115 for Hen Island, 83 for Middle Sister Island and 55 for North Harbour Island. The reports in Oldham represent an increase in the number of species compared to the number of species reported in Stuckey and Duncan (2010) of approximately 42 percent for Pelee Island, 71 percent for Middle Island, 67 percent for East Sister Island, -three percent for Hen Island, 30 percent for Middle Sister Island and nine percent for North Harbour Island.

A comparison of the taxa listed by Oldham (2001) with the catalogue in Stuckey and Duncan (2010) shows that 1,015 taxa reported for the Erie Islands are documented by a least one specimen. Of these 1,015 taxa, 146 were reported for the first time by Oldham (2001) and are found only on the Canadian islands. Taxa reported by both Oldham (2001) and by Stuckey and Duncan (2010) total 653. Taxa only on the United States islands total 176 (reported by Stuckey and Duncan but not by Oldham).

Erie, Lucas and Ottawa counties, containing the United States islands, possess a vascular flora averaging approximately 1,470 taxa. The vascular flora of Ohio contains 3,787 taxa and of Ontario, 4,192 taxa (Kartesz 2010). The Erie Islands comprise about one percent of the land area of these mainland counties and significantly less that one percent of the total area of Ohio and of Ontario. Despite the small land area of the islands, their vascular flora contains approximately 57percent of the taxa of the average mainland county and approximately 20 percent of

the total flora of Ohio or of Ontario. The diverse habitats and unique climate of the islands probably accounts for the presence of this large, diverse flora.

Digital Floristic Data for the Erie Islands

The authors have agreed to construct a digital dataset derived from Oldham (2001), Stuckey and Duncan (2010) and papers discussed above in order to integrate and analyze all floristic data for the Erie Islands. The dataset will include all species reported, their island distributions, citation of at least one specimen for each species reported, distribution outside the islands and life form for each indigenous taxon. These data will be incorporated within the Biota of North America Program *Floristic Synthesis for North America* (Kartesz 2010) as one means of distribution. A taxon by island matrix describing the presence or absence of a taxon on each island, derived from Stuckey and Duncan (1976), and prepared for Cooper and Herdendorf (1977), provided test data for documenting the occurrence of species on each island within the *Floristic Synthesis of North America.* A data model for creating an integrated digital floristic data set for the flora of the Erie Islands is under discussion.

ECOLOGICAL RESEARCH

Alvars on the Erie Islands

Beschel (1968) first applied the Estonian habitat type, "alvar," to habitats in southern Ontario characterized by limestone bedrock covered by a thin layer of soil. The Alvar Working Group defines alvars as "natural communities of humid and sub-humid climates, centered around areas of glaciated horizontal limestone/dolomite (dolostone) bedrock pavement with a discontinuous thin soil mantle. These communities are characterized by distinctive flora and fauna with less than 60 percent tree cover that is maintained by associated geologic, hydrologic and other landscape processes. Alvar communities occur in an ecological matrix with similar bedrock and hydrologically influenced communities." (Reschke and others 1999). Catling and others (1975) and Catling (1995) surveyed the alvar vegetation of Ontario. Alvars in Ontario occur on Manitoulin and Pelee islands and along the contact line between Precambrian and Ordovician bedrock. Schneider (1996) discussed alvars in Ohio. On the American islands, the most significant alvar occurs on the north shore of Kelleys Island with smaller alvar sites on Green Island (see also Cusick 1998).

Jacques and Kirk (1985) and Kirk (1994) discuss the history and management of the largest alvar on Pelee Island, Stone Road Alvar, with 48 provincially rare plant species present at this site. In 2007, Ambrose and others (2007) surveyed the Shaughnessy Cohen Memorial Savannah that contains 80 percent of rare plant species occurring at the Stone Road Alvar. At least five species have their entire current Canadian range on Pelee Island (*Blephilia ciliata, Carex leavenworthii, Muhlenbergia sobolifera, Triosteum angustifolium* and *Viola rafinesquii*) and several others, mostly or entirely on the Erie Islands (e.g. *Solidago umlifolia, Myosotis macrosperma, Valerianella umbilicata, Camassia scilloides, Phacelia purshii, Carex aggregate, Corydalis flavula*). The most significant threat to this area is the spread of invasive plants, particularly Garlic-Mustard (*Alliaria petiolata*). This and other invasive species are discussed in the *Forest Composition and Succession* section below.

Ordination analyses of the species composition of alvars in Ontario (Belcher and others 1992) clearly demonstrate that southern Ontario alvar sites differ floristically from sites that are more northern. Further analyses by Catling and Brownell (1995) showed that Stone Road Alvar is different from all other alvars in Canada by the presence of a high number of species with southern and western distributions. Stuckey and Duncan (1976, 2010) discuss the significance of southern and western floristic elements in the Erie Islands flora. These elements constitute 25 percent of indigenous species reported by them. Alvars, rare worldwide, have become a conservation priority and the conservation of Great Lakes alvars is addressed in Reschke and others (1999).

Forest Composition and Succession

Core (1948) and Hamilton and Forsyth (1972) stated that forest composition on the Erie Islands is correlated with soil types. Stuckey and Duncan (1976, 2010) postulated that forest composition was more highly correlated with available moisture rather than soil type. Boerner (1984) examined the factors affecting forest composition using species importance values in quadrats along a transect across each site for 26 sites located on South Bass Island (12), Middle Bass Island (3), North Bass Island (3), Green Island (2), Kelleys Island (3) and Pelee Island (2) and mainland Ohio (1). Using reciprocal averaging and regression methods, these data were analyzed to identify factors that account for the variation in forest composition at these sites. From these analyses, Boerner concluded that the primary factor controlling forest composition is elevation above lake level and its effect on soil moisture. Lower elevation forests are largely influenced by water movement from the lake whereas upland sites are largely influenced by the balance between precipitation and evapotranspiration. The distinctive Sugar Maple (*Acer saccharum*) - Common Hackberry (*Celtis occidentalis*) forests on most islands is due to cutting mammal-dispersed species of Oak (*Quercus*) and Hickory (*Carya*) and the inability of these species to become re-established. Historical accounts that describe the forests of the Erie Islands at and shortly after settlement are provided in Stuckey and Duncan (2010).

Boerner (1985) also studied successional patterns in sites with different land use histories and time since abandonment. Eleven abandoned vineyards of 20-80 years since abandonment, eight orchards of 20-90 years since abandonment and two quarry sites of 40-45 years since abandonment were studied and compared with eight sites used in Boerner (1984). Historical data for date of abandonment were derived from maps in Stuckey and Duncan (1976, 2010) and interviews with local residents. Using the same transect sampling methods and importance value calculations in Boerner (1984), the data matrix was analyzed. From this analysis, he concluded that quarries have a successional sequence that is strikingly different from orchards, vineyards and woodlots. Abandoned quarries have not developed a closed canopy and it is unlikely that they will. Forty years after abandonment the two quarry sites in these analyses had only scattered Eastern Red Cedar (*Juniperus virginiana*) of very small size.

Orchards, vineyards and woodlots were separated into two groups based on elevation. Length of time since abandonment was important in accounting for the change in species composition in orchards but not in vineyards, where elevation is the most important factor. Comparing upland vineyards and orchards, vineyards abandoned more that 25 years ago have woody closed canopies while orchards support a distinct suite of woody species. Farming practices in orchards with appropriately spaced trees on flat ground and annual weed removal compared to vineyards with a furrow and mound topography with vegetation in the furrows account for these differences. Differences in canopy species composition in lowland and upland vineyards probably correspond to the different successional stages of the Sugar Maple (*Acer saccharum*) - Common

Hackberry (*Celtis occidentalis*) association reported by Hamilton and Forsyth (1972). This forest type is treated as a simplified version of the Oak (*Quercus*) - Maple (*Acer*) forest occurring more widely in Ohio and Ontario (Anderson 1982). Assuming a common end point to succession, orchards will continue to see species turnover while vineyards will largely see relative abundance change in species already present.

Sugar Maple (*Acer saccharum*) and Common Hackberry (*Celtis occidentalis*) dominate upland forests with more than 100 years since the last disturbance. Data from abandoned vineyards and orchards indicate that in early stages of succession, Common Hackberry is more frequent than Sugar Maple but over time Sugar Maple increases through more effective regeneration whereas Common Hackberry maintains its presence by more effective regeneration in canopy gaps produced by death of trees or destruction of trees during winter storms.

Since 1976, the floristic composition of woodlots is undergoing significant change due to the presence or expansion of populations of deleterious plants. Garlic-Mustard (*Alliaria petiolata*) has had a significant influence on the understory herbaceous vegetation on many islands. First collected on Kelleys Island in 1897 by E. L. Moseley and reported only from Kelleys Island by Core (1948), it is now reported from almost all islands (Stuckey and Duncan 1976, 2010; Oldham 2001). The Ohio Department of Natural Resources provides information for the management of areas with this species in Ohio (Anonymous 2001; http://www.dnr.state.oh.us/tabid/2005/Default.aspx; accessed 2010 Sep). The Nature Conservancy of Canada (2007) prepared a management plan for Ontario Nature Reserves to minimize the damage by Garlic-Mustard; LEIC-BSC monitors the abundance of Garlic-Mustard and other invasive plants on the Erie Islands (Anonymous 2001). Invasive plants of woodlots include Amur Honeysuckle (*Lonicera maackii*), Wintercreeper (*Euonymus fortunei)*, Common Periwinkle (*Vinca minor*) and English Ivy (*Hedera helix*). These plants are spreading in woodlots to the detriment of the native flora.

Invasive birds, mammals and insects are also having a detrimental effect on the native woodlot flora. On several islands, Double-Crested Cormorant (*Phalacrocorax auritis*) populations have greatly increased, inflicting significant damage to trees (Hebert and others 2005). Middle Island and Green Island, in particular, show extensive damage from Double-Crested Cormorant disturbance. In 2007, an infestation of Ash (*Fraxinus*) trees at Kelleys Island State Park by European Ash Borer (*Agrilis planipennis*) was reported (Eckardt 2008). The infestation was heavy and Ash is expected to disappear from Kelleys and be replaced by other dominant tree species, particularly Maple (*Acer)*. Infestations are more recent and less widespread on South Bass Island, Middle Bass Island, North Bass Island and Gibraltar Island (Kane and others 2009; Primer and Kane 2010). The existence of Ash as an important component element of the forests of the Erie Islands is predicted to be of limited duration. White-tailed Deer (*Odocoileus virginianus*) populations quadrupled in size in Ohio between 1987 and 2007 (http://ourohio.org/magazine2007-2/march-april-may-2007/deerly-departed/; accessed 2010 Sep). On the Erie Islands, a population of several hundred White-tailed Deer exists on Kelleys Island and a population of less than 100 on South Bass Island. These populations pose a threat to the native and cultivated flora, particularly on South Bass Island.

Biogeography

Klinkenberg (1983, 1988, 1992, 2001) examined the flora of the Erie Islands using the theory and methods of island biogeography (McArthur and Wilson 2001). Using data from Duncan and Stuckey (1970) and Stuckey and Duncan (1976) as well as extensive field work and herbarium studies, the relationship between island size and number of species present was examined. Klinkenberg's analysis revealed that the number of non-indigenous species increases more rapidly with island size compared to the increase in the number of indigenous species. Plants indigenous to the Erie Islands display a relationship between the number of indigenous species on an island and the size of that island is in accordance with island biogeographic equilibrium theory. Similar results were obtained for spiders and reptiles using data from Downhower (1988). The number of non-indigenous species on an island is related to degree and extent of disturbance on the island rather than the size of the island.

An analysis of floristic similarity among islands was conducted by calculating a floristic similarity value for each pair of islands using Preston's similarity measure. A matrix of pairwise similarities was calculated for indigenous and non-indigenous, respectively. For indigenous species, the similarities among large islands are consistent with island biogeographic theory. Similarities among smaller islands is less than expected perhaps because the number of habitat types is more limited and/or the smaller islands share habitats of limited distribution on larger islands. Middle Island has a distinctive flora. The acquisition of Middle Island (see Conservation Activities on the Canadian Islands below) is a significant action given these results. For non-indigenous species, the similarities among South Bass, Middle Bass, North Bass and Kelleys Islands are consistent with island biogeographic theory. All other islands have a non-indigenous flora that is a random subset of the non-indigenous species on these four islands.

Restoration of Lake Erie

By the late 1960s, environmental conditions in Lake Erie were sufficiently unpleasant due to algae blooms and increasing amounts of effluent in the lake that many observers were of the opinion that Lake Erie was approaching "death." Ashworth (1987), in an environmental history of the Great Lakes, dismisses the notion that the lake was dying by pointing out that the eutrophication of Lake Erie meant that the lake was "too alive for its own good." The increased eutrophication of the lake is reflected in Stuckey's (1971) analysis of the drastic changes in the aquatic flora of Put-in-Bay Harbor due to increasing siltation and turbidity in the harbor.

By the late 1980s, due to reductions in phosphorus entering the lake and international agreements on water quality management (Jeanneret 1989) as well as the initiation of habitat restoration projects (Makarewicz and Bertram 1991), the Lake Erie environment significantly improved. Improvement in water quality in the Lake Erie basin is reflected by the return of large populations of mayflies (*Hexagenia*)(Krieger 1998) and improvements in fish diversity and population size (Ludsin and others 2001). Stuckey and Moore (1995) re-examined the aquatic plants of Put-in-Bay Harbor and reported that seven of the 20 species that disappeared during periods of high turbidity returned and indigenous species that were less frequent than reported in the early 1900s increased in abundance. Those species that had become more common

during periods of high turbidity were now less common. Moore (2007) reported two additional taxa rediscovered in Hatchery Bay. Long-Leaf Pondweed (*Potamogeton nodosus*) was growing in substantial colonies in Hatchery Bay in 1.5 meters of water. Flat-Stem Pondweed (*Potamogeton zosteriformis*) and Illinois Pondweed (*Potamogeton illinoensis*) were observed growing near The Ohio State University docks on South Bass Island. Survival of these populations is uncertain due to increasing algal blooms in Put-in-Bay Harbor.

Despite improved water quality, decreasing agricultural and industrial pollution and successful restoration of aquatic habitats in the 1980s and early 1990s, environmental conditions in Lake Erie deteriorated over the last decade. Research on the current state of Lake Erie is provided through the University of Windsor at the Lake Erie Millennium Network (http://web2.uwindsor.ca/lemn/index.htm; accessed 2010 Sep) and the State of the Straight (http://web4.uwindsor.ca/units/stateofthestraight/softs.nsf/inToc/10FF8B04FF3A317885256D88005720F6?OpenDocument; accessed 2010 Sep) websites.

HISTORICAL RESEARCH

Post-Glacial Geological History and Pre-Settlement Vegetation

A review of the deglaciation of North America about 12,000 years before present (ybp) provided new details on the early development of Lake Erie and the limestone and dolomite ridges that became the islands (Teller 1987). Early Lake Erie was formed about 12,500 ybp as the Laurentide ice sheet retreated. With crustal rebound and deeper outflow channels, early Lake Erie was of much less areal extent than it is today. Early Lake Erie was three eastward-descending and deepening sub-lakes. Channels connecting the three lakes cut across bedrock ridges of the Cincinnati Arch that now form the Erie Islands. Much of the western basin of Lake Erie remained dry during this period. Isostatic uplift changed outflow patterns and early Lake Erie had no outflow route for a period after 11,500 ybp. By approximately 10,000 ybp, glacial retreat along the Huron Basin allowed outflow through the St. Lawrence River and from this time the glacial margin no longer determined water levels in the Great Lakes east of the Superior basin. At 9,500 ybp major parts of the western basin of Lake Erie remained dry. The level of the lake continued to drop after the opening of the St. Lawrence River as the outflow for Lake Erie. With isostatic rise, current levels of Lake Erie were reached about 4,500 ybp, the extent of Lake Erie increased and the Lake Erie islands were formed.

Jacobson and others (1987) examined the patterns and rates of vegetation change during the past 10,000 years using pollen profiles from 250 sites in eastern North America. Various prominent plant groups, including Sedge (*Carex*), Spruce (*Picea)*, Birch (*Betula*), Oak (*Quercus*), Hickory (*Carya*) and Ash (*Fraxinus*) were identified in these pollen profiles. The expansion of Sedge (*Carex*) into western Ohio between 8,000 and 6,000 ybp is consistent with the eastward expansion of prairies during this period. By 10,000 ybp, extensive populations of Spruce south of the glacial margin began to collapse and, by 8,000 ybp, temperate forests began to replace boreal forests that thrived prior to deglaciation. With the decline in spruce, other tree species such as Oak, Hickory and Ash became more common with Hickory increasing after the arrival of Oak and Ash. By 8,000 ybp, the composition of what would become the pre-settlement forests of the Erie Islands was largely determined.

Hamilton and Forsyth (1972) did not believe that American Beech (*Fagus grandifolia)* was part of the pre-settlement forests of the Erie Islands. Stuckey and Duncan (1976, 2010) discuss the historical reports of American Beech on the islands and concluded that American Beech was part of the pre-settlement forests. Bennett (1988) examined the post-glacial expansion of American Beech in Ontario. His results show that American Beech increased from 7,500 ybp to 6,000 ybp along with Birch (*Betula)* and Sugar Maple (*Acer saccharum*) and support the results of Jacobson and others (1987). Therefore, American Beech was probably part of the pre-settlement forests of the Erie Islands.

Biographies of Botanists

Niederhofer and Stuckey (1998) and Stuckey (2003) document the life and scientific accomplishment of Edwin Lincoln Moseley, author of the *Sandusky Flora.* Clarkson and Clovis (1984) outline Earl L. Core's long botanical career and his contribution to the botany of the southeastern United States. Cooperider (1985), in his recollections of Earl L. Core, cites a letter from Core dated October 31, 1984, shortly before his death, stating "[o]ne of my great pleasures was the preparation of my *Flora of the Erie Isles*, the product of three delightful summers at Put-in-Bay." The late Jane L. Forsyth, a leader in the field of geobotany—linking plant distributions and plant communities with geological history and substrates—was also one of the leading authorities on the geological features and history and soils of the Erie Island (Forsyth 1988, 1991) and contributed a chapter on these topics for Stuckey and Duncan (1976, 2010). Stuckey compiled Forsyth's publications into a single volume with commentary on her career (Forsyth 2003). John L. Thieret, faculty member at the Franz Theodore Stone Laboratory and collaborator in Stuckey and Duncan (1976, 2010), is commemorated by his friends and colleagues in Stuckey (2006).

Cultural and Economic History

Several books and articles, published since 1976, added to our knowledge of the cultural and economic history and development of the Erie Islands (Stuckey and Duncan 2010 provide a summary of the cultural and economic history of the Erie Islands prior to 1976). Martin (1990) provides a history of Kelleys Island and short vignettes of the other American islands. A collection of photographs taken by Thomas H. Langlois from 1936 to 1960 on South Bass Island illustrates the island and its habitats during that period (Titchener 2002). A brief history of North Bass Island is presented in Woischke (2004). Stuckey (2002) compiled newspaper articles, primarily from the *Sandusky Register,* about the early history of the islands focusing on articles by Lydia J. Ryall (writing under the pseudonym, Theresa Thorndale). Ryall's articles (Ryall 1913) provide early descriptions of areas now under the ownership of the State of Ohio. Stuckey and Duncan (1976, 2010) used quotes from Ryall as an introduction to most chapters. Waffen (2006) provides a historical essay on the islands with excellent photographs accompanying the text. Cruickshank (1999) provides a history of the South Bass Island Lighthouse, constructed in 1897, acquired by The Ohio State University in 1967 and placed on the National Register of Historic Places in 1990. Ligbel and Wright (1987) wrote a guided architectural tour guide for the Bass Islands. Barbour (2005) and Wells (2003) document this history of the Rattlesnake Island local post and its stamps and provide detailed historical information of the island. Several publications of the Pelee Island Heritage Centre document human and natural history of Pelee Island (http://www.peleeislandmuseum.ca; accessed 2010 Sep; Tiessen 1992, 1997, 1999, Tiessen and others 2002 and Tiessen 2003). The Ohio Sea Grant, Ohio Chapter of The Nature Conservancy and the Lake Erie Coastal Ohio Trail National Scenic Byway recently published an

extensive guide to natural and cultural on the Erie Islands (Weber and Huntley 2009).

CONSERVATION ACTIVITIES

United States Islands

The first attempt at conservation on the United States Erie Islands was a "public lawn" or open space for visitors and residents. On 14 June 1866, Jose de Rivera St. Jurgo gave the people of South Bass Island the Lawn or Grove, a village park with usage specifications and a prohibition on buildings of any kind. Today, known as DeRivera Park, the area that was de Rivera's Lawn serves as a testament to the community's continuing belief in his insistence on land use restrictions (Dodge 1975).

Early 20th century attempts at land preservation on a national level brought about the West Sister Island National Wildlife Refuge in 1937 to protect the largest wading bird nesting colonies on the Great Lakes. West Sister Island became Ohio's only federal wilderness area in 1975. Green Island State Wildlife Area was transferred to the Ohio Division of Wildlife from the General Services Administration in 1961 and includes several caves and rare plant species.

The Franz Theodore Laboratory had a significant role in identifying areas and habitats for preservation through its teaching program, support for scientific research and collaboration with The Center for Lake Erie Area Research. The history of The Franz Theodore Stone Laboratory, the oldest freshwater biological field station in the United States, is outlined in Stuckey and Duncan (1976, 2010) and Bocking (1990). Cooper and Herdendorf (1977) and Stuckey and Duncan (1976, 2010) identified important areas and habitats for protection. The Ohio Chapter of The Nature Conservancy remains active in documenting island resources through their bi-national Western Lake Erie Islands and Reefs Conservation Plan (Anonymous 2003).

The State of Ohio acquired parkland on South Bass Island at the site of the former Hotel Victory by purchasing three parcels between 1938 and 1946. This area now forms the South Bass Island State Park that features high dolomite cliffs and bedrock shores. The Oak Point State Park on South Bass was purchased as a Wildlife Area in 1938 and transferred to The Ohio Department of Parks in 1972 (Ohio Department of Natural Resources unpublished land inventory 2006).

On Kelleys Island, spectacular glacial grooves are located at the Glacial Grooves State Memorial owned by the Ohio Historical Society and extensive sand beaches occur at the Kelleys Island State Park managed by The Ohio Department of Parks. Kelleys Island State park occupies approximately 25 percent of the 1,133 hectare (2,800 acre) island. The 267 hectare (660 acre) park was originally acquired by the Cleveland Museum of Natural History through a 1955 donation by a major lime company with the stipulation that the land would be purchased from by the State of Ohio when funds were secured. The purchase was completed the following year. The Cleveland Museum of Natural History retained some isolated tracts of land that became the first natural areas under their management. Holdings for the Cleveland Museum of Natural History expanded by the efforts of botanist James Bissell and now include six natural areas with over 48.6 hectares (120 acres of habitat protected, including woodland, alvar and Rock Elm savanna (http://www.cmnh.org/site/Conservation/NaturalAreas/Map/KelleysIsland.aspx; accessed 2010 Sep). The North Pond (Carp Pond) State Nature Preserve, dedicated in 1999, protects a 12 hectare (30 acre) wetland that opens to Lake Erie. The 0.2 hectare (0.5 acre) North Shore Alvar State Nature Preserve contains Ohio's last remaining intact alvar community. (http://www.kelleysislandnature.com/; accessed 2010 Sep).

In 1992, a small group of Kelleys Island residents formed the Kelleys Island Audubon Club to protect, preserve and develop natural habitat for the birds and wildlife that inhabit the island. They secured protection for areas such as the North Pond and North Shore Alvar and lead successful birding, ecotourism and educational programs (http://www.kelleysislandnature.com/; accessed 2010 Sep). The Friends of Hanck's Pond was formed in 1995 to purchase and preserve the wetland now known as Kuehnle State Wildlife Area on Middle Bass Island. A local fund-raising campaign matched funds available from Ducks Unlimited to purchase the wildlife area for the state (San Gregory 1999). In 2000, the Ohio Department of Natural Resources (ODNR) purchased 123 acres of lakefront property on Middle Bass Island including the former Lonz Winery and holdings protecting nearly one mile of Lake Erie shoreline, a harbor and marina and natural areas with endangered plant and wildlife species. In 2004, The State of Ohio used state and federal funds to purchase 87 percent of North Bass Island. The wetlands formerly known as Fox's Marsh and Honey Point contain important plant collecting localities (Stuckey and Duncan 2010, Arbour and Gardner 2009) and are managed by the Division of Wildlife. The remainder of the state owned acreage will be managed by the Division of Parks.

The private DeRivera Park Trust purchased 7.3 hectares (18 acres) of woods and caves formerly owned by the Cooper family on South Bass Island. The Friends of Coopers Woods was formed to ensure the protection of this acreage. Because of these efforts, residents formed a conservancy to support private conservation efforts on the Bass Islands.

The Lake Erie Islands Chapter of the Black Swamp Conservancy (LEIC-BSC)was established in 2000 to encourage conservation and protection of natural and agricultural lands in the Lake Erie Islands for the benefit of future generations. Petersen Woods (2004) and the Lawrence Evans tracts (2006) were protected adjacent to Kuehnle Wildlife Area on Middle Bass Island. LEIC-BSC has also been active in preserving habitat through conservation easements for the federally threatened and state endangered Lake Erie Water Snake (*Nerodia sipedon* ssp. *insularum*) to aid in its recovery (U.S. Fish and Wildlife Service 2003). Wooded and shoreline habitats were preserved on South Bass Island at Ladd Carr Wildlife Woods in 2005 (Woischke 2005), Jane Coates Wildflower Trail in 2008 (with an addition in 2010) and Scheeff East Point Nature Reserve in 2008 (Woischke 2008b). LEIC-BSC operates a Nature Camp program for children and, with the Lake Erie Islands Historical Society, operates the Lake Erie Islands Nature and Wildlife Center on South Bass, dedicated in 2008. The Put-in-Bay Township Park District (PIBTPD) was established in 2006 to preserve island habitat. The Western Reserve Land Conservancy was instrumental in assisting the PIBTPD with securing the Scheeff East Point Nature Preserve. The Trust for Public Land is also working with the PIBTPD to acquire and protect property on the Erie Islands.

The Natural Heritage Database, managed by the Ohio Division of Natural Areas and Preserves' Natural Heritage Program, was started in 1976 by The Nature Conservancy. It now contains more than 17,000 records representing known locations for Ohio's rare plants and animals, high quality sites illustrating Ohio's plant communities and other natural features. This database has been

an important resource for island conservation efforts. As of June 2010, this database became part of the Ohio Biodiversity Database managed by The Ohio Division of Wildlife.

Canadian Islands

The Canadian islands in western Lake Erie, which are located in Essex County, Ontario, have long been recognized for their significant biodiversity values. John Macoun, Dominion Botanist of the National Museum of Canada, visited Pelee Island in 1892 and first documented many of the island's rare plants (Macoun 1890, 1893), including Common Redbud (*Cercis canadensis*), a species not seen since (Stuckey 1986).

With their southern location, diverse and unusual habitats and large number of rare species, the Canadian islands in western Lake Erie continue to be a focus of conservation efforts. Several sites on the islands have been identified as regionally significant Environmentally Sensitive Areas (Oldham 1983b) and provincially significant Areas of Natural and Scientific Interest (Oldham 1983b, Kamstra and others 1995). Three of the most significant natural areas were acquired for conservation in the early 1970s by the Ontario Ministry of Natural Resources and regulated as Provincial Nature Reserves. These areas are East Sister Island (15 hectares, 37 acres), Fish Point at the southern tip of Pelee Island (110 hectares, 272 acres) and Lighthouse Point at the northern tip of Pelee Island (96 hectares, 237 acres).

Another highly significant area, the Stone Road Alvar on Pelee Island (Jacques and Kirk 1985; Kirk 1994), was acquired by several conservation organizations including Ontario Nature, Essex Region Conservation Authority (ERCA) and The Nature Conservancy of Canada. The unique alvar vegetation at Stone Road (Catling and Brownell 1995, 1999) gradually became overgrown by shrubs and trees and prescribed burns were conducted at the site in 1993, 1997, 1999 and 2005.

Additional natural areas on Pelee Island were recently acquired for conservation purposes, largely by The Nature Conservancy of Canada, but also by the Pelee Island Winery. Other significant organizations in the conservation and promotion of natural areas on Pelee Island include the Pelee Island Heritage Centre and Pelee Island Bird Observatory.

Canada's most southern piece of land, Middle Island, comprising 18.5 hectare (45 acres), was acquired from a private United States owner in 1999 by The Nature Conservancy of Canada (Gibson 1999; Kavanaugh 1999) and transferred to Parks Canada in 2000. It is now part of Point Pelee National Park and is managed as a Zone 1 Special Protection Area.

Prior to 1976, island habitat conservation was accomplished by lack of development of surplus government lands, abandoned quarries, abandoned lighthouses and obsolete military firing ranges. Efforts now focus on identifying important island resources and protecting them through government acquisition, grants and a growing number of non-profit organizations working together so that future generations will be able to enjoy important habitat components of the Erie Islands.

Acknowledgments. Thanks are extended to the University of California, Merced Library for providing access to digital literature databases and interlibrary loan services. The following individuals provided information on conservation activities on the Canadian Erie Islands: John Riley and James Duncan (The Nature Conservancy of Canada), Dan Lebedyk (Essex Region Conservation Authority), Sandy Dobbyn (Ontario Parks), Ron Tiessen (Pelee Island Heritage Centre) and Brian Craig (Parks Canada).

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