IV. Assessing Threats to Great Lakes Islands Biodiversity

A. Context

The composition of plants and animals on and around Great Lakes islands has changed substantially over the centuries since Europeans first arrived. After the last glaciers receeded from the Great Lakes region, scouring out islands from resistant bedrock and leaving land masses isolated by huge lakes, plants began to flourish. Eventually, wetland, beach, and forested climax communities developed on most islands. When settlers first arrived on many of the islands, the trees were timbered for use in building ships and homes for the new islanders. Land was quickly converted from forest and wetland to agriculture wherever feasible. The tempering effect of the lake provided a longer growing season for crops, and was especially good for growing fruits including grapes, particularly in the southern lakes. Beginning in the mid 20th century, vacation cottages and second homes became more popular, and the islands became a destination spot for tourism and recreation, and this trend continues today on many Great Lakes islands. Agricultural islands began to be developed with homes, which lead to the secondary development of roads, airports, marinas, hotels, stores, and restaurants. The advent of so much development on the islands, mixed with proximity to the strong natural forces of the lakes, led to shoreline modifications to protect structures, which in turn resulted in a loss of additional natural areas. To facilitate development, bridges to islands were constructed, resulting in a loss of the isolation that defines the very character of islands. Channels near and around the islands were dredged to further accommodate access and shipping needs, disrupting sensitive nearshore habitats.

The 1952 Grand Island Centennial Book (GINews.net 2005) chronicled the history of Grand Island, NY (Niagara River) and included the following descriptions of the progression of the island from a forested wilderness, to a productive agricultural community, and eventually to a residential haven:

> "The farmers who purchased land in 1849 or a little later had to clear it before crops could be planted. This was a difficult job, involving the felling of trees, the pulling out of the stumps with the aid of oxen and then the burning of the brush… Once the land was cleared, it produced abundant crops of hay, wheat and grains. Mr. Lewis F. Allen reported that in the year 1860 he produced 350 tons of hay on his farm. The island soil was excellent for fruit trees. It is said that the first peach orchards in this area were on Grand Island. The Northern Spy apple was the variety found in many orchards as well as Greenings and Baldwins. Cherries, both sweet and sour, as well as Bartlett, Flemish Beauty and Seckle pears grew abundantly… As the metropolitan areas of Buffalo, Niagara Falls and Tonawanda expanded, the sylvan quietude of the island became very attractive to city dwellers… Island residents marked the opening of the bridges [Between Buffalo, NY, Grand Island, NY and Niagara Falls, ON] with a celebration on July 13, 1935… Since the opening of the bridges Grand Island has been in a state of transition from a rural to a suburban area. Many subdivisions have been developed such as Sandy Beach, Grandyle Village, East Park and Coldbrook Manor. The population of the town has increased from less than 1,000 in the early 1930's to almost 4,500 in 1952, and is growing steadily."

In the absence of bridges, airports, car ferries and high speed passenger ferries were built to improve the efficiency with which visitors could access the islands. With this increased access came more people, more cars, more foreign plants, animals, and seeds,

which would become established on the islands and compete with the plants and animals that had for so long been isolated with limited competition.

As described previously, island ecosystems are made up of specialized habitats determined by physical conditions such as geologic composition, soils, temperatures, and weather events. Based on these unique combinations of physical features, only certain plants can grow, and in turn, only those animals that can survive within the range of physical conditions and specific flora will naturally occur on islands. These combinations of physical features and biotic communities, often called ecosystems, have evolved together over thousands of years, and have become interdependent on each other for survival. When one or more of the ecosystem's components is removed, all of the other remaining components are affected in some way. Most healthy ecosystems can tolerate some level of loss and still function effectively, although the extent of loss that can be tolerated is difficult to quantify and varies by ecosystem type. At some point, loss of native biodiversity reaches a level at which the impacts on the remaining components are significant, and the ecosystem ceases to function as it has in the past. Although some species can still persist in changed ecosystems, many of the most sensitive species cannot, and may eventually become rare or extinct within the ecosystem. The impact of the loss of biodiversity is felt more severely on islands because there are no adjacent areas from which animals and plants can replenish their numbers. In addition, once habitat for a species or group of species has been lost, there is no place for the species to migrate to because of the very finite boundaries of islands. In general, the relatively small size and isolation of islands include the potential for rapid change (Judziewicz 2001) which may result in islands being especially vulnerable to biological change or, on a more positive note, elimination of species injurious to island biota. A corollary of this observation is that re-colonization may be difficult once change has occurred (Jalava et al. 2005). This suggests that extra care be exercised, for example, to avoid bringing non-native species to islands, perhaps especially small islands. However, because re-colonization of islands is hindered, it also means that eradication programs can be successful, as has been demonstrated on islands world-wide.

This assessment of threats to the biodiversity of the Great Lakes islands is a first attempt to identify, define, and assess the impacts of current and future threats within the Great Lakes island ecosystem. This threat analysis will be used in conjunction with assessments of biodiversity value of island areas to identify those high-quality islands most in need of conservation action. Future efforts will identify specific actions that can be taken to alleviate these threats and in turn, preserve the native biodiversity of the Great Lakes island ecosystem.

B. Types of Threats Faced by the Islands

This assessment identifies threats or stressors to Great Lakes islands biodiversity, as well as sources of these stressors. Borrowing from The Nature Conservancy's "Conservation by Design: A Framework for Mission Success" (1996), which describes the identification of systems, stresses and sources of stress, the following definitions are provided:

> Systems: "The focal conservation targets and their key ecological attributes." For the purposes of this assessment, the systems of concern are Great Lakes islands' native plant, animal, and nearshore communities.

Stresses (Threats): "The most serious types of destruction or degradation affecting the conservation targets or key ecological attributes." There are six major human-induced stresses that this project has identified within the Great Lakes system that contribute substantially to the loss of biodiversity. These are: habitat loss; fragmentation; overharvest; contaminants/pollution; invasive species; and climate change. Notably, these threats are nearly identical to the "six classes of human interference" that threaten the biospatial hierarchy world-wide, as described by Soulé (1991).

Sources of Stress: "The causes or agents of destruction or degradation." The stressors or threats listed above are caused by a wide variety of sources, for example, development, transportation, or recreation. Most can be traced back to larger issues including economic development, anthropocentrism, human population growth within the island environment, time scale of biodiversity loss, and cultural transitions, again, similar to most of those described on a world-wide basis (Soulé 1991). The loss of biodiversity and the causes of this loss observed at a microscale on the Great Lakes Islands then is similar to patterns of biodiversity loss throughout world.

Scope: "The geographic scope of impact to the conservation target expected within 10 years under current circumstances." The scope of each of the identified threats varies significantly. While some threats, such as global climate change and associated changes in water levels, are expected to impact island biodiversity throughout the entire Great Lakes, other threats, such as habitat loss, may only affect biodiversity at a local level.

Severity: "The level of damage to the conservation target over at least some portion of the target occurrence that can reasonably be expected within 10 years under current circumstances." Some threats may completely eliminate segments of biodiversity, for example, conversion of a forested habitat to a residential subdivision. Other threats may only result in limited impacts to biodiversity, for example introduction of an invasive species may displace some of the original species, while others persist.

Irreversibility: "The reversibility of the stress caused by a source of stress." While The Nature Conservancy uses the term "Irreversibility," we have used the term "reversibility" for ease of understanding and clarity, but with essentially the same definition. The reversibility of each of these stresses also varies considerably. Many of the stresses are permanent. Once an invasive species becomes established in the Great Lakes system, it is unlikely that it will ever be completely removed. On the other hand, with effort, lost habitat can sometimes be restored to its former state.

Table XXXX General assessment of stresses and sources of stresses to Great Lakes Islands Biodiversity, watershed-wide. Note that in following chapters each Lake or connecting channel will have its own table similar to that below but specific to the islands of that particular waterbody.

Stress/Threat	Sources	Scope	Severity	Reversibility
Habitat Loss	Agriculture, residential/commercial development, roads, shoreline modifications, inappropriate land management, dredging, mining, marinas, light/noise pollution, dams, water level management, erosion, forestry, recreational development	High	High	Moderate
Fragmentation	Agriculture, residential/commercial development, roads, shoreline modifications, mining, light/noise pollution, dams, water level management, erosion, forestry, recreational development	High	Moderate	Moderate
Overharvest	Commercial fishing, subsistence fishing, recreational fishing?, eradication programs, illegal collecting, poaching	Low	Moderate	Moderate
Contaminants	Industry, sediments, agriculture, sewers, development runoff, lighthouses, dredging	Moderate	Moderate	Moderate
Invasive Species	Ballast water, aquariums/pets, exotic fish markets, hydrological modifications (eg, Chicago Shipping Canal), accidental transport of seeds via animals, purposeful introductions (deer, carp), horticulture industry	High	High	Low
Climate Change	Greenhouse gases from power plants, vehicles, burning fossil fuels, deforestation	High	High	Low

Below follows a more detailed description of each threat, followed by a description of some of the most common sources:

Threats: Habitat loss and fragmentation

Throughout history, island landowners, although sometimes aware that island ecosystems are different from the mainland, still managed island properties the same way as they would manage mainland areas. Islands were farmed, grazed, timbered, and developed with little consideration of impacts to the native plant and animal communities that inhabited these unique areas. In recent times, islands are quickly being developed to provide vacation resorts or second homes, complete with golf courses, lawns, hotels, restaurants, shopping centers, airports, and everything typical of a mainland community. Even those areas set aside as parks in some cases were turned into heavily managed areas dominated by mowed grass. As described above, due to

their isolation and finite size, the impacts of habitat loss and inappropriate habitat management are felt more severely on islands than on the mainland. Because of the finite size of islands, actions on islands that remove habitat have magnified impacts on biodiversity when compared to similar actions on the mainland. In general, the relatively small size and isolation of islands include the potential for rapid change (Judziewicz 2001) which may result in islands being especially vulnerable to biological change.

Fragmentation can be defined as the loss of connectivity between parcels of natural habitat, resulting in small, isolated blocks of habitat. Often, native species cannot successfully cross through developed areas to reach other isolated parcels of habitat. This can lead to small, isolated pockets of natural habitat separated from other areas of natural habitat. In effect, we are creating "islands" of natural habitat surrounded by a "sea" of development. Species that cannot move between these parcels will have fewer opportunities to forage and mate, and will have only a limited area within which to find suitable habitat and all the resources needed to survive (USEPA 2003). Human-made obstacles that often result in fragmentation include homes, lawns, roads, parking lots, and buildings. Fragmentation can result in direct loss of biodiversity, for example, roadkill mortality has been documented within the juvenile Lake Erie Watersnake *(Nerodia sipedon insularum)* population as the snakes attempt to move between summer habitat on the shoreline and hibernation areas inland (USFWS 2003). Fragmentation can also cause indirect loss of biodiversity by limiting opportunities for foraging and mating to only those resources within the isolated parcel.

Source: Accessibility

Islands, by their nature, are isolated from other land masses. This isolation is part of what defines island habitat, and is a main reason why only certain plants and animals have colonized these unique habitats. Each island has evolved in relative isolation from other land for thousands of years, and its native communities reflect this isolation. When an island is made readily accessible to humans, plants, and animals through an artificial connection to another land mass, significant changes in the island ecosystem can occur. Accessibility can take many forms; Public transportation such as bridges, ferries, airports, and marinas all promote increased accessibility to islands. With this increased access typically comes more human visitation, and increased likelihood of new species of animals and plants arriving on the island. The implications of the arrival of people, plants, and animals can vary substantially, but generally result in disturbances to the native ecosystems. These disturbances will be further explored under other source definitions.

Source: Agriculture

Agriculture can reduce native biodiversity by converting natural landscapes into heavily managed monocultures of single crop species. Aside from the direct loss of natural island habitat, other common agricultural practices include installation of drainage tiles or ditches, applications of fertilizers, herbicides and pesticides, and soil disturbances associated with planting and harvesting crops. These practices can all have significant impacts on native biodiversity. Drainage facilitates loss of wetlands, typically high biodiversity areas, as well as higher rates of runoff and sedimentation, and does not allow for normal nutrient absorption (USEPA 2003). Soil disturbances can alter the typical soil horizons, adversely impacting those plant species that rely on historic soils, and disturbing the native seed bank within the soil. Furthermore, due to the geologic formation of islands, many Great Lakes islands have very shallow soils which are quickly

depleted of nutrients by agricultural practices. Once nutrients have been depleted, many of the native plant species are no longer able to grow, and hardier, non-native plants will often establish and thrive.

Source: Development

Because of their close proximity to water and recreational opportunities and their isolated nature, islands are often romanticized and perceived as vacation areas or tourist destinations. Put-in-Bay (Lake Erie), Mackinac Island (Lake Huron), Thousand Islands (St. Lawrence River), and Belle Isle (Detroit River) are well-known tourist destinations that bring significant amounts of money to local economies every year**.** Islands are also targeted locations for second homes or vacation cottages. As island ecosystems are developed with homes and the associated infrastructure necessary to support human communities, loss of biodiversity is eminent. Habitat is lost to the footprint of development, and is fragmented into smaller and smaller parcels by roads, maintained lawns, parking lots, and other structures (USEPA 2003). Development brings human beings and their perceptions of certain native wildlife as "nuisances" and native plants as "weeds," which are then targeted for eradication. The whole variety of human actions (intentional and unintentional) brought on by development, when considered collectively, can and has had substantial impacts on the native species of the Great Lakes islands.

Source: Dredging

Dredging of submerged sediments is a tool commonly used to deepen water to allow for boat access. Historically, dredging occurred not only within the Lakes and connecting channels themselves, but also in coastal wetland areas as a way to open them up for boat access and dockage. For example, in 1960 a large coastal wetland on Middle Bass Island (Lake Erie) was dredged out to create a sheltered open water marina (Barr and Gora 2004)**.** Coastal wetlands and associated nearshore areas are typically high in plant and animal biodiversity, and disturbance of the sediments that these species depend on can result in significant losses of biodiversity. Coastal wetlands and nearshore areas that support submerged aquatic vegetation, sandy or rocky substrate, shoals, or reefs are extremely important for fish spawning and nursery habitat (Goodyear et al. 1982), and provide high quality nesting and foraging habitat for a variety of birds including shorebirds and waterfowl. In addition, these areas are extremely productive for aquatic insects such as mayflies *(Hexagenia* spp.) which provide important food sources for other wildlife (Edsall 2001). Loss of coastal wetlands and productive nearshore habitats can result in a loss of important habitat for fish, wildlife, and plants, as well as localized population declines.

Source: Erosion

Erosion, the loss of land mass due to the forces of water, wind, or ice, is both a natural and anthropogenically-induced threat. Erosion due to wave action and ice scour is common on the islands, particularly those islands made of sedimentary rock (sandstone, limestone), or unconsolidated sediments (such as sand, silt), and is less common on islands composed of harder rock (granite). Although erosion is typically due to natural factors, human actions can significantly exacerbate erosion. Such actions could include the following: 1) Removal of native shoreline vegetation which destabilizes the soils and facilitates quicker erosion that if the vegetation remained (USEPA 2003); and 2) Modification of shoreline/nearshore habitats, for example shoreline armoring, beach nourishment, jetty construction, dredging, and filling. When structures

are added to or removed from the shoreline and nearshore areas, the natural processes that deposit sand and other fine-grained sediments are often disrupted or changed. This typically results in changed erosion and deposition patterns on adjacent properties. In general, the shape of the island shoreline results from the combined effects of erosion and accretion. Anthropogenic influences have disrupted these natural patterns resulting in increased erosion and decreased deposition in particular areas and the result is the loss of shoreline and nearshore habitat.

Source: Forestry

Forestry or logging has been a source of economic prosperity for the Great Lakes region since Europeans first arrived. Much of the Great Lake region's vast forested habitats were cleared of trees, both for lumber and to facilitate urban and agricultural expansion (USEPA 2003). The islands have in the past, and now continue to face similar threats. Many of the permanent islands within the Great Lakes Region were historically dominated by woody plant communities. On Pelee Island (Lake Erie), by 1892 more than 2181 hectares (5390 ac) of the 2869 hectares (7090 ac) of woods on the island had been harvested for lumber (Wilds of Pelee 2003). The vegetative and animal communities associated with the islands are dependent on the forested systems for their survival. Forested areas provide critical stopover sites for migratory birds as they travel between their nesting and wintering grounds, and various islands or groups of islands (such as Western Lake Erie islands) have been identified as key stopover sites for migratory birds (Ewert et.al 2005). Forestry, if conducted at too large a scale, or if not conducted using sustainable practices, could result in a significant threat to the persistence of biodiversity on the islands via the elimination of native habitat and lack of potential for regeneration.

Source: Hydrological modifications

Hydrological change, or changes in the water regime of a specific area, can have very significant impacts on biodiversity. Hydrological changes could include installation of dams, changes to flow patterns or flood regimes, draining of wet areas, rerouting/channelizing/culverting of streams, or increasing impervious surfaces such that the rates of stream flow are significantly impacted (USEPA 2003). Many of the most significant threats to islands in the St. Lawrence River are closely related to impacts from the creation, use, and maintenance of the St. Lawrence Seaway navigation channel and associated locks and dams used both for navigation and power generation. Damming and flooding of sections of the river has raised the water level of portions of the river significantly, covering some islands and shoals completely, and increasing scour areas and erosion on other islands. Upstream of the Moses-Saunders Power Dam on the St. Lawrence River lies Lake St. Lawrence. Based on the water needs of the hydroelectric facility, water levels here are subject to extreme changes (up to 2 m (6.6 ft.)) at any time of year (RE Grant and Associates, undated). While wetland and backwater areas created by the flooding could provide suitable habitat, the unpredictable and dramatic water level fluctuations impede use by many aquatic species (LaPan et al. 2002). Dredging of the navigation channel has resulted in significant island habitat loss. La Pan et al. (2002) note that seaway construction and maintenance activities in the Red Mills, NY/Cardinal, ON area destroyed Galop Rapids and altered the physical location and connectivity of a complex of 11 nearby islands.

Source: Mining

Due to the geologic composition of the Great Lakes islands, they historically and currently provide a source of economically valuable raw materials such as limestone, sand, and gravel. An active quarry on Kelleys Island (Lake Erie) produces more than 1 million tons of limestone per year (Lafarge North America Inc. 2004). Removal of sand and gravel in the nearshore areas of islands, which often provide substrate necessary for fish spawning and nursery habitat, could impact local fish, mussel, and benthic invertebrate populations. A mined area at the head of the St. Clair River was historically a spawning area for lake sturgeon (Goodyear et al. 1982). Major deposits of sand and gravel have been identified in Lake Ontario near Niagara, Hamilton, Toronto, and Wellington, and mining has occurred on the Niagara Bar at the mouth of the Niagara River, a nursery area for at least one species of fish (Goodyear et al. 1982). Strawberry Island (Niagara River) is a five-acre island that shelters a 400-acre area of vegetated shallows from the erosive forces of the river and has been designated a "Significant Coastal Fish and Wildlife Habitat" by the New York Department of State. Due to the impacts of gravel mining within areas on and adjacent to the island, a habitat restoration project on this island was recently funded (Office of the Governor of New York 1996). Depending on the extent of mining, a few acres of habitat or an entire island could be lost to these practices, while indirect impacts to species and their habitats from erosion, runoff, and noise could also occur.

Source: Light pollution

The impacts of a bright nighttime sky on fish, wildlife, and plants may at first glance not seem significant, but research is revealing that artificial lighting in natural habitats can significantly impact the behavior of many different species. Plants, animals, and humans have all evolved in an environment of regular dark and light periods. These cycles of darkness and light influence circadian rhythm (patterns of activity and rest), metabolism, and even hormone production in some species. Research has shown that redback salamanders will not emerge to feed and reproduce when light brighter than a full moon is present (Harder 2004). Some tree frogs will not call when exposed to light, and if the males do not call, they cannot attract females to mate (Harder 2004, Guynup 2003). Nocturnal snakes are absent from regions of California where they once occurred and suitable habitat still exists, but where lights from nearby cities shine brightly (Harder 2004). Lights can attract migrating birds, causing them to fly off course or collide with man-made structures. Research on zooplankton shows that when exposed to lighted conditions at night when they typically rise to the surface to feed on algae, the zooplankton are discouraged from ascending and feeding (Harder 2004). This could lead to substantial algal blooms. Many nocturnal insects are attracted to certain types of light. This could draw them out of their natural habitats and into developed areas, where the animals that depend on the insects as a food source would not have access to them.

Source: Noise Pollution

Sources of noise pollution that could impact island wildlife populations include recreational vehicles such as ATVs or snowmobiles, aircraft, boats, automobiles, and large construction machinery. The study of animal response to noise is a function of many variables including characteristics of the noise and duration, life history characteristics of the species, habitat type, season and current activity of the animal, sex and age, previous exposure and whether other physical stressors (e.g. drought) are present (Manci et al., 1988). The responses to noise stimuli could include heart rate acceleration and behavioral responses such as avoidance, while exposure to persistent noise can cause changes in metabolism,

hormone balance, chronic stress, and physical damage to auditory systems (Fletcher 1990). Considered cumulatively with other threats, noise pollution could further stress already troubled species and contribute to a decline in biodiversity.

Source: Recreation

The rapid development of Great Lakes islands for recreational use has been well documented. Often, local, state, provincial, Federal, or Crown governments will create recreational areas to provide opportunities for visitors to enjoy the natural beauty of the islands. While some uses such as hiking, photography, and wildlife viewing typically have only minimal impacts on island biodiversity, other uses such as ATV/ORV/snowmobile trails, campgrounds, and even fishing or hunting, can have significant negative impacts on biodiversity if island dynamics are not considered. Intense recreational development can result in habitat loss, and intensive public use can trample or destroy vegetation, introduce pollution, injure or kill wildlife (especially smaller species), and disturb some of the more sensitive species or habitats. Overhunting or overfishing of island areas can cause populations to crash to the point where natural reproduction cannot keep up with sources of mortality. This is an especially significant concern on small islands. Careful evaluation of recreational uses prior to implementation can often alleviate this threat by identifying the most sensitive resources that should be avoided, and the more resilient areas that may be only minimally impacted by proposed activities. If public use areas are designed and managed to promote native island biodiversity, this threat may not be significant, but ultimately the significance of this source of stress will depend on the sensitivity of the resources to be impacted.

Source: Shoreline modification:

Island shoreline accounts for a significant portion of total Great Lakes shoreline. Historically, the shoreline of the Great Lakes has been dynamic, due to precipitation, storms, isostatic rebound, glaciers, waves, water flow patterns, and a variety of other natural processes. Since Europeans first attempted to settle on the shores of the lakes, shoreline hardening has been a tried and true method to stabilize the location of the shoreline and protect land and property from storms, waves, ice, and erosion. Shoreline hardening could include the installation of large rock breakwaters, steel sheet piling, concrete shore walls, or various other structures. While shoreline hardening may protect human habitat, the loss of natural shoreline habitat is a threat to many coastal species, including the Federally endangered Piping Plover *(Charadrius melodus)* and other shorebirds, the Federally threatened Dwarf Lake Iris *(Iris lacustris)*, Houghton's Goldenrod *(Solidago houghtonii)*, and Pitcher's Thistle *(Cirsium pitcheri)*, and other native coastal plants, and a huge variety of other animals and plants that inhabit shoreline areas. Furthermore, the natural processes of erosion and deposition form various habitat types along the shoreline that provide essential wildlife habitat, buffer the upland areas from storm surges, and contribute sand to the littoral system. Armored shorelines do not provide such benefits.

Source: Towers and Turbines

One needs only to gaze off into the horizon to notice the frequency with which telecommunication towers are springing up across the landscape. Towers serve a variety of purposes, including transmitting television or radio waves or phone signals, monitoring weather conditions, and notifying people of emergency situations. With the technological advances being made across the U.S. and

Canada, the number of towers on the landscape is predicted to increase continually (Towerkill.com undated). The Federal Aviation Administration requires towers over 200 feet in height to be lighted for aviation safety. Such tall towers, especially when lighted, with supporting guy wires, have been documented to kill large numbers of birds in certain adverse weather conditions (Avery et al. 1980, Weir 1976). Many of the Great Lakes islands have been specifically identified as significant areas for birds, either as migration stopover sites for neotropical migrants, as nesting areas for colonial nesting waterbirds and shorebirds, or as permanent homes for many resident species of birds (Ewert et al. 2005). During foggy nights throughout the migratory season, bright lights on towers tend to confuse and/or attract these birds in large numbers. Wind power is a rapidly expanding form of clean energy, generally harnessed by constructing large (up to 400-foot) turbines in areas with suitable wind resources. This form of energy has no emissions, and requires very little input to produce a useable form of energy. Wind turbines in a few specific locations have, however, been documented to kill large numbers of birds and bats. The geography of the Great Lakes creates a significant wind resource over the water and on coastal areas, making wind power development very attractive in these locations. Wolfe Island, Ontario (Lake Ontario) has been designated a globally significant Important Bird Area by Nature Canada and Bird Studies Canada due to its large congregations of waterfowl, specifically Greater Scaup and Canvasback, and hawks and owls (Bird Life International undated), and has been proposed as an area to support an 86-turbine wind installation (Canadian Hydro Developers Inc. 2006). Placement of wind turbines on islands has the potential to injure or kill large numbers of birds and bats, and the impacts on other avian species, such as insects, has yet to be determined.

Threat: Overharvest

Overharvest of fish and other wildlife and plants, whether for commercial or recreational purposes, has the potential to reduce biodiversity of Great Lakes islands and surrounding habitats. Unregulated commercial harvest of Great Lakes fish in the nineteenth and early twentieth centuries resulted in catastrophic population declines of some fish, for example the Lake Trout (*Salvelinus namaycush*), formerly the Great Lake's top predator (Hansen and Peck 2005). Despite basin-wide reintroduction efforts over the past 60 years, as well as bag limits and control of Sea Lamprey (*Petromyzon marinus*), an invasive species that contributed to the trout's decline, the Lake Trout has yet to become reproductively successful in 3 of the 5 lakes (Hansen and Peck 2005). While overharvest has been somewhat abated by fishing regulations, licenses, and quotas, some fish species, including the Lake Trout, still rely on stocking programs to survive angling pressure. Intentional overharvest of some other wildlife species has been widespread, and documented to contribute to populations declines. For example, as the western basin Lake Erie islands were developed with homes and recreational opportunities, the island-endemic Lake Erie Watersnake became the target of eradication efforts. This eradication effort eventually resulted in the snake being listed as a Federal threatened species in the U.S. and a Federal endangered species in Canada.

Source: Poaching/Illegal Collecting

The poaching of fish and game and the illegal collecting of native plants can have significant impacts on native island biodiversity. In general, most states/provinces have established regulations for the harvest of fish and game, and in some instances, plants. These harvests are carefully monitored, and the population surveyed to ensure that the harvests will leave behind a sustainable population for the continued benefit of the resource and those that depend on it

for food and/or recreation. Poaching and illegal collection of plants attempts to sidestep the regulations and harvest these resources in a manner that may not be sustainable. Poaching and illegal collecting can impact small and fragile island populations to such an extent that the populations are no longer able to survive and reproduce, and become extirpated from the island.

Threat: Contaminants

Contaminants can be defined as any substances that pollute a natural system, making it unfit for use by native species or causing direct harm to native species. Contaminants are typically left over on islands from prior uses, such as lighthouses, military operations, automobiles, paints, and industrial pollution. Lead is a contaminant commonly found in older paints and in lead shot that can sicken and kill wildlife if high concentrations are ingested. Mercury is a contaminant introduced into the ecosystem primarily through burning of fossil fuels and is commonly found in the great lakes sediments and on islands. Polychlorinated biphenyls (PCBs) and organochlorine pesticides are known to bioaccumulate in the fat cells of mammals, birds, and reptiles, contributing to problems with reproduction and metabolism. Mercury and PCBs are the main contaminants responsible for fish consumption advisories throughout the Great Lakes, as they can harm humans as well as wildlife. Significant contamination from automobile oil and/or gas can also occur if vehicles are not appropriately maintained or disposed. Oil can significantly harm a variety of aquatic species if introduced into aquatic settings. While contaminated areas can often be remediated, this is a very expensive process and is disruptive of the native species that may remain in the area. The impact of contaminants on biodiversity generally includes a decrease in habitat suitability and decreased survival and reproduction in local populations of plants and animals.

Source: Agriculture

Modern agricultural practices call for the use of an array of chemicals to maximize yield. Fertilizers, if not correctly applied, can lead to excess levels of nitrogen, phosphorus, and potassium in adjacent water bodies. These excess chemicals can cause overgrowth of algae, known as eutrophication, which negatively impacts aquatic species and their habitats (USEPA 2003). Pesticides are intended to kill a variety of both native and non-native insects that prey on crops, while herbicides are intended to kill both native and non-native plants that compete with crops, and therefore biodiversity can be directly impacted by herbicide and pesticide use.

Source: Dredging

Dredging of submerged sediments is a tool commonly used to deepen water to allow for boat access. Dredging has been known to re-suspend toxic substances that have been buried in contaminated sediments, redistributing them into the water column.

Source: Industry

Industrial discharges into the Great Lakes during the industrial era of the mid 20th century are responsible for much of the contamination still found in sediments today. PCBs are typically found in nearshore sediments and are associated with industrial developments. Mercury is another contaminant commonly associated with industrial developments. Fish eating birds, such as the Bald Eagle *(Haliaeetus leucocephalus*) and colonial nesting waterbirds are often susceptible to contamination and adverse affects from these contaminants.

Source: Lighthouses
Mercury was commonly used in old lighthouses that dot the island landscape throughout the Great Lakes region. Mercury is also toxic to wildlife and humans, causing neurological problems. High concentrations of mercury in Great Lakes fish is one of the main reasons for human fish consumption advisories throughout the Great Lakes**.**

Source: Sewers
As Great Lakes islands become more populated, sewage issues must be addressed. Disposal of human waste was often addressed on islands by the installation of individual septic systems or package sewer plants, however as island communities grow and become more densely populated, large-scale collection and treatment systems may become necessary. Furthermore, the shallow soils on many islands do not lend themselves well to the installation of effective septic systems. An island-wide outbreak of gastrointestinal illness occurred in at least 1,450 visitors to South Bass Island, OH (Lake Erie) in the summer of 2004, and was attributed to island drinking water that had been contaminated with coliforms and *E. coli* from septic systems, among other sources (Ohio Dept. of Health 2004). Similar outbreaks on other islands could affect both human and wildlife populations.

Threat: Invasive species
We define "invasive species" as a plant or animal that is non-native (or alien) to the Great Lakes ecosystem, and once established, is likely to cause economic, human health, or environmental damage in the Great Lakes ecosystem. Invasive species impact native biodiversity by altering the established food webs, competing with native species for habitat and food, degrading the quality of some habitats, and displacing many types of native plants (USEPA 2003). Some of the most well-documented invasive species in the Great Lakes basin include Brown Carp (*Carpiodes cyprinus*), Round Goby (*Neogobius melanostomus*), Zebra Mussel (*Dreissena polymorpha*), Quagga Mussel *(Dreissena bugensis*), Spiny Water Flea (*Bythotrephes cederstroemi*), Purple Loosestrife (*Lythrum salicaria*), *Phragmites* spp., Reed Canary Grass (*Phalaris arundinacea*), Sea Lamprey (*Petromyzon marinus*), Alewife (*Alosa psuedoharengus*), and Eurasian River Ruffe (*Gymnocephalus cernuus*). The impacts these species have on native biodiversity is dependant on the degree of infestation, and vary significantly depending on the nature of the invasive species and those species that are impacted by it, however the consequences of some invasives have been well documented. The sea lamprey, the earliest recorded invasive native to the Atlantic coast of Europe and the Americas, decimated native populations of Lake Trout *(Salvelinus namaycush)* after the construction of the Welland Canal in 1921, significantly impacting commercial and recreational fisheries (USFWS undated). Currently, tributaries where sea lampreys spawn must be treated regularly with a lampricide to ensure that sea lamprey populations are controlled and native fish can persist. Kolar and Lodge (2002) used two risk assessment models to predict which alien fish species were most likely to become established, spread, and become nuisances within the Great Lakes. Their results indicated that 26 species were likely to become established in the Great Lakes, if introduced (intentionally or unintentionally), and of these, their models predicted that six species were likely to become nuisances if introduced (Kolar and Lodge 2002).

Source: Ballast Water
The ballast water carried in ocean-going vessels is widely implicated in the introduction of many non-native and invasive species introduced to the Great Lakes from around the world. The State of the Lakes Ecosystem Conference Report (Environment Canada and U.S. Environmental Protection Agency 2001) estimates an increase of one new species per year introduced into the Great Lakes system, and states that 50% of all aquatic non-natives introduced into the Great Lakes region have been reported in the St. Lawrence River, the connecting channel that brings international ships into the Great Lakes system.

Source: Hydrological Modifications
Significant hydrological modifications to the Great Lakes system have occurred over the years. These include the creation of the Chicago Shipping and Sanitary Canal, which connected the Great Lakes system to the Illinois River and Mississippi River drainage, and the establishment of the Great Lakes-St. Lawrence Seaway, which made the St. Lawrence River and Great Lakes navigable by ocean-going freighters, eliminating former navigation barriers such as Niagara Falls. These modifications have allowed invasive species to pass between formerly isolated aquatic systems. For example, great attention has been given to two species of Asian carp (Bighead [*Hypophthalmichthys nobilis*] and Silver [*Hypophthalmicthys molitrix*]), which are voracious predators, and are moving from the Illinois River toward Lake Michigan.. Significant efforts and dollars have been put forward to construct barriers to prevent these species from entering the Great Lakes, due to the potential for impacts to native aquatic species.

Source: Purposeful Introduction of non-native species
Occassionally non-native species are purposefully introduced into the Great Lakes or onto Great Lakes islands by well-meaning or ill-advised persons. Documented cases include the introduction of fish from aquariums and live fish markets; Pigs were introduced to the Lake Erie islands in the 1800's to control snake populations (McDermott 1947); Pheasants were released on Pelee Island (Lake Erie) in 1918 for hunting purposes, and later became a nuisance to corn farmers due to their high population numbers (Wilds of Pelee 2003); Deer were introduced to South Fox Island (Lake Michigan) around 1915 by the landowner for hunting purposes (Hatt et al. 1948); Plants are frequently brought to islands for landscaping purposes which can then spread into the natural areas. Furthermore, domestic animals can have significant impacts on local plant and wildlife populations. Feral cats are thought to kill millions of birds, reptiles, and small mammals each year. The American Bird Conservancy's (undated) factsheet on domestic cat predation on wildlife states that, "Domestic cats are considered primarily responsible for the extinction of eight island bird species, and the eradication of over 40 bird species from New Zealand islands alone." Some introduced species can bring diseases that impact local wildlife, compete with native animals for resources, destroy native vegetation, or kill or injure native wildlife. Deer introduced to North Manitou Island (Lake Michigan) in 1926 browsed so heavily on herbaceous vegetation and specific species of trees that the forest composition changed over the years: Conifers decreased while Maple and Beech increased (David Flaspohler pers. comm.). Compared to South Manitou where no deer were present, North Manitou had seven times less herbaceous and fern coverage and four times more sapling cover (David Flaspohler pers. comm.). In other cases the impact of the introduction is not felt as strongly; The significance of the threat to the system will vary depending on

the sensitivity of the habitats to disturbance, the type of disturbance, and even the size of the island.

Threat: Climate change

Changes in the global climate patterns due to trapping of greenhouse gases, particularly carbon dioxide, within the atmosphere are being widely predicted by scientists all over the world. Global climate change is expected to bring not only variations in temperature, but changed distribution patterns of precipitation, melting of glaciers, and hence changes in local water levels. Several models of climate change within the Great Lakes region have been undertaken to provide possible scenarios for weather and precipitation should carbon dioxide levels double within the coming years. In particular, models focused on the Great Lakes region have predicted that doubled carbon dioxide in the atmosphere will result in increased air temperature (2.7-9.1°C higher), increased water temperature, local increases and decreases in precipitation, less snowfall and lake ice cover, higher evapotranspiration rates, and lower lake levels (0.2-2.5 m lower) and connecting channel flow (Mortsch and Quinn 1996, Magnuson et al. 1997). The impacts of such a change on Great Lakes island biodiversity are very wide in scope and extremely difficult to predict. Decreases in Great Lakes water levels, which define the boundaries of islands, can lead to increases in the area of an island exposed, expansion or loss of coastal wetland habitat (depending on elevation and topography), connection of some islands to the mainland, changes in extent and/or composition of island shoreline habitat, and changes in erosion and accretion patterns. Even slight changes in average or maximum/minimum temperatures and the associated alterations of precipitation can impact the life cycles and distribution of some plant and animal species**.** For example, it has been predicted that in portions of Canada, climate change could result in moist boreal forests being replaced with transitional grasslands and cool temperate forests (Rizzo and Wilken 1992). Likewise, changes in precipitation, lake levels, runoff, and soil moisture are likely to result in a reduction in wetland coverage, and an increase in incidences of fire and drought, all of which could significantly alter plant and animal composition (Magnuson et al. 1997), and we suspect this is particularly true on the already vulnerable Great Lakes islands.

The ramifications of global climate change on aquatic species that rely on the nearshore island environment are also potentially significant. Because different species of fish are dependent on specific seasonal temperature regimes, different species will be affected in unique ways. For example, warmer water temperatures in the lakes can result in an extended growing season for fish that depend on warmer water for growth and development, but is also expected to result in less available oxygen (and potentially anoxic conditions) in the cooler, deeper portions of the lake that cool water fish species need to survive (Magnuson et al. 1997).

Because climate change is a global issue that is likely to affect all Great Lakes islands, and because it must be addressed at a global level, this threat will not be specifically addressed within each individual lake assessment section. Consequently our recommendations to address the threat of global climate change are presented here:

1. At an international level, work with other countries to address world-wide carbon dioxide emissions at a global scale.
2. Take steps at a national (U.S. and Canada) level to reduce emissions of carbon dioxide into the atmosphere from fossil fuel burning, particularly from power plants and vehicles.

3. At a local, state/provincial level, limit carbon dioxide emissions from regulated industry sources, and provide incentives for vehicles that do not emit carbon dioxide.
4. As large-scale deforestation can contribute to increased carbon dioxide in the atmosphere as well, at multiple levels, practice timber management that promotes rapid regeneration and encourage re-forestation of previously disturbed areas.

An underlying source for all of the threats described above is our lack of knowledge about the islands as a collection, the plants and animals that inhabit these unique ecosystems, and the significant impact that seemingly typical daily activities of human beings can have on these delicate systems. Without this knowledge, we are ill-equipped to identify and prioritize conservation efforts to ensure that the most representative conservation targets are afforded permanent protective status. Prior to the Collaborative for the Conservation of Great Lakes Islands undertaking this island research, we did not know the number and location of the islands, the island areas of most ecological significance, the full slate of Great Lakes island-specific conservation targets, and the overall conservation status of the islands. We did not even have an accepted definition of what constitutes an "island." Until we have sound scientific information about the islands as a binational collection, we are ill-equipped to make intelligent management decisions or to prioritize conservation efforts, and hence opportunities to preserve the significant biodiversity of the Great Lakes islands are slipping away each day.

In addition, a combination of anthropocentrism, economic drivers, and a rapid cultural transition from undeveloped/agricultural to vacation lands means the current focus on islands is for development first. Ecological issues take a backseat, if they are thought of at all. Though in a cultural sense humans may view islands as distinct, this view rarely translates into an understanding of the complex biological and ecological roles of islands. Therefore the sources of stress described above combine to reveal a dire situation for island biodiversity.

C. Implications for Conservation

While islands may be isolated in one sense, ecologically they are linked to the lakes, other islands, the mainland, and even the rest of the world through the flow of species, weather, and water. If protection of biodiversity on Great Lakes islands is to be a reality, bold measures must be taken by island residents, local, state/provincial, and federal governments, and interested citizens to halt and reverse those threats that result in the most significant losses. Island owners and land managers must halt the loss and fragmentation of high quality island habitats at a local level. Land managers should ensure that island management and recreation are compatible with native species and habitats. Regionally, resource managers must ensure that overharvest is not contributing to population declines when factoring in other stresses, and must continue to remediate contaminated sites, and ensure that introduction of new chemicals into island environments are done appropriately. Nationally, governments must take legislative action to halt the spread of invasive species by regulating ballast water releases, and blocking existing sources of new invasives, for example the Chicago shipping and sanitary canal. Worldwide, governments must take legislative action to halt or reverse human-induced global climate change stemming from the release of greenhouses gases into the atmosphere. Threats to Great Lakes islands' biodiversity are wide in source, scope, and severity, and without focused efforts to protect biodiversity, islands, much like the rest of the world, will face a spiraling loss of diversity.

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