## Coastal Wetland Invertebrate Community Health
Indicator #4501

*Note: This indicator has not yet been put into practice. The following evaluation was constructed using input from investigators collecting invertebrate community composition data from Great Lakes coastal wetlands over the last several years. Neither experimental design nor statistical rigor has been used to specifically address the status and trends of invertebrate communities of coastal wetlands of the five Great Lakes.*

**Assessment: Not Assessed**

**Purpose**
- To directly measure specific components of invertebrate community composition; and
- To infer the chemical, physical and biological integrity and range of degradation of Great Lakes coastal wetlands.

**State of the Ecosystem**
Development of this indicator is still in progress. Thus, the state of the ecosystem could not be determined using the wetland invertebrate community health indicator during the last 2 years.

Teams of Canadian and American researchers from several research groups (e.g. the Great Lakes Coastal Wetlands Consortium, the Great Lakes Environmental Indicators project investigators, the U.S. Environmental Protection Agency (USEPA) Regional Environmental Monitoring and Assessment Program (REMAP) group of researchers, and others) sampled large numbers of Great Lakes wetlands during the last two years. They have reported an array of invertebrate communities in Great Lakes wetlands in presentations at international meetings, reports, and peer-reviewed journals.

In 2002 the Great Lakes Coastal Wetlands Consortium conducted extensive surveys of wetland invertebrates of the 4 lower Great Lakes. These data are not entirely analyzed to date. However, the Consortium-adopted Index of Biotic Integrity (IBI, Uzarski *et al.* 2004) was applied in wetlands of northern Lake Ontario. The results can be obtained from Environment Canada (Environment Canada and Central Lake Ontario Conservation Authority 2004).

Uzarski *et al.* (2004) collected invertebrate data from 22 wetlands in Lake Michigan and Lake Huron during 1997 through 2001. They determined that wetland invertebrate communities of northern Lakes Michigan and Huron generally produced the highest IBI scores. IBI scores were primarily based on richness and abundance of Odonata, Crustacea plus Mollusca taxa richness, total genera richness, relative abundance Gastropoda, relative abundance Sphaeriidae, Ephemeroptera plus Trichoptera taxa richness, relative abundance Crustacea plus Mollusca, relative abundance Isopoda, Evenness, Shannon Diversity Index, and Simpson Index. Wetlands near Escanaba and Cedarville, Michigan, scored lower than most in the area. A single wetland near the mouth of the Pine River in Mackinac County, MI, consistently scored low, also. In general, all wetlands of Saginaw Bay scored lower than those of northern Lakes Michigan and Huron. However, impacts are more diluted near the outer bay and IBI scores reflect this. Wetlands near Quanicassee and Almeda Beach, MI, consistently scored lower than other Saginaw Bay sites.

Burton and Uzarski (unpublished) also studied drowned river mouth wetlands of eastern Lake Michigan quite extensively since 1998. Invertebrate communities of these systems show linear relationship with latitude. However, this relationship also reflects anthropogenic disturbance. Based on the metrics used (Odonata richness and abundance, Crustacea plus Mollusca richness, rotal genera richness, relative abundance Isopoda, Shannon Index, Simpson Index, Evenness, and relative abundance Ephemeroptera), the sites studied were placed in increasing community health in the order Kalamazoo, Pigeon, Muskegon, White, Pentwater, Pere Marquette, Manistee, Lincoln, and Betsie. The most impacted systems of eastern Lake Michigan are located along southern edge and impacts decrease to the north.

Wilcox *et al.* (2002) attempted to develop wetland IBIs for the upper Great Lakes using microinvertebrates. While they found attributes that showed promise during a single year, they concluded that natural water level changes were likely to alter communities and invalidate metrics. They found that Siskiwit Bay, Bark Bay, and Port Wing had the greatest overall taxa richness with large catches of cladocerans. They ranked microinvertebrate communities of Fish Creek and Hog Island lower than the other four western Lake Superior sites. Their work in eastern Lake Michigan testing potential metrics placed the sites studied in decreasing community health in the order Lincoln River, Betsie River, Arcadia Lake/Little Manistee River, Pentwater River, and Pere Marquette River. This order was primarily based on the median number of taxa, the median Cladocera genera richness, and also a macroinvertebrate metric (number of adult Trichoptera species).

**Pressures**
Physical alteration and eutrophication of wetland ecosystems continue to be a threat to invertebrates of Great Lakes coastal wetlands. Both can promote establishment of non-native vegetation, and physical alteration can destroy plant communities altogether while changing the natural hydrology to the system. Invertebrate community composition is directly related to vegetation type and densities; changing either of these components will negatively impact the invertebrate communities.

**Acknowledgments**
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**Authors' Commentary**
Progress on indicator development has been substantial, and implementation of basin-wide sampling to indicate state of the ecosystem should be possible before SOLEC 2006.

**Last Updated**
*State of the Great Lakes 2005*

**Coastal Wetland Fish Community Health**
Indicator ID: 4502

**Overall Assessment: N/A**

**Note: This indicator has not yet been put into practice. The following evaluation was constructed using input from investigators collecting fish community composition data from Great Lakes coastal wetlands over the last several years. Neither experimental design nor statistical rigor has been used to specifically address the status and trends of fish communities of coastal wetlands of the five Great Lakes.**

## Purpose
To assess the fish community composition and to infer suitability of habitat and water quality for Great Lakes coastal wetland fish communities.

### State of the Ecosystem
Development of this indicator is still in progress. Fish indices of biological integrity have been proposed for selected parts of the ecosystem (e.g., Lake Erie river mouths (Thoma 1999) Michigan and Ontario coastal wetlands (Uzarski *et al*. 2005), and coordinated basinwide sampling has recently been completed by several groups. Thus, progress on indicator development has been substantial, and assessment of data derived from sampling conducted between 2002 and 2005 to indicate the state of the ecosystem should be possible before the next SOLEC. Teams of Canadian and American researchers from several research groups (e.g., the Great Lakes Coastal Wetlands Consortium of the Great Lakes Commission (GLCWC), the U.S. EPA Star Grant funded Great Lakes Environmental Indicators group in Duluth, MN (GLEI), a group of Great Lakes Fishery Commission researchers led by Patricia Chow-Fraser of McMaster University (GLFC), the U.S. EPA REMAP group of researchers led by Tom Simon, and others) have sampled large numbers of Great Lakes wetlands during the last 5 years using comparable methods. They have reported on an array of fish communities in Great Lakes wetlands in presentations at international meetings and in reports. These data are now beginning to appear in refereed journals as individual studies (Uzarski *et al*. 2005, Seilhamer and Chow Fraser 2006) Work is also underway to integrate the datasets for true basinwide assessment (e.g., Brazner *et al*. 2006; Bhagat *et al*. in review). The composition of fish communities is related to plant community type within wetlands and, within plant community type, is related to amount of certain types of anthropogenic disturbance (Uzarski *et al*. 2005; Wei *et al*. 2004, Seilhamer *et al*. 2006; Johnson *et al*. 2006), especially water quality as affected by urban and agricultural development (Seilhamer and Chow Fraser 2006; Bhagat *et al*. in review). Uzarski *et al*. (2005) found no relationship between wetland fish composition and Great Lake suggesting that fish communities of any single Great Lake were more impacted than any other. However, of the 61 wetlands sampled in 2002 from all five lakes, Lakes Erie and Ontario tended to have more wetlands containing cattail communities (a plant community type that correlates with nutrient enrichment), and the fish communities found in cattails tended to have lower richness and diversity than fish communities found in other vegetation types. In contrast, Thoma (1999) and Johnson *et al*. (2006) were unable to find coastal wetlands on the US side of Lake Erie that experienced minimal anthropogenic disturbances. Wetlands found in northern lakes Michigan and Huron tended to have relatively high quality coastal wetland fish communities. The seven wetlands sampled in Lake Superior contained relatively unique vegetation types so fish

communities of these wetlands were not directly compared with those of wetlands of other lakes. When the fish communities of reference wetlands are compared across the entire Great Lakes, the most similar sites come from the same ecological province rather than from any single Great Lake or specific wetland types. Data from several GLEI project studies indicate that the characteristic groups of fish species in reference wetlands from each ecological province tend to have similar water temperature and aquatic productivity preferences. When a wetland becomes affected by human development, the fish community changes to the fish community typical of a warmer, richer, more southerly wetland. This finding may help us anticipate the likely effects of regional climate change on the fish communities of Great Lakes coastal wetlands. Brazner *et al*. looked at how 8 different candidate fish IBI components varied by lake, wetland type, ecological province and anthropogenic stress at 80 wetlands across the entire US Great Lakes. Overall, each of these 4 features explained approximately equal amounts of variation in those components.

John Brazner and co-workers from the U.S. EPA Laboratory in Duluth, MN sampled fishes of Green Bay, Lake Michigan, wetlands in 1990, 1991, 1995, 2002, and in 2003. They sampled three lower bay and one middle bay wetland in 2002 and 2003 and their data suggested that these sites were improving in water clarity and plant cover, and supported a greater diversity of both macrophyte and fish species, especially more centrarchid species, than they had in previous years. They also noted that the 2002, and especially 2003, year classes of yellow perch were very large. Brazner's observations suggest that the lower bay wetlands are improving slowly and the middle bay site seems to be remaining relatively stable in moderately good condition (J. Brazner, personal observation). The most turbid wetlands in the lower bay were characterized by mostly warm-water, turbidity-tolerant species such as gizzard shad, *Dorosoma cepedianum*; white bass, *Morone chrysops*; freshwater drum, *Aplodinotus grunniens;* common shiners, *Luxilus cornutus,* and common carp, *Cyprinus carpio*, while the least turbid wetlands in the upper bay were characterized by several centrarchid species, golden shiner, *Notemigonus chrysoleucas*; logperch, *Percina caprodes*; smallmouth bass, *Micropterus dolomieu*, and northern pike, *Esox lucius*. Green sunfish, *Lepomis cyanellus,* was the only important centrarchid in the lower bay in 1991, while in 1995, bluegill and pumpkinseed sunfishes,*L. macrochirus* and *L. gibbosus*, had become much more prevalent and a few largemouth bass, *M. salmoides*, were also present. There were more banded killifish, *Fundulus diaphanus*, in 1995 and 2003 compared with 1991 and white perch were very abundant in 1995, as this exotic species became dominant in the bay. The upper bay wetlands were in relatively good condition based on the fish and macrophyte communities that were observed. Although mean fish species richness was significantly lower in developed wetlands across the whole bay, differences between less developed and more developed wetlands were most pronounced in the upper bay where the highest quality wetlands in Green Bay are found (Brazner 1997).

Round gobies, *Neogobius melanostomus*, were introduced to the St. Clair River in 1990 (Jude *et al*. 1992), and have since spread to all of the Great Lakes. Jude studied them in many tributaries of the Lake Huron-St. Clair River-Lake Erie corridor and found that both species (round and tubenose gobies *Proterorhinus marmoratus*) were very abundant at river mouths and colonized far upstream. They were also found at the mouth of Old Woman Creek in Lake Erie, but not within the wetland proper. Jude and Janssen's work in Green Bay wetlands showed that round gobies had not invaded three of the five sites sampled, but few were found in lower Green Bay along the sandy and rocky shoreline west of Little Tail Point.

Uzarski and Burton (unpublished) consistently collected a few round gobies from a fringing wetland near Escanaba, MI where cobbles were present. In the Muskegon River-Muskegon Lake wetland complex on the eastern shoreline, round gobies are abundant in the heavily rip-rapped harbor entrance to Lake Michigan, Muskegon Lake, and have just begun to enter the river/wetland complex on the east side of Muskegon Lake (D. Jude, personal observations; Ruetz, Uzarski, and Burton, personal observations). Based on intensive fish sampling prior to 2003 at more than 60 sites spanning all of the Great Lakes, round gobies have not been sampled in large numbers at any wetland or been a dominant member of any wetland fish community (Jude *et al*. 2005). Round gobies were collected at 11 of 80 wetlands sampled by the GLEI project (Johnson *et al*. unpublished data). Lapointe (2005) assessed fish-habitat associations in the shallow (<3 m) Canadian waters of the Detroit River in 2004 and 2005 using boat-mounted electorfishing and boat seining techniques. The round goby avoided complex macrophytes in all seasons at upper, mid, and downstream segments of the Detroit River. However, in 2006 beach seining surveys at shoreline sites in Canadian waters of Lake St. Clair, the Detroit River, and western Lake Erie, both tubenose and round gobies were collected in areas with aquatic vegetation (L.D. Corkum, Univ. of Windsor, unpublished data). It seems likely that wetlands may be a refuge for native fishes, at least with respect to the influence of round gobies (Jude *et al*. 2005).

There is little information on the habitat preferences of the tubenose goby within the Great Lakes with the exception of studies on the Detroit River (Lapointe 2005), Lake St. Clair and the St. Clair River (Jude and DeBoe 1996, Pronin *et al*. 1997; Leslie *et al*. 2002). Within the Great Lakes, tubenose goby that were studied at a limited number of sites along the St. Clair River and on the south shore of Lake St. Clair occurred in turbid water associated with rooted submersed vegetation (*Vallisneria americana, Myriophyllum spicatum, Potamogeton richardsonii* and *Chara* sp.) (Leslie *et al*. 2002). Few specimens were found on sandy substrates devoid of vegetation, supporting similar findings by Jude and DeBoe (1996). Leslie *et al*. (2002) collected tubenose goby in water with no or slow flow on clay or alluvium substrates, where turbidity varies and where rooted vegetation was sparse, patchy or abundant. Lapointe (2005) found that the association between tubenose goby and aquatic macrophytes differed seasonally in the Detroit River. For example, tubenose goby was strongly negatively associated with complex macrophytes in the spring and summer, but positively associated with complex macrophytes in the fall (Lapointe 2005). Because tubenose goby shared habitats with fishes representing most ecoethological guilds, Leslie *et al*. (2002) suggested that the tubenose goby would expand its geographic range within the Great Lakes.

Ruffe have never been found in high densities in coastal wetlands anywhere in the Great Lakes. In their investigation of the distribution and potential impact of ruffe on the fish community of a Lake Superior coastal wetland, Brazner *et al*. (1998) concluded that coastal wetlands in western Lake Superior provide a refuge for native fishes from competition with ruffe. The mudflat-preferring ruffe actually avoids wetland habitats due to foraging inefficiency in dense vegetation that characterizes healthy coastal wetland habitats. This suggests that further degradation of coastal wetlands or heavily vegetated littoral habitats could lead to increased dominance of ruffe in shallow water habitats elsewhere in the Great Lakes.

There are a number of carp introductions (see Wetland Restoration and Rehabilitation or common carp discussion) that have the potential for substantial impact on Great Lakes fish communities, including coastal wetlands. Goldfish, *Carassius auratus*, are common in some shallow habitats, and occurred along with common carp young-of-the-year in many of the wetlands we sampled along Green Bay. In addition, there are several other carp species, e.g., grass carp, *Ctenopharyngodon idella*, bighead carp *Hypophthalmichthys nobilis*, and silver carp, *Hypophthalmichthys molitrix* that escaped aquaculture operations and are now in the Illinois River and migrating toward the Great Lakes through the Chicago Sanitary Canal. The black carp, *Mylopharygodon piceus*, has also probably been released, but has not been recorded near the Great Lakes yet. Most of these species attain large sizes; some are planktivorous, and also eat phytoplankton, snails, and mussels, while the grass carp eats vegetation. These species represent yet another substantial threat to food webs in wetlands and nearshore habitats with macrophytes (USFWS 2002).

In 2003, Jude and Janssen (unpublished data) determined that bluntnose minnows, *Pimephales notatus*, and johnny darters, *Etheostoma nigrum*, were almost absent from lower bay wetland sites, but comprised 22% and 6% respectively, of upper bay catches. In addition, other species, usually associated with plants and/or clearer water, such as rock bass, sand shiners *Notropis stramineus*, and golden shiners *Notemigonus crysoleucus*, were also present in upper bay samples, but not in lower bay samples. In 2003, Jude and Janssen found that there were no alewife *Alosa pseudoharengus* or gizzard shad in upper Green Bay site catches when compared with lower bay wetland sites, where they composed 2.7 and 34% respectively of the catches by number.

Jude and Pappas (1992) found that fish assemblage structure in Cootes Paradise, a highly degraded wetland area in Lake Ontario, was very different from other less degraded wetlands analyzed. They used ordination analyses to detect fish-community changes associated with degradation.

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**Last Updated**
SOLEC 2006

## Wetland-Dependent Amphibian Diversity and Abundance

Indicator #4504

### Overall Assessment

Status: Mixed
Trend: Deteriorating
Primary Factors Determining Status and Trend: Species across the Great Lakes basin exhibited both positive and negative population trend tendencies. Five species exhibited significantly negative species population trends while only one species exhibited a significantly positive species population trend.

### Lake-by-Lake Assessment

**Lake Superior**

Status: Not Assessed
Trend: Undetermined

**Lake Michigan**

Status: Poor
Trend: Unchanging
Primary Factors Determining Status and Trend: Most species in this lake basin exhibited negative population trend tendencies. However, of the only two significant species population trends, one was positive and one was negative.

**Lake Huron**

Status: Mixed
Trend: Deteriorating
Primary Factors Determining Status and Trend: Species in this lake basin exhibited both positive and negative population trend tendencies. However, four out of eight species exhibited significantly negative population trends. There were no significantly positive species population trends.

**Lake Erie**

Status: Mixed
Trend: Deteriorating
Primary Factors Determining Status and Trend: Species in this lake basin exhibited both positive and negative population trend tendencies. Two focal species (Bullfrog and Northern Leopard Frog) exhibited significant population trend declines. Only one species exhibited a significantly positive population trend.

**Lake Ontario**

Status: Mixed
Trend: Unchanging
Primary Factors Determining Status and Trend: Species in this lake basin exhibited both positive and negative population trend tendencies. Two species exhibited significantly increasing population trends, while only one species showed a significant declining species population trend.

**Purpose**
To directly measure species composition and relative occurrence of frogs and toads and to indirectly measure the condition of coastal wetland habitat as it relates to factors that influence the health of this ecologically important component of wetland biotic communities.

**Ecosystem Objective**
To restore and maintain diversity and self-sustaining populations of Great Lakes coastal wetland amphibian communities. Breeding populations of amphibian species across their historical range should be sufficient to maintain populations of each species and overall species diversity (Anonymous 1989).

**State of the Ecosystem**
Background
Numerous amphibian species occur in the Great Lakes basin and many of these are associated with wetlands during part of their life cycle. Because frogs and toads are relatively sedentary and have semi-permeable skin, they are likely to be more sensitive to, and indicative of, local sources of wetland contamination and degradation than are most other vertebrates. Assessing species composition and relative abundance of calling frogs and toads in Great Lakes wetlands can therefore help to infer wetland habitat quality.

Geographically extensive and long-term monitoring of calling amphibians is possible through the enthusiasm, skill and coordination of volunteer participants trained in the application of standardized monitoring protocols. Information about abundance, distribution and diversity of amphibians provides data for calculating trends in population indices as well as investigating habitat associations, which can contribute to effective long-term conservation strategies.

Status of Amphibians
Since 1995, Marsh Monitoring Program (MMP) volunteers have collected amphibian data at 548 discrete routes across the Great Lakes basin. An annual summary of amphibian routes monitored is provided in Table 1.

Thirteen amphibian species were recorded during the 1995 – 2005 period (Table 2). Spring Peeper was the most frequently detected species and was commonly recorded in full chorus (Call Level Code 3) when it was encountered. Green Frog was detected in more than half of the survey stations and was most often recorded at Call Level Code 1 (calling individuals could be discretely counted). Grey Treefrog, American Toad and Northern Leopard Frog were also common, being recorded in approximately one-third or more of all survey stations. Grey Treefrog was recorded with the second highest average calling code (1.8), indicating that MMP observers usually heard several individuals calling simultaneously at each survey station. Chorus Frog, Bullfrog and Wood Frog were detected in approximately one-quarter of survey stations, while the remaining five species were detected in less than 3 percent of survey stations.

Trends in amphibian occurrence were assessed for eight species commonly detected on MMP routes (Figure 1). For each species, the annual proportion of stations where that species was present within a route was calculated to derive annual indices of occurrence. The overall temporal trend in occurrence for each species was assessed by combining route-level trends in station occurrence. Statistically significant declining trends were detected for American Toad, Bullfrog, Chorus Frog, Green Frog and Northern Leopard Frog. Spring Peeper exhibited a statistically significant increasing population trend.

These data will serve as baseline data with which to compare future survey results. Anecdotal and research evidence suggests that wide variations in occurrence of many amphibian species at a given site is a natural and ongoing phenomenon. Additional years of data will help distinguish whether the patterns observed (i.e., decline in American Toad, Bullfrog, Chorus Frog, Green Frog and Northern Leopard Frog population indices) indicate significant long-term trends or simply natural variation in population sizes inhabiting marsh habitats. Bullfrog, for example, did not experience a significant population index trend from 1995 to 2004 (Crewe *et al.* 2006; Archer *et al.* 2006) but with the addition of 2005 data, its population index declined significantly. Further data are thus required to conclude whether Great Lakes wetlands are successfully sustaining these amphibian populations. MMP amphibian data are being evaluated to determine how information from their community composition can be used to gain a better understanding of Great Lakes coastal wetland condition in response to various human induced stressors.

**Future Pressures**
Habitat loss and deterioration remain the predominant threat to Great Lakes amphibian populations. Many coastal and inland Great Lakes wetlands are located along watersheds that experience very intensive industrial, agricultural and residential development. Therefore, these wetlands are under continued stress as increased pollution from anthropogenic runoff is washed down watersheds into these sensitive habitats. Combined with other impacts such as water level stabilization, sedimentation, contaminant and nutrient inputs, climate change and invasion of exotic species, Great Lakes wetlands will likely continue to be degraded and as such, should continue to be monitored.

**Future Activities**
Because of the sensitivity of amphibians to their surrounding environment and the growing international concern about amphibian population status, amphibians in the Great Lakes basin and elsewhere will continue to be monitored. Wherever possible, efforts should be made to maintain high quality wetland habitat as well as associated upland areas adjacent to coastal wetlands. There is also a need to address other impacts that are detrimental to wetland health such as inputs of toxic chemicals, nutrients and sediments. Restoration programs are underway for many degraded wetland areas through the work of local citizens, organizations and governments. Although significant progress has been made in this area, more work remains for many wetland areas that have yet to receive restoration efforts.

**Further Work Necessary**
Effective monitoring of Great Lakes amphibians requires accumulation of many years of data, using a standardized protocol, over a large geographic expanse. A reporting frequency for SOLEC of five years would be appropriate because amphibian populations naturally fluctuate through time, and a five-year timeframe would be sufficient to indicate noteworthy changes in population indices. More rigorous studies will relate trends in species occurrence or relative abundance to environmental factors. Reporting will be improved with establishment of a network of survey routes that accurately represent the full spectrum of marsh habitat in the Great Lakes basin.

Most MMP amphibian survey routes have been georeferenced to the survey station level. Volunteer recruitment has also improved significantly since the last status reporting period. Four additional important tasks are in progress: 1) develop the SOLEC wetland amphibian indicator as an index for evaluating coastal wetland health; 2) improve the program's capacity to monitor and report on status of wetland specific Beneficial Use Impairments among Great Lakes Areas of Concern; 3) develop and improve the program's capacity to train volunteer participants to identify and survey amphibians following standard MMP protocols, and; 4) develop the capacity to incorporate a regional MMP coordinator network component into the MMP to improve regional and local delivery of the program throughout the Great Lakes basin. Also, further work is required to determine the relationship between calling codes used to record amphibian occurrence and survey count estimates.

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**Last Updated**
SOLEC 2006

| Year | Number of Routes |
|---|---|
| 1995 | 115 |
| 1996 | 177 |
| 1997 | 208 |
| 1998 | 168 |
| 1999 | 163 |
| 2000 | 158 |
| 2001 | 166 |
| 2002 | 156 |
| 2003 | 156 |
| 2004 | 146 |
| 2005 | 177 |

**Table 1**. Number of routes surveyed for amphibians within the Great Lakes basin, from 1995 to 2005.
Source: Marsh Monitoring Program

| Species | Percent Station-Years Present [1] | Average Calling Code |
|---|---|---|
| Spring Peeper | 69.3 | 2.5 |
| Green Frog | 54.3 | 1.3 |
| Grey Treefrog | 39.2 | 1.8 |
| American Toad | 36.9 | 1.5 |
| Northern Leopard Frog | 31.1 | 1.3 |
| Chorus Frog | 26.5 | 1.7 |
| Bullfrog | 25.8 | 1.3 |
| Wood Frog | 18.0 | 1.6 |
| Fowler's Toad | 2.4 | 1.4 |
| Pickerel Frog | 2.4 | 1.1 |
| Cope's Grey Treefrog | 1.6 | 1.4 |
| Mink Frog | 1.2 | 1.2 |
| Blanchard's Cricket Frog | 0.6 | 1.5 |

[1] MMP survey stations monitored for multiple years considered as individual samples

**Table 2**. Frequency of occurrence (Percent Station-Years Present) and average Call Level Code for amphibian species detected at MMP survey stations within the Great Lakes basin, from 1995 through 2005. Average calling codes are based on the three level call code standard for all MMP amphibian surveys; Code 1 = little overlap among calls, numbers of individuals can be determined, Code 2 = some overlap, numbers can be estimated, Code 3 = much overlap of calls, too numerous to be estimated.
Source: Marsh Monitoring Program

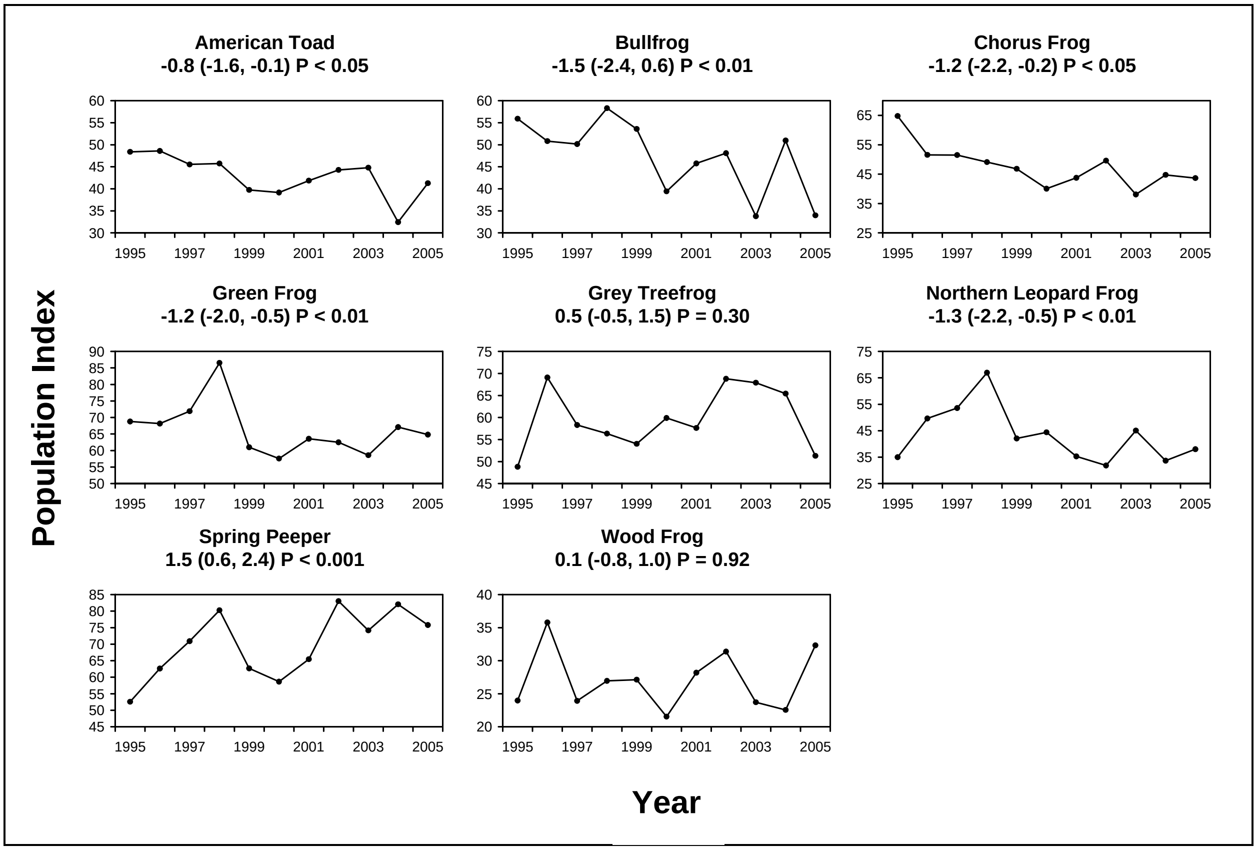


**Figure 1**. Trends (percent annual change) in station occurrence (population index) of eight amphibian species commonly detected at Marsh Monitoring Program routes, from 1995 to 2005. Values in parentheses are upper and lower 95% confidence limits, respectively, for trend values given.
Source: Marsh Monitoring Program

## Contaminants in Snapping Turtle Eggs
Indicator #4506

### Overall Assessment
Status: Mixed
Trend: Trend not assessed
Primary Factors Determining Status and Trend: Contaminants at AOCs exceeded concentrations at reference sites. Dioxin equivalents and DDE concentrations in eggs exceeded the Canadian Environmental Quality Guidelines, and sum PCBs exceeded partial restriction guidelines for consumption from some sites.

### Lake-by-Lake Assessment

#### Lake Superior
Status: Not Assessed
Trend: Trend Not Assessed due to insufficient data

#### Lake Michigan
Status: Not Assessed
Trend: Trend Not Assessed due to insufficient data

#### Lake Huron
Status: Not Assessed
Trend: Trend Not Assessed due to insufficient data

#### Lake Erie
Status: Mixed
Trend: Trend Not Assessed
Primary Factors Determining Status and Trend: Contaminants at AOCs exceeded concentrations at reference sites. Dioxin equivalents and DDE concentrations in eggs exceeded the Canadian Environmental Quality Guidelines, and sum PCBs exceeded partial restriction guidelines for consumption from some sites.

#### Lake Ontario
Status: Mixed
Trend: Trend Not Assessed
Primary Factors Determining Status and Trend: Contaminants at AOCs exceeded concentrations at reference sites. Dioxin equivalents and DDE concentrations in eggs exceeded the Canadian Environmental Quality Guidelines, and sum PCBs exceeded partial restriction guidelines for consumption from some sites.

### Purpose
•To assess the accumulation of organochlorine chemicals and mercury in snapping turtle eggs;
•To assess contaminant trends and physiological and ecological endpoints in snapping turtles; and
•To obtain a better understanding of the impact of contaminants on the physiological and ecological health of the individual turtles and wetland communities.

**Ecosystem Objective**
Snapping turtle populations in Great Lakes coastal wetlands and at contaminated sites should not exhibit significant differences in concentrations of organochlorine chemicals, mercury, and other chemicals, compared to turtles at clean (inland) reference site(s). This indicator supports Annexes 1, 2, 11 and 12 of the Great Lakes Water Quality Agreement.

**State of the Ecosystem**
Background
Snapping turtles inhabit (coastal) wetlands in the Great Lakes basin, particularly the lower Great Lakes. While other Great Lakes wildlife species may be more sensitive to contaminants than snapping turtles, there are few other species that are as long-lived, as common year-round, inhabit such a wide variety of habitats, and yet are limited in their movement among wetlands. Snapping turtles are also at the top in the aquatic food web and bioaccumulate contaminants. Plasma and egg tissues offer a nondestructive method to monitor recent exposure to chemicals as well as an opportunity for long-term contaminant and health monitoring. Since they inhabit coastal wetlands throughout the lower Great Lakes basin, they allow for multi-site comparisons on a temporal and spatial basis. Consequently, snapping turtles are a very useful biological indicator species of local wetland contaminant trends and the effects of these contaminants on wetland communities throughout the lower Great Lakes basin.

Status of Contaminants in Snapping Turtle Eggs
For more than 20 years, the Canadian Wildlife Service (CWS) has periodically collected snapping turtle eggs and examined the species' reproductive success in relation to contaminant levels on a research basis. More recently (2001-2005), CWS is examining the health of snapping turtles relative to contaminant exposure in Canadian Areas of Concern (AOCs) of the lower Great Lakes basin. The work by the CWS has shown that contaminants in snapping turtle eggs differ over time and among sites in the Great Lakes basin, with significant differences observed between contaminated and reference sites (Bishop et al. 1996, 1998). Snapping turtle eggs collected at two Lake Ontario sites (Cootes Paradise and Lynde Creek) had the greatest concentrations of polychlorinated dioxins and number of furans (Bishop et al. 1996, 1998). Eggs from Cranberry Marsh (Lake Ontario) and two Lake Erie sites (Long Point and Rondeau Provincial Park) had similar levels of polychlorinated biphenyls (PCBs) and organochlorines among the study sites (Bishop et al. 1996, 1998). Eggs from Akwesasne (St. Lawrence River) contained the greatest level of PCBs (Bishop et al. 1998). From 1984 to 1990/91, levels of PCBs and dichlorodiphenyl-dichloroethene (DDE) increased significantly in eggs from Cootes Paradise and Lynde Creek, and levels of dioxins and furans decreased significantly at Cootes Paradise (Struger et al. 1993; Bishop et al. 1996). More recently, American researchers have also used snapping turtles as indicators of contaminant exposure (Dabrowska et al. 2006).

Eggs with the greatest contaminant levels also showed the poorest developmental success (Bishop et al. 1991, 1998). Rates of abnormal development of snapping turtle eggs from 1986-1991 were highest at all four Lake Ontario sites compared to other sites studied (Bishop et al. 1998).

Lake Erie and connecting channels

From 2001 to 2003, CWS collected snapping turtle eggs at or near three Canadian Lake Erie or connecting channels AOCs: Detroit River, St. Clair River, and Wheatley Harbour AOCs, as well as two reference sites. Mean sum PCBs ranged from 0.02 µg/g at Algonquin Park (reference site) to 0.93 µg/g at Detroit River. Sum PCB levels were highest at Turkey Creek (Detroit River), followed by Wheatley Harbour, then St. Clair NWA (near St. Clair River AOC) and lastly, Algonquin Provincial Park, an inland reference site (Figure 1). Dioxin equivalents of sum PCBs in eggs from the Detroit River, Wheatley Harbour, and St. Clair River AOCs, and p,p'-DDE levels in eggs from the Wheatley Harbour and the Detroit River AOCs, exceeded the Canadian Environmental Quality Guidelines. Sum PCBs in eggs from the Detroit River and Wheatley Harbour AOCs exceeded partial restriction guidelines for consumption (de Solla and Fernie 2004). An American study in 1997 funded by the Great Lakes Protection Fund found that sum PCBs appeared to be higher in the American AOCs in Ohio, where concentrations ranged from 0.18 to 3.68 µg/g; concentrations were highest from the Ottawa River AOC, followed by the Maumee River AOC, Ashtabula River AOC, and the Black River within Maumee River AOC (Dabrowska et al. 2006). The reference sites used near the American AOCs may have higher contaminant exposure than the Canadian reference sites.

Lake Ontario and connecting channels

From 2002 to 2003, CWS collected snapping turtle eggs at or near seven Lake Ontario and connecting channel AOCs: Hamilton Harbour, Niagara River (Ontario), St. Lawrence River (Ontario), and Toronto, as well as two reference sites. Mean sum PCBs varied ranged from 0.02 µg/g at Algonquin Park (reference site) to 1.76 µg/g at Hamilton Harbour (Grindstone Creek). Sum PCB levels were highest at Hamilton Harbour (Grindstone Creek), followed by the second site at Hamilton Harbour (Cootes Paradise), then Lyons Creek (Niagara River) (Figure 1). There is evidence that PCB levels in snapping turtle eggs have been declining at the inland reference site of Algonquin Park (1981-2003) and the heavily contaminated Hamilton Harbour AOC (1984-2003). Long term trends at the St. Lawrence River AOC are difficult to determine, due to the high degree of variability of contaminant sources in the area; PCBs have been reported as high as 738 µg/g at Turtle Creek, Akwesasne (de Solla et al. 2001).

Flame retardants (polybrominated diphenyl ethers [PBDEs]) are one of the chemicals of emerging concern because they are bioaccumulative and may potentially affect wildlife and human health. Sum PBDE concentrations varied, but they were an order of magnitude lower than sum PCBs in snapping turtle eggs collected from the seven AOCs (2001-2003). Sum PBDE levels were lowest at Algonquin Park (6.1 ng/g sum PDBE), where airborne deposition is likely the main contaminant source, and greatest at the Hamilton Harbour (Cootes Paradise; 67.6 ng/g) and Toronto (Humber River; 107.0 ng/g) AOCs, indicative of urban areas likely being the main source of PBDEs.

**Pressures**
Future pressures for this indictor include all sources of toxic contaminants that currently have elevated concentrations (e.g. PCBs, dioxins), as well as contaminants whose concentrations are expected to increase in Great Lakes wetlands (e.g. PBDEs). Non-bioaccumulative compounds in which there are chronic exposures (e.g. PAHs) also pose a potential threat. Snapping turtle populations face additional pressures from harvesting of adult turtles, road-side killings during the nesting season in June, and habitat destruction.

**Management Implications**

The contaminants measured by are persistent and bioaccumulative, with diet being the primary source of exposure for snapping turtles, and thus indicate contamination that is available throughout the aquatic food web. Although commercial collection of snapping turtles has ceased, collection for private consumption persists. Therefore, consumption restrictions are required at selected AOCs. Currently, only eggs are routinely sampled for contaminants, but body burdens of females could be estimated using egg burdens, and thus used for determining if consumption guidelines are needed. At some AOCs (i.e., Niagara River [Lyons Creek], Hamilton Harbour), there are localized sediment sources of contaminants that may be rehabilitated through dredging or capping. Mitigation of contaminant sources should eventually reduce contaminant burdens in snapping turtles.

**Comments from the author(s)**

Contaminant status of snapping turtles should be monitored on a regular basis across the Great Lakes basin where appropriate. Once the usefulness of the indicator is confirmed, a complementary U.S. program is required to interpret basin-wide trends. This species offers an excellent opportunity to monitor contaminant concentrations in coastal wetland populations. Newly emerging contaminants also need to be examined in a long-term monitoring program. As with all long-term monitoring programs, and for any indicator species used to monitor persistent bioaccumulative contaminants, standardization of contaminant data is necessary for examining temporal and spatial trends or combining data from different sources.

**Acknowledgments**

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**List of Figures**



**Last updated**
SOLEC 2006

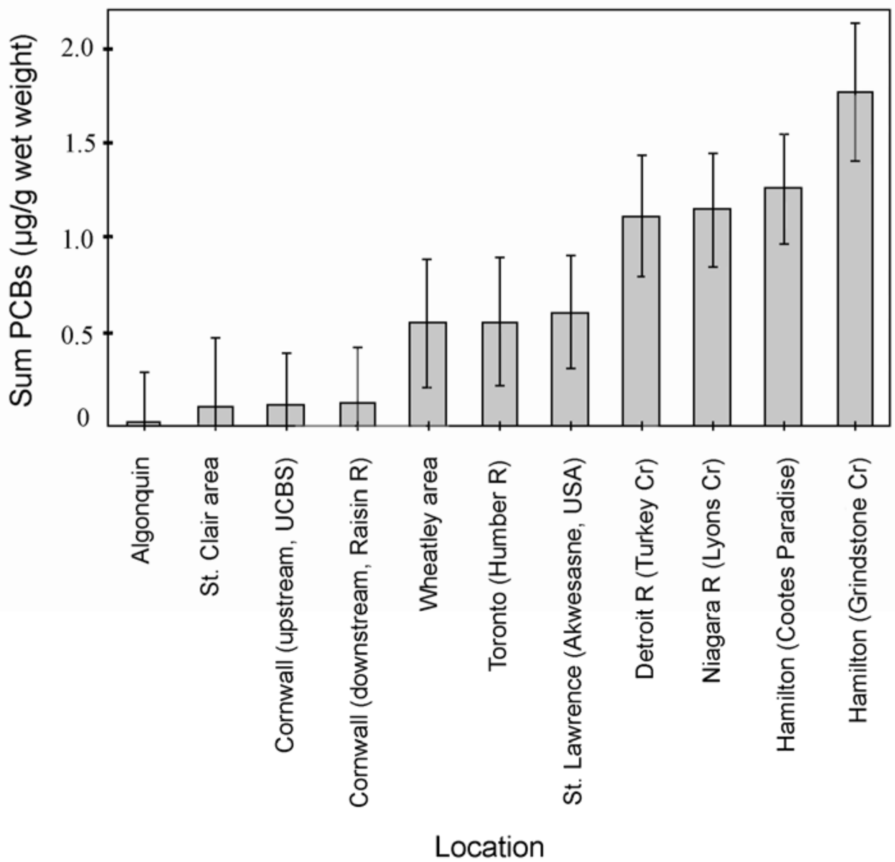


**Figure 1**. Sum PCB concentrations in snapping turtle eggs from various Canadian locations throughout the lower Great Lakes basin, 2001 through 2003. Means ± standard errors are presented.
Source: Canadian Wildlife Service

## Wetland-Dependent Bird Diversity and Abundance
Indicator #4507

**Overall Assessment**

| | |
|---|---|
| Status: | Mixed |
| Trend: | Deteriorating |
| Primary Factors Determining Status and Trend | Species across the Great Lakes basin exhibited both positive and negative population trend tendencies. Significantly negative population trends occurred for 14 species, while only six species exhibited significantly positive population trends. |

**Lake-by-Lake Assessment**

**Lake Superior**

| | |
|---|---|
| Status: | Not Assessed |
| Trend: | Undetermined |

**Lake Michigan**

| | |
|---|---|
| Status: | Mixed |
| Trend: | Deteriorating |
| Primary Factors Determining Status and Trend | Species in this lake basin exhibited both positive and negative population trend tendencies. Despite an equal number of significantly positive and negative trends among species, certain focal species did not occur at a level sufficient for trend analysis, or were absent from monitoring stations. |

**Lake Huron**

| | |
|---|---|
| Status: | Poor |
| Trend: | Deteriorating |
| Primary Factors Determining Status and Trend | Most species in this lake basin exhibited a negative population trend. Eight significantly negative species population trends occurred, while there were no significantly positive species population trends. |

**Lake Erie**

| | |
|---|---|
| Status: | Mixed |
| Trend: | Deteriorating |
| Primary Factors Determining Status and Trend | Species in this lake basin exhibited both positive and negative population trend tendencies. Significantly negative population trends occurred for seven species, while only three species exhibited significantly positive population trends. |

**Lake Ontario**

| | |
|---|---|
| Status: | Mixed |
| Trend: | Deteriorating |
| Primary Factors Determining Status and Trend | Species in this lake basin exhibited both positive and negative population trend tendencies. Significantly negative population trends occurred for six species, while only two species exhibited significantly positive population trends. |

**Purpose**

- To assess wetland bird species composition and relative abundance, and to infer condition of coastal wetland habitat as it relates to factors that influence the biological condition of this ecologically and culturally important component of wetland communities.

**State of the Ecosystem**

Background

Assessments of wetland-dependent bird diversity and abundance in the Great Lakes are used to evaluate health and function of coastal and inland wetlands. Breeding birds are valuable components of Great Lakes wetlands and rely on the physical, chemical and biological condition of their habitats, particularly during breeding. Presence and abundance of breeding individuals therefore provide a valuable source of information about wetland status and population trends. Because several wetland-dependent birds are listed as species at risk due to the loss and degradation of their habitats, the combination of long-term monitoring data and analysis of habitat characteristics can help to assess how well Great Lakes coastal wetlands are able to provide habitat for these sensitive species as well as other birds and wetland-dependent wildlife.

Geographically extensive and long-term monitoring of wetland-dependent birds is possible through the enthusiasm, skill and coordination of volunteer participants trained in the application of standardized monitoring protocols. Information about abundance, distribution and diversity of marsh birds provides data for calculating trends in population indices as well as investigating habitat associations which can contribute to effective, long-term conservation strategies.

Status of Wetland-Dependent Birds

Since 1995, Marsh Monitoring Program (MMP) volunteers have collected bird data at 508 discrete routes across the Great Lakes basin. An annual summary of bird routes monitored is provided in Table 1.

From 1995 through 2005, MMP volunteers recorded 56 bird species that use marshes (wetlands dominated by non-woody emergent plants) for feeding, nesting or both throughout the Great Lakes basin. Red-winged Blackbird was the most commonly recorded non-aerial foraging bird species observed by MMP participants, followed by Swamp Sparrow, Marsh Wren and Yellow Warbler. Among birds that nest exclusively in marsh habitats, the most commonly recorded species was Marsh Wren, followed by Virginia Rail, Common Moorhen, Pied-billed Grebe, American Coot and Sora. Among bird species that typically forage in the air above marshes, Tree Swallow and Barn Swallow were the two most commonly recorded bird species.

With eleven years of data collected across the Great Lakes basin, the MMP is becoming an established and recognized long-term marsh bird population monitoring program. Bird species occurrence, abundance, activity and detectability vary naturally among years and within seasons. Population indices and trends (i.e., average annual percent change in population index) are presented for several bird species recorded at Great Lakes MMP routes, from 1995 through 2005 (Figure 1). Species with significant basin-wide declines were American Coot (not shown), Black Tern, Blue-winged Teal (not shown), Common Grackle (not shown), Common Moorhen (not shown), Least Bittern, undifferentiated Common Moorhen/American Coot (calls of these two species are difficult to distinguish from one another), Northern Harrier (not shown), Pied-billed Grebe, Red-winged Blackbird, Sora, Tree Swallow and Virginia Rail (Figure 1). Statistically significant basin-wide population increases were observed for Common Yellowthroat, Mallard, Northern Rough-winged Swallow (not shown), Purple Martin (not shown), Trumpeter Swan (not shown), Willow Flycatcher (not shown) and Yellow Warbler (not shown). American Bittern and Marsh Wren populations did not show a significant trend in abundance indices from 1995 through 2005 (Figure 1). Declines in population indices of species that use wetlands almost exclusively for breeding such as Least Bittern, Black Tern, Common Moorhen, American Coot, Sora, Pied-billed Grebe and Virginia Rail, combined with an increase in some wetland edge and generalist species (e.g., Common Yellowthroat, Willow Flycatcher and Mallard) suggest changes in wetland habitat conditions may be occurring. Difference in habitats, regional population densities, timing of survey visits, annual weather variability and other factors likely interplay with water levels to explain variation in wetland dependent bird populations. American Bittern, for example, showed a significant declining population index from 1995 to 2004 (Crewe *et al.* 2006; Archer *et al.* 2006) but recently its population index has rebounded. As such, further years of data will hopefully help explain natural population variation from significant population trends.

**Future Pressure**

Future pressures on wetland-dependent birds will likely include continuing loss and degradation of important breeding habitats through wetland loss, water level stabilization, sedimentation, contaminant and nutrient inputs and invasion of exotic plants and animals.

**Future Activities**

Wherever possible, efforts should be made to maintain high quality wetland habitat and adjacent upland areas. There is also a need to address other impacts that are detrimental to wetland health such as water level stabilization, invasive species and inputs of toxic chemicals, nutrients and sediments. Restoration programs are underway for many degraded wetland areas through the work of local citizens, organizations and governments. Although significant progress has been made, considerably more conservation and restoration work is needed to ensure maintenance of healthy and functional wetland habitats throughout the Great Lakes basin.

**Further Work Necessary**

MMP wetland monitoring activities will continue across the Great Lakes basin. Continued monitoring of at least 100 routes through 2006 is projected to provide good resolution for most of the wetland-dependent birds recorded by MMP volunteers. Recruitment and retention of program participants will therefore continue to be a high priority. Priority should also be placed on establishing regional goals and acceptable thresholds for species-specific abundance indices and species community compositions. Assessments to determine relationships among survey indices, bird population parameters and critical environmental parameters are also needed.

Previous studies have ascertained marsh bird habitat associations using MMP bird and habitat data. As more data is accumulated, these studies should be periodically updated in order to provide a better understanding of the relationships between wetland bird species and habitat. Most MMP bird survey routes have been georeferenced to the level of individual survey stations. Volunteer recruitment has also improved significantly since the last status reporting period. Five additional important tasks are in progress: 1) develop the SOLEC wetland bird indicator as an index for evaluating coastal wetland health; 2) improve the program's capacity to monitor and report on status of wetland specific Beneficial Use Impairments among Great Lakes Areas of Concern; 3) improve and revise MMP bird survey protocols to coincide with continentally accepted marsh bird monitoring survey standards; 4) develop and improve the program's capacity to train volunteer participants to identify and survey marsh birds following standard MMP protocols, and; 5) develop the capacity to incorporate a regional MMP coordinator network component into the MMP to improve regional and local delivery of the program throughout the Great Lakes basin.

Although more frequent updates are possible, reporting trends in marsh bird population indices every five or six years is most appropriate for this indicator. A variety of efforts are underway to enhance reporting breadth and efficiency.

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Authors: Steve Timmermans and Ryan Archer, Bird Studies Canada
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**List of Tables**



**List of Figures**



**Last Updated**

SOLEC 2006

| Year | Number of Routes |
|---|---|
| 1995 | 145 |
| 1996 | 177 |
| 1997 | 175 |
| 1998 | 151 |
| 1999 | 154 |
| 2000 | 153 |
| 2001 | 146 |
| 2002 | 170 |
| 2003 | 131 |
| 2004 | 118 |
| 2005 | 183 |

**Table 1**. Number of routes surveyed for marsh birds within the Great Lakes basin, from 1995 to 2005.

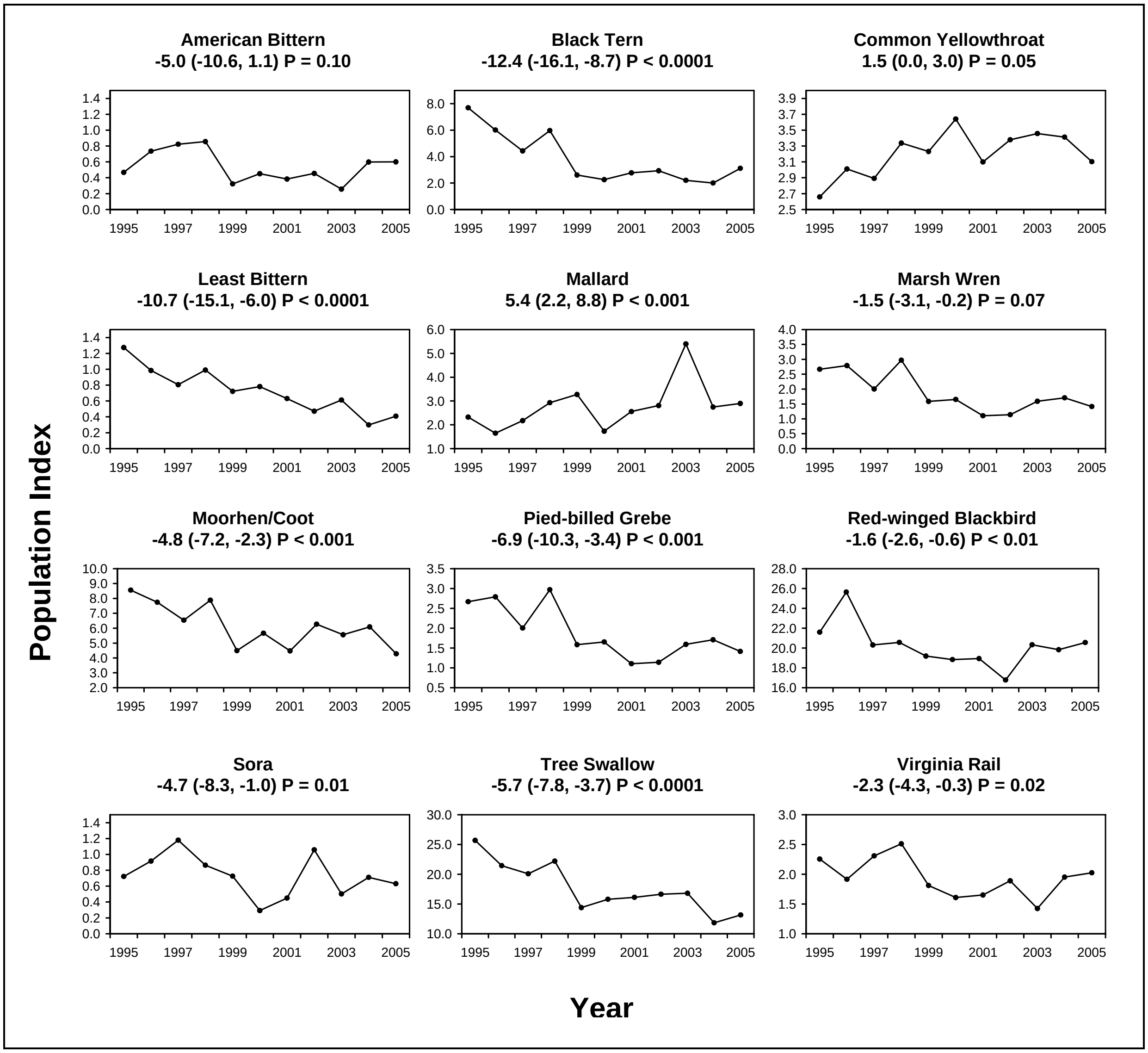


**Figure 1**. Trends (percent annual change) in relative abundance (population index) of marsh nesting and aerial foraging bird species detected at Marsh Monitoring Program routes, from 1995 to 2005. Values in parentheses are upper and lower 95% confidence limits, respectively, for trend values given.
Source: Marsh Monitoring Program

## Coastal Wetland Area by Type

Indicator #4510

**Overall Assessment**

Status: **Mixed**
Trend: **Deteriorating**

**Lake-by-Lake Assessment**

**Lake Superior**

Status: Not Assessed
Trend: Undetermined

**Lake Michigan**

Status: Not Assessed
Trend: Undetermined

**Lake Huron**

Status: Not Assessed
Trend: Undetermined

**Lake Erie**

Status: Not Assessed
Trend: Undetermined

**Lake Ontario**

Status: Not Assessed
Trend: Undetermined

**Purpose**

To assess the periodic changes in area (particularly losses) of coastal wetland types, taking into account natural lake level variations.

**Ecosystem Objective**

Maintain total areal extent of Great Lakes coastal wetlands, ensuring adequate representation of coastal wetland types across their historical range (Great Lakes Water Quality Agreement, Annexes 2 and 13).

**State of the Ecosystem**

The status of this indicator has not been updated since the *2005 State of the Lakes* report. Future updates to the status of this indicator will require the repeated collection and analysis of remotely sensed information. Currently, technologies and methods are being assessed for an ability to estimate wetland extent. Next steps, including determination of funding and resource needs, as well as pilot investigations must occur before an indicator status update can be made. The timeline for this is not yet determined. However, once a methodology is established, it will be applicable for long-term monitoring of this indicator, which is imperative for an improved understanding of wetland functional responses and adaptive management. The 2005 assessment of this indicator follows.

Wetlands continue to be lost and degraded, yet the ability to track and determine the extent and rate of this loss in a standardized way is not yet feasible.

In an effort to estimate the extent of coastal wetlands in the basin, the Great Lakes Coastal Wetland Consortium (GLCWC) coordinated completion of a binational coastal wetland database. The project involved building from existing Canadian and U.S. coastal wetland databases (Environment Canada and Ontario Ministry of Natural Resources 2003, Herdendorf *et al*. 1981a-f), and incorporating additional auxiliary Federal, Provincial and State data to create a more complete, digital Geographic Information System (GIS) vector database. All coastal wetlands in the database were classified using a Great Lakes hydrogeomorphic coastal wetland classification system (Albert *et al*. 2005). The project was completed in 2004.The GIS database provides the first spatially explicit seamless binational summary of coastal wetland distribution in the Great Lakes system. Coastal wetlands totaling 216,743 ha have been identified within the Great Lakes and connecting rivers up to Cornwall, Ontario (Figure 1). However, due to existing data limitations, estimates of coastal wetland extent, particularly for the upper Great Lakes are acknowledged to be incomplete.

Despite significant loss of coastal wetland habitat in some regions of the Great Lakes, the lakes and connecting rivers still support a diversity of wetland types. Barrier protected coastal wetlands are a prominent feature in the upper Great Lakes, accounting for over 60,000 ha of the identified coastal wetland area in Lake Superior, Lake Huron and Lake Michigan (Figure 2). Lake Erie supports 22,057 ha of coastal wetland, with protected embayment wetlands accounting for over one third of the total area (Figure 2). In Lake Ontario, barrier protected and drowned rivermouth coastal wetlands account for 19,172 ha, approximately three quarters of the total coastal wetland area.

Connecting rivers within the Great Lakes system also support a diverse and significant quantity of wetlands (Figure 3). The St. Clair River delta occurs where the St. Clair River outlets into Lake St. Clair, and it is the most prominent single wetland feature accounting for over 13,000 ha. The Upper St. Lawrence River also supports a large area of wetland habitats that are typically numerous small embayment and drowned rivermouth wetlands associated with the Thousand Island region and St. Lawrence River shoreline.

**Pressures**
There are many stressors which have and continue to contribute to the loss and degradation of coastal wetland area. These include: filling, dredging and draining for conversion to other uses such as urban, agricultural, marina, and cottage development; shoreline modification; water level regulation; sediment and nutrient loading from watersheds; adjacent land use; invasive species, particularly non-native species; and climate variability and change. The natural dynamics of wetlands must be considered in addressing coastal wetland stressors. Global climate variability and change have the potential to amplify the dynamics by reducing water levels in the system in addition to changing seasonal storm intensity and frequency, water level fluctuations and temperature.

**Management Implications**

Many of the pressures result from direct human actions, and thus, with proper consideration of the impacts, can be reduced. Several organizations have designed and implemented programs to help reduce the trend toward wetland loss and degradation.

Because of growing concerns around water quality and supply, which are key Great Lakes conservation issues, and the role of wetlands in flood attenuation, nutrient cycling and sediment trapping, wetland changes will continue to be monitored closely. Providing accurate useable information to decision-makers from government to private landowners is critical to successful stewardship of the wetland resource.

**Comments from the author(s)**

Development of improved, accessible, and affordable remote sensing technologies and information, along with concurrent monitoring of other Great Lakes indicators will aid in implementation and continued monitoring and reporting of this indicator.

The GLCWC database represents an important step in establishing a baseline for monitoring and reporting on Great Lakes coastal wetlands including extent and other indicators. Affordable and accurate remote sensing methodologies are required to complete the baseline and begin monitoring change in wetland area by type in the future. Other GLCWC-guided research efforts are underway to assess the use of various remote sensing technologies in addressing this current limitation. Preliminary results from these efforts indicate the potential of using radar imagery and methods of hybrid change detection for monitoring changes in wetland type and conversion.

The difficult decisions on how to address human-induced stressors causing wetlands loss have been considered for some time.  Several organizations and programs continue to work to reverse the trend, though much work remains. A better understanding of wetland functions, through additional research and implementation of biological monitoring within coastal wetlands, will help ensure that wetland quality is maintained in addition to areal extent. An educated public is critical to ensuring that wise decisions about the stewardship of the Great Lakes basin ecosystem are made.

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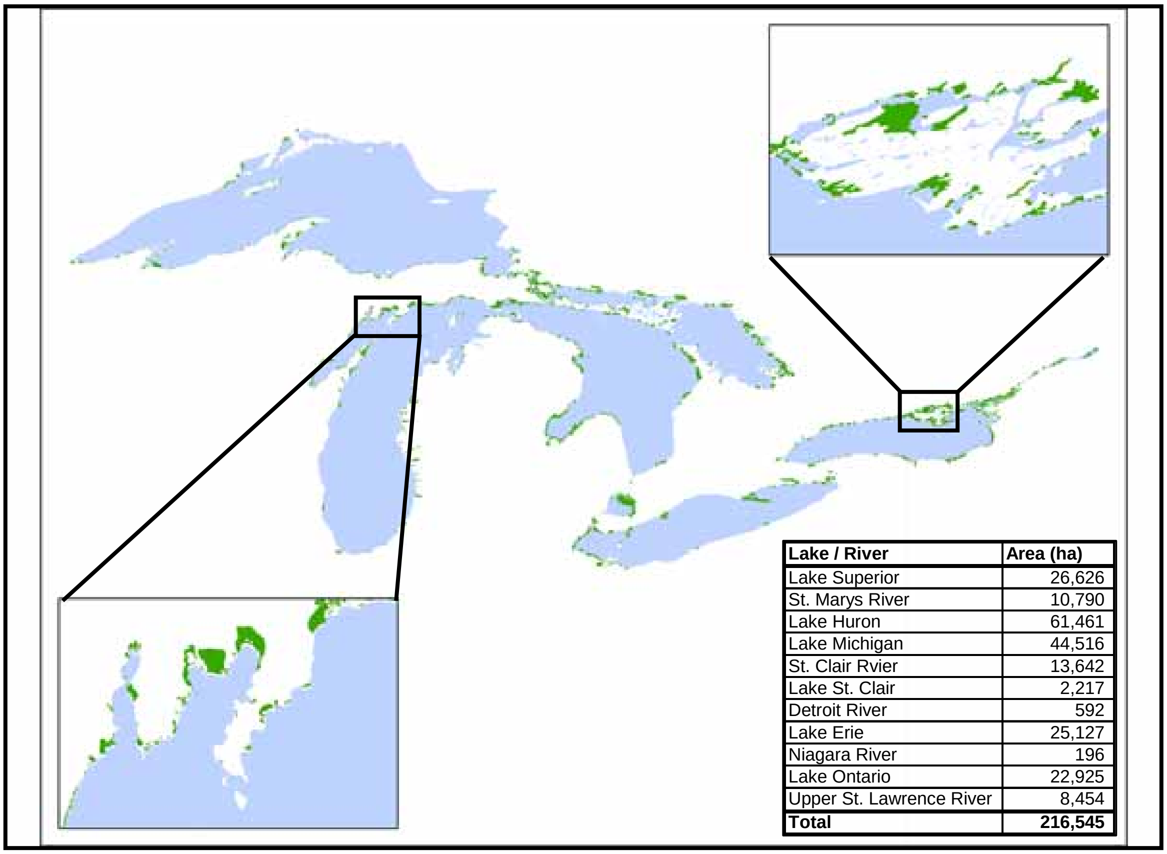
Figure 1. Great Lakes coastal wetland distribution and total area by lake and river.
Source: Great Lakes Coastal Wetlands Consortium

Figure 2. Coastal wetland area by geomorphic type within lakes of the Great Lakes system.
Source: Great Lakes Coastal Wetlands Consortium

Figure 3. Coastal wetland area by geomorphic type within connecting rivers of the Great Lakes system.
Source: Great Lakes Coastal Wetlands Consortium

**Last updated**
SOLEC 2006



| Lake / River | Area (ha) |
|---|---|
| Lake Superior | 26,626 |
| St. Marys River | 10,790 |
| Lake Huron | 61,461 |
| Lake Michigan | 44,516 |
| St. Clair Rvier | 13,642 |
| Lake St. Clair | 2,217 |
| Detroit River | 592 |
| Lake Erie | 25,127 |
| Niagara River | 196 |
| Lake Ontario | 22,925 |
| Upper St. Lawrence River | 8,454 |
| **Total** | **216,545** |

**Figure 1**. Great Lakes coastal wetland distribution and total area by lake and river.
Source: Great Lakes Coastal Wetlands Consortium

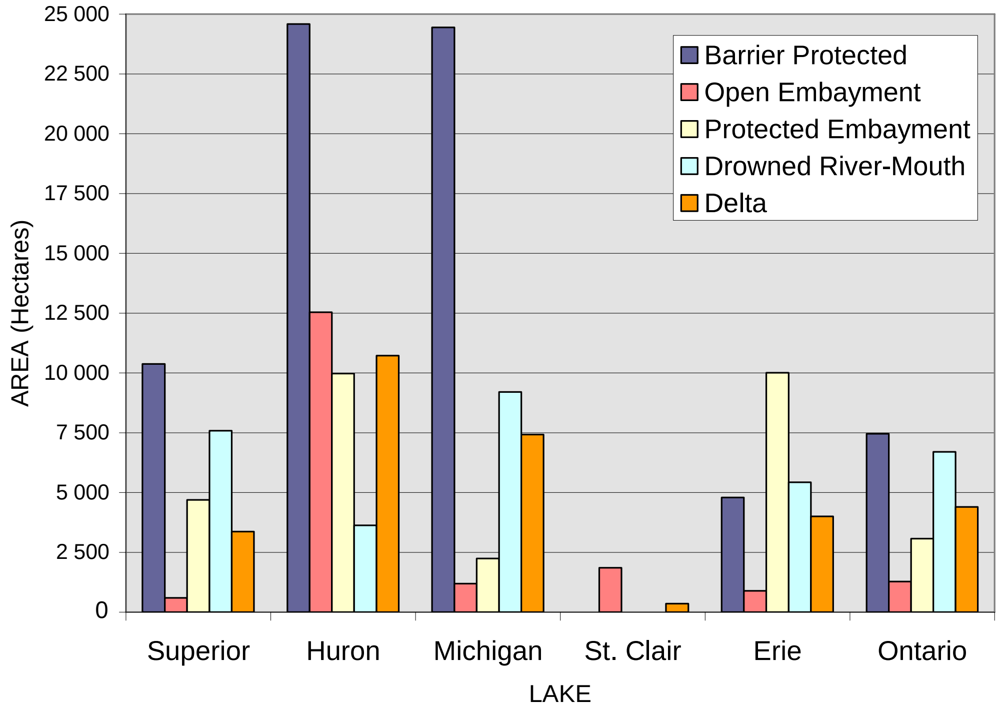



**Figure 2**. Coastal wetland area by geomorphic type within lakes of the Great Lakes system.
Source: Great Lakes Coastal Wetlands Consortium

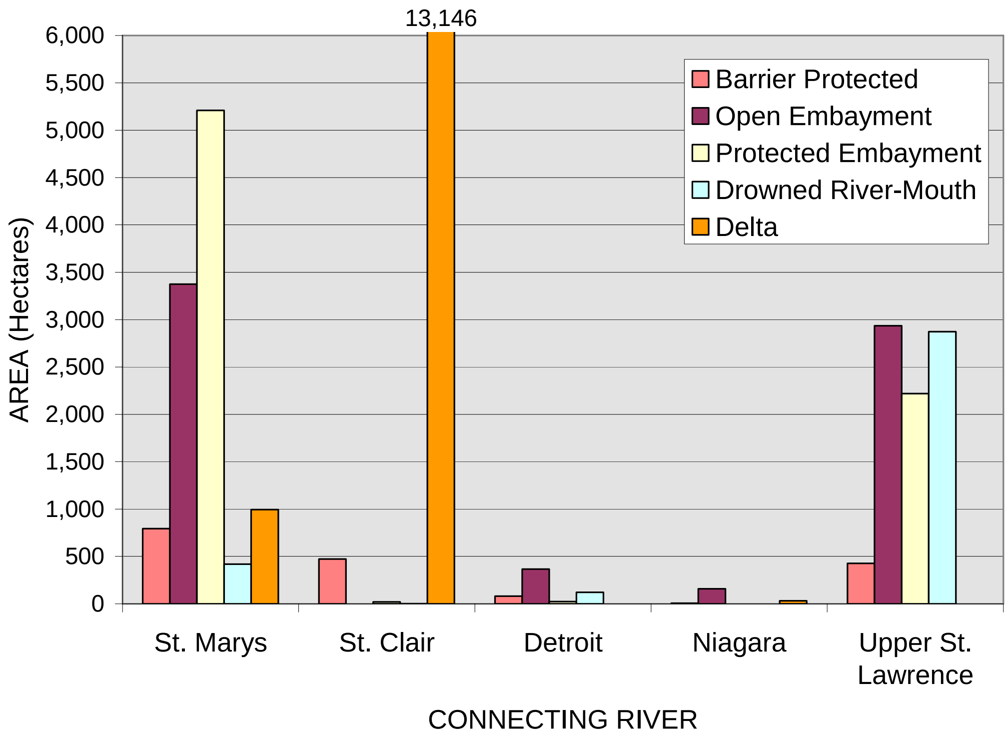



**Figure 3**. Coastal wetland area by geomorphic type within connecting rivers of the Great Lakes system.
Source: Great Lakes Coastal Wetlands Consortium

## Ice Duration on the Great Lakes
Indicator #4858

**Overall Assessment**

Status: **Mixed**
Trend: **Deteriorating (with respect to climate change)**

**Purpose**

•To assess the ice duration and thereby the temperature and accompanying physical changes to each lake over time, in order to infer the potential impact of climate change.

**Ecosystem Objective**

This indicator is used as a potential assessment of climate change, particularly within the Great Lakes basin. Changes in water and air temperatures will influence ice development on the Lakes and, in turn, affect coastal wetlands, nearshore aquatic environments, and inland environments.

**State of the Ecosystem**

Background

Air temperatures over a lake are one of the few factors that control the formation of ice on that surface. Colder winter temperatures increase the rate of heat released by the lake, thereby increasing the freezing rate of the water. Milder winter temperatures have a similar controlling effect, only the rate of heat released is slowed and the ice forms more slowly. Globally, some inland lakes appear to be freezing up at later dates, and breaking-up earlier, than the historical average, based on a study of 150 years of data (Magnuson et al. 2000). These trends add to the evidence that the earth has been in a period of global warming for at least the last 150 years.

The freezing and thawing of lakes is a very important aspect to many aquatic and terrestrial ecosystems. Many fish species rely on the ice to give their eggs protection against predators during the late part of the ice season. Nearshore ice has the ability to change the shoreline as it can encroach upon the land during winter freeze-up times. Even inland systems are affected by the amount of ice that forms, especially within the Great Lakes basin. Less ice on the Great Lakes allows for more water to evaporate and be spread across the basin in the form of snow. This can have an affect on the foraging animals (like deer), that need to dig through snow during the winter in order to obtain food.

**Status of Ice Duration on the Great Lakes**

Observations of the Great Lakes data showed no real conclusive trends with respect to the date of freeze-up or break-up. A reason for this could be that due to the sheer size of the Lakes, it wasn't possible to observe the whole lake during the winter season (at least before satellite imagery), and therefore only regional observations were made (inner bays and ports). However, there was enough data collected from ice charts to make a statement concerning the overall ice cover during the season. There appears to be a decrease in the maximum ice cover per season over the last thirty years (Figure 1).

The trends on each of the five Lakes show that during this time span the maximum amount of ice forming each year has been decreasing, which, in-fact, can be correlated to the average ice cover per season observed for the same time duration (Table 1). Between the 1970s and 1990s there was at least a 10% decline in the maximum ice cover on each Lake, and almost as much as 18% in some cases, with the greatest decline occurring during the 1990s. Since a complete freeze-up did not occur on all the Great Lakes, a series of inland lakes (known to freeze every winter) in Ontario were examined to see if there was any similarity to the results in the previous studies. Data from Lake Nipissing and Lake Ramsey were plotted (Figure 2) based on the ice-on date (complete freeze-over date) and the break-up date (ice-off date). As it turns out, the freeze-up date for Lake Nipissing appears to have the same trend as the other global inland lakes: freezing over later in the year. Lake Ramsey however, seems to be freezing over earlier in the season. The ice-off date for both however, appear to be increasing, or occurring at later dates in the year. These results contradict what is said to be occurring with other such lakes in the Northern Hemisphere (see Magnuson et al. 2000).

The satellite data used in this analysis can be supplemented by on-the-ground citizen science collected data. The IceWatch program of Environment Canada's Ecological Monitoring and Assessment Network and Nature Canada have citizen scientists collecting ice-on and ice-off dates of lakes throughout the Ontario portion of the Great Lakes basin. These volunteers use the same criteria for ice-on and ice-off as does the satellite data, although the volunteers only collect data for the portion of the lake that is visible from a single vantage point on the shore. The IceWatch program began in 2000 as a continuation of a program run by the Meteorological Service of Canada. Data from this program date back to the 1850s. An analysis of data from this database and the Canadian Ice Database (Canadian Ice Services/Meteorological Service of Canada) showed that ice break-up dates were occurring approximately one day earlier every seven years between 1950 and 2004 for 341 lakes across Canada (Futter et al. 2006. *In press*). The data from IceWatch is not as comprehensive as the satellite collected data, but does show some trends in the Great Lakes basin. From two sites with almost 100 years of data, Lake Nipissing is shown to be thawing later in the season (Figure 3). IceWatch data from near Lake Ramsay indicate that lakes have been freezing later over the past thirty years.

**Pressures**

Based on the results of Figure 1 and Table 1, it seems that ice formation on the Great Lakes should continue to decrease in total cover if the predictions on global atmospheric warming are true. Milder winters will have a drastic effect on how much of the lakes are covered in ice, which in turn, will have an effect on many aquatic and terrestrial ecosystems that rely on lake ice for protection and food acquisition.

**Management Implications**

Only a small number of data sets were collected and analyzed for this study, so this report is not conclusive. To reach a level of significance that would be considered acceptable, more data on lake ice formation would have to be gathered. While the data for the Great Lakes is easily obtained from 1972-present, smaller inland lakes, which may be affected by climate change at a faster rate, should be examined. As much historical information that is available should be obtained. This data could come from IceWatch observers and the IceWatch database from throughout the Great Lakes basin. The more data that are received will increase the statistical significance of the results.

**Acknowledgments**
Author: Gregg Ferris, Environment Canada Intern, Downsview, ON.
Updated by: Heather Andrachuk, Environment Canada, Ecological Monitoring and Assessment Network (EMAN); Heather.Andrachuk@ec.gc.ca; (905)336-4411.
All data analyzed and charts created by the author.

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Ice charts obtained from the National Oceanic and Atmospheric Administration (NOAA) and the Canadian Ice Service (CIS).

Data for Lake Nipissing and Lake Ramsey obtained from Walter Skinner, Climate and Atmospheric Research, Environment Canada-Ontario Region.

**Comments from the author**

Increased winter and summer air temperatures appear to be the greatest influence on ice formation. Currently there are certain protocols, on a global scale, that are being introduced in order to reduce the emission of greenhouse gases.

It would be convenient for the results to be reported every four to five years (at least for the Great Lakes), and quite possibly a shorter time span for any new inland lake information. It may also be feasible to subdivide the Great Lakes into bays and inlets, etc., in order to get an understanding of what is occurring in nearshore environments.

**Last Updated**

SOLEC 2006

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Figure 3. Ice-off dates and trend line from 1900-2000 on Lake Nipising.
Source: Ecological and Monitoring Assessment Network (EMAN)

| Lake | 1970 - 1979 | 1980 - 1989 | 1990 - 1999 | Change from 1970s to 1990s |
|---|---|---|---|---|
| Erie | 94.5 | 90.8 | 77.3 | -17.2 |
| Huron | 71.3 | 71.7 | 61.3 | -10.0 |
| Michigan | 50.2 | 45.6 | 32.4 | -17.8 |
| Ontario | 39.8 | 29.7 | 28.1 | -11.7 |
| Superior | 74.5 | 73.9 | 62.0 | -12.6 |

**Table 1**. Mean ice coverage, in percent, during the corresponding decade.
Source: National Oceanic and Atmospheric Administration

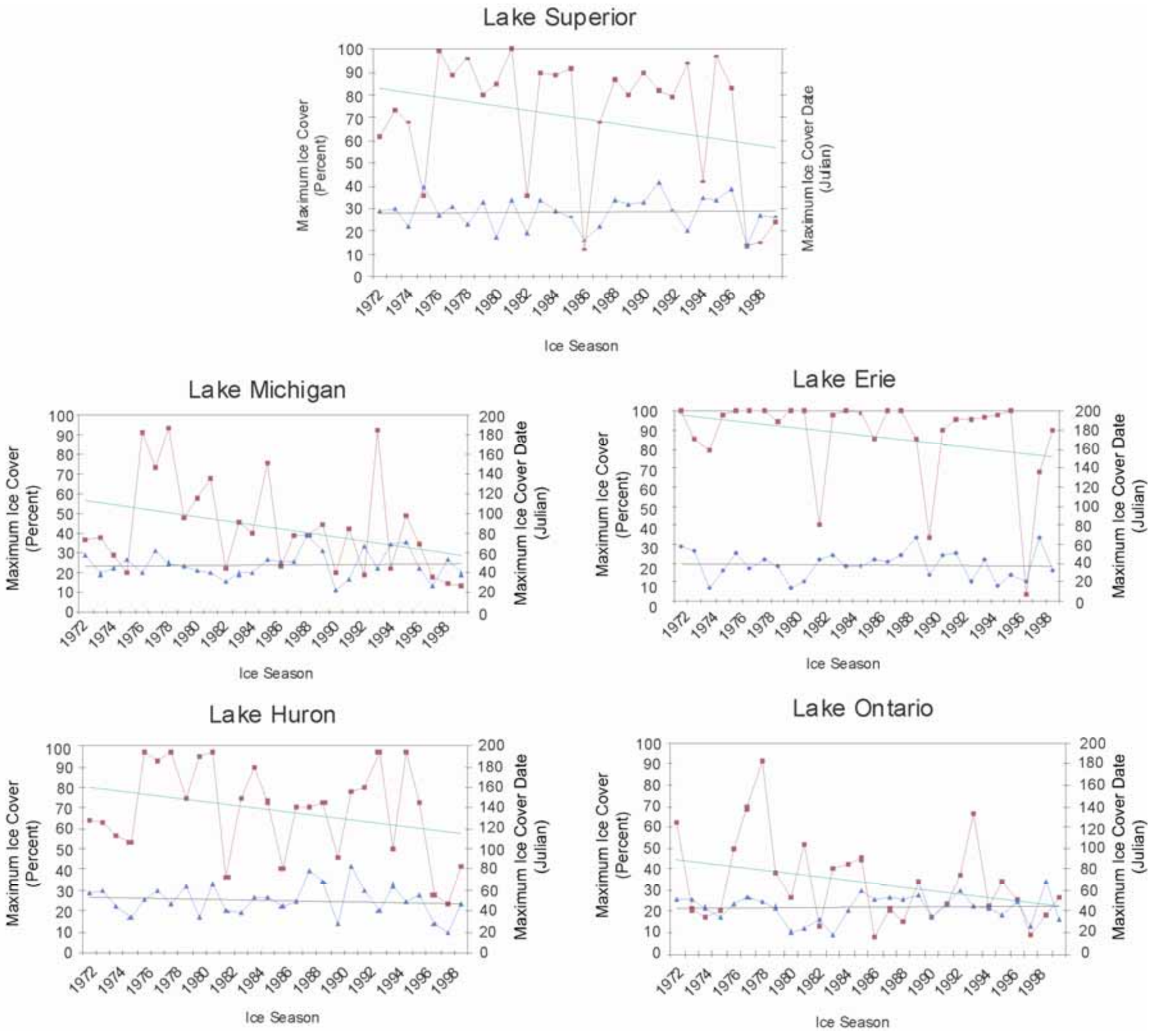


**Figure 1**. Trends of maximum ice cover and the corresponding date on the Great Lakes, 1972-2000. The red line represents the percentage of maximum ice cover and the blue line represents the date of maximum ice cover.
Source: National Oceanic and Atmospheric Administration

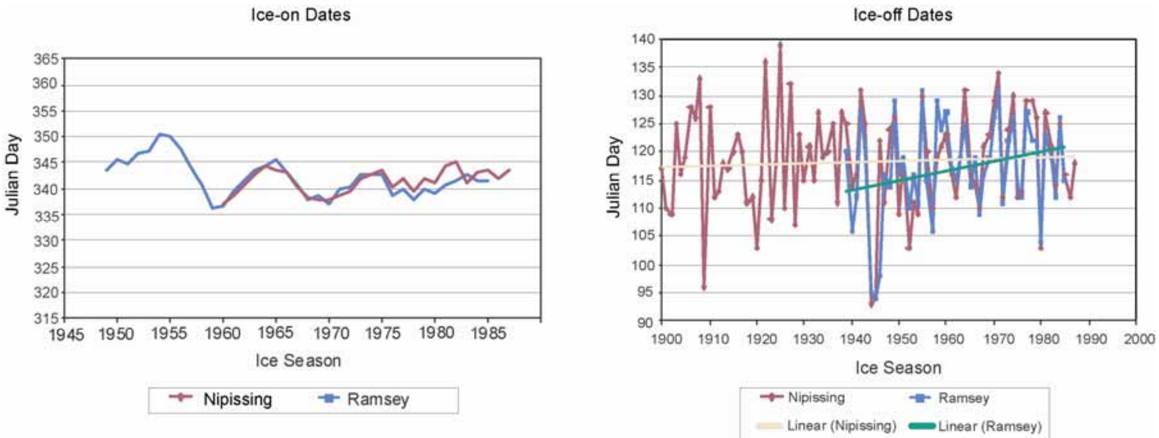


**Figure 2**. Ice-on and ice-off dates for Lake Nipissing (red line) and Lake Ramsey (blue line). Data were smoothed using a 5-year moving average.
Source: Climate and Atmospheric Research and Environment Canada

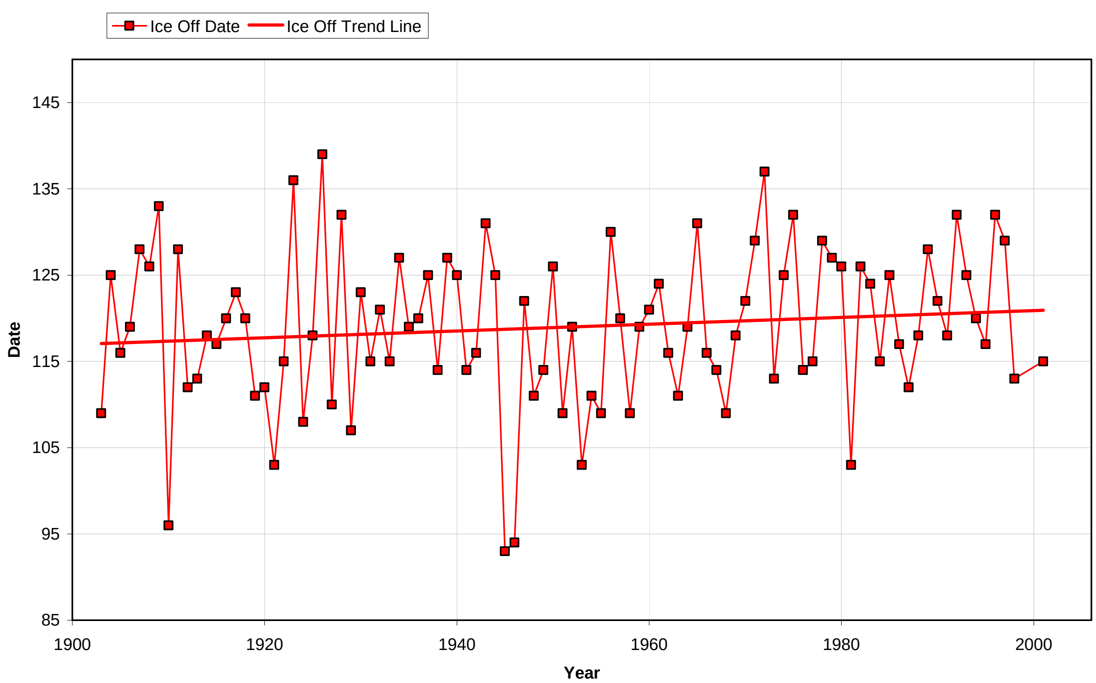


**Figure 3**. Ice-off dates and trend line from 1900-2000 on Lake Nipising.
Source: Ecological and Monitoring Assessment Network (EMAN)

## Effect of Water Level Fluctuations

Indicator #4861

**Assessment: Mixed, Trend Not Assessed**

Data are available for water level fluctuations for all Lakes. A comparison of wetland vegetation along regulated Lake Ontario to vegetation along unregulated Lakes Michigan and Huron provides insight into the impacts of water level regulation.

**Purpose**

- To examine the historic water levels in all the Great Lakes, and compare these levels and their effects on wetlands with post-regulated levels in Lakes Superior and Ontario, where water levels have been regulated since about 1914 and 1959, respectively; and
- To examine water level fluctuation effects on wetland vegetation communities over time as well as aiding in the interpretation of estimates of coastal wetland area, especially in those Great Lakes for which water levels are not regulated.

**Ecosystem Objective**

The ecosystem objective is to maintain the diverse array of Great Lakes coastal wetlands by allowing, as closely as is possible, the natural seasonal and long-term fluctuations of Great Lakes water levels.

**State of the Ecosystem**

Background

Naturally fluctuating water levels are known to be essential for maintaining the ecological health of Great Lakes shoreline ecosystems, especially coastal wetlands. Thus, comparing the hydrology of the Lakes serves as an indicator of degradation caused by the artificial alteration of the naturally fluctuating hydrological cycle.

Great Lakes shoreline ecosystems are dependent upon natural disturbance processes, such as water level fluctuations, if they are to function as dynamic systems. Naturally fluctuating water levels create ever-changing conditions along the Great Lakes shoreline, and the biological communities that populate these coastal wetlands have responded to these dynamic changes with rich and diverse assemblages of species.

Status of Great Lakes Water Level Fluctuations

Water levels in the Great Lakes have been measured since 1860, but 140 years is a relatively short period of time when assessing the hydrological history of the Lakes. Sediment investigations conducted by Baedke and Thompson (2000) on the Lake Michigan-Huron system indicate quasi-periodic lake level fluctuations (Figure 1), both in period and amplitude, on an average of about 160 years, but ranging from 120-200 years. Within this 160-year period, there also appear to be sub-fluctuations of approximately 33 years. Therefore, to assess water level fluctuations, it is necessary to consider long-term data.

Because Lake Superior is at the upper end of the watershed, the fluctuations have less amplitude than the other lakes. Lake Ontario (Figure 2), at the lower end of the watershed, more clearly shows these quasi-periodic fluctuations and the almost complete elimination of the high and low levels since the lake level began to be regulated in 1959, and more rigorously since 1976. For example, the 1986 high level that was observed in the other lakes was eliminated from Lake Ontario. The level in Lake Ontario after 1959 contrasts with that of the Lake Michigan-Huron system (Figure 3), which shows the more characteristic high and low water levels.

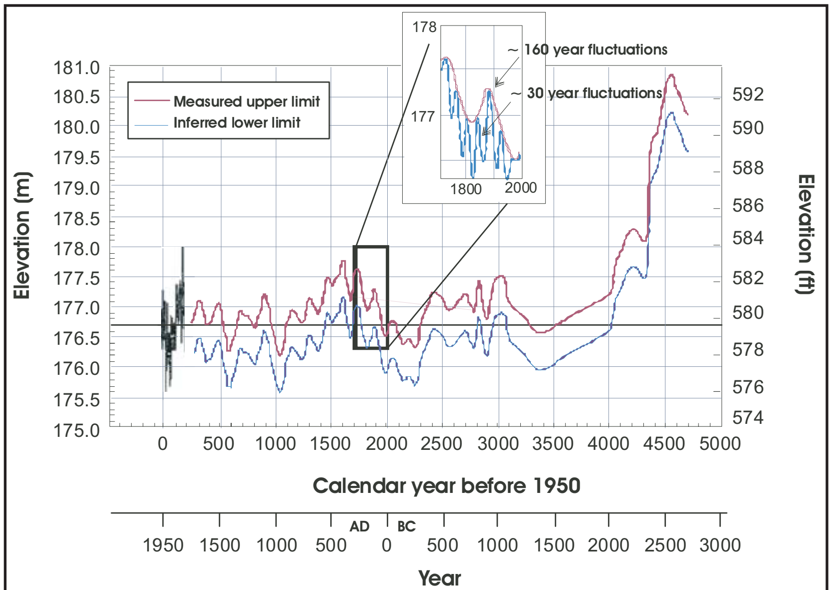


Figure 1. Sediment investigations on the Lake Michigan-Huron system indicates quasi-periodic lake level fluctuations.
Source: National Oceanic and Atmospheric Administration, 1992 (and updates)

The significance of seasonal and long-term water level fluctuations on coastal wetlands is perhaps best explained in terms of the vegetation, which, in addition to its own diverse composition, provides the substrate, food, cover, and habitat for many other species dependent on coastal wetlands.

Seasonal water level fluctuations result in higher summer water levels and lower winter levels. Additionally, the often unstable summer water levels ensure a varied hydrology for the diverse plant species inhabiting coastal wetlands. Without the seasonal variation, the wetland zone would be much narrower and less diverse. Even very short-term fluctuations resulting from

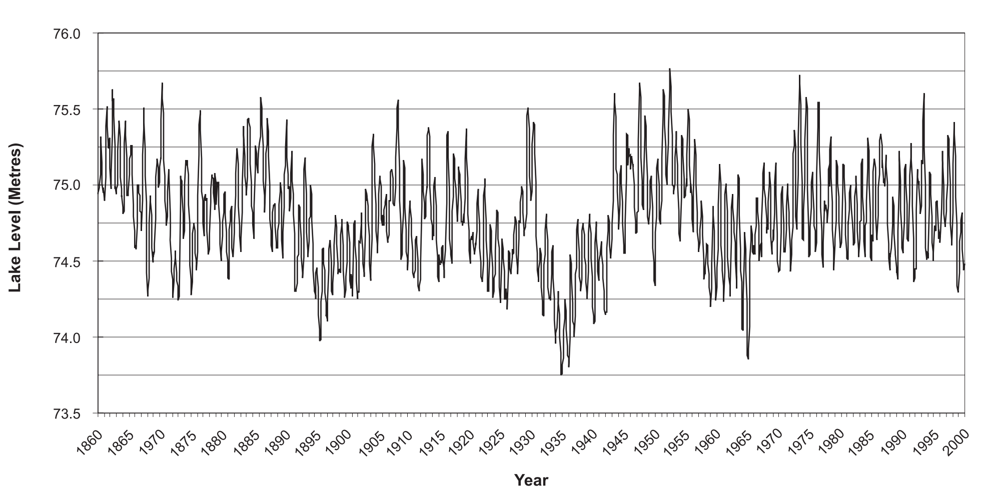


Figure 2. Actual water levels for Lake Ontario. IGLD-International Great Lakes Datum. Zero for IGLD is Rimouski, Quebec, at the mouth of the St. Lawrence River. Water level elevations in the Great Lakes/St. Lawrence River system are measured above water level at this site.
Source: National Oceanic and Atmospheric Administration, 1992 (and updates)

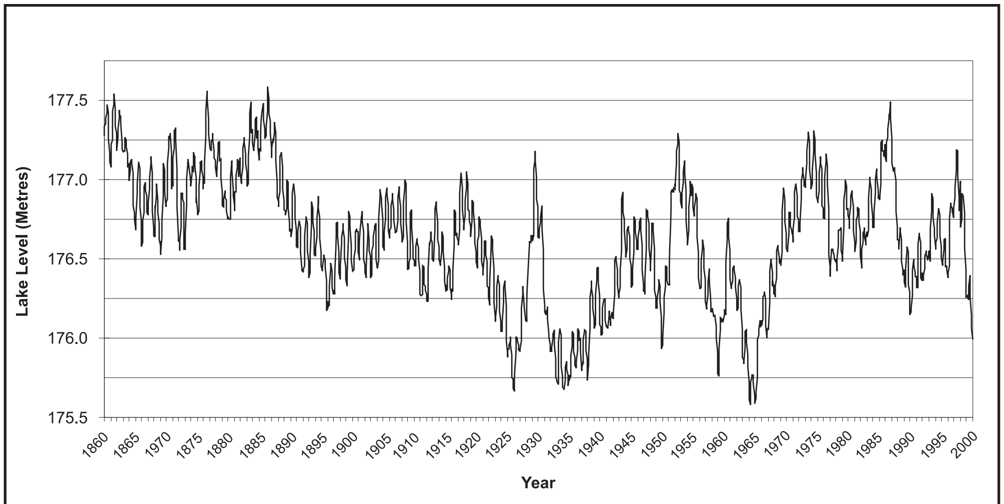


Figure 3. Actual water levels for Lakes Huron and Michigan. IGLD-International Great Lakes Datum. Zero for IGLD is Rimouski, Quebec, at the mouth of the St. Lawrence River. Water level elevations in the Great Lakes/St. Lawrence River system are measured above water level at this site.
Source: National Oceanic and Atmospheric Administration, 1992 (and updates)

changes in wind direction and barometric pressure can substantially alter the area inundated, and thus, alter the coastal wetland community.

Long-term water level fluctuations, of course, have an impact over a longer period of time. During periods of high water, there is a die-off of shrubs, cattails, and other woody or emergent species that cannot tolerate long periods of increased depth of inundation. At the same time, there is an expansion of aquatic communities, notably submergents, into the newly inundated area. As the water levels recede, seeds buried in the sediments germinate and vegetate this newly exposed zone, while the aquatic communities recede out-ward back into the lake. During periods of low water, woody plants and emergents expand again to reclaim their former area as aquatic communities establish themselves further outward into the lake. The long-term high-low fluctuation puts natural stress on coastal wetlands, but is vital in maintaining wetland diversity. It is the mid-zone of coastal wetlands that harbors the greatest biodiversity. Under more stable water levels, coastal wetlands occupy narrower zones along the lakes and are considerably less diverse, as the more dominant species, such as cattails, take over to the detriment of those less able to compete under a stable water regime. This is characteristic of many of the coastal wetlands of Lake Ontario, where water levels are regulated.

**Pressures**

Future pressures on the ecosystem include additional withdrawals or diversions of water from the Lakes, or additional regulation of the high and low water levels. These potential future pressures will require direct human intervention to implement, and thus, with proper consideration of the impacts, can be prevented. The more insidious impact could be caused by global climate change. The quasi-periodic fluctuations of water levels are the result of climatic effects, and global warming has the potential to greatly alter the water levels in the Lakes.

**Management Implications**

The Lake Ontario-St. Lawrence River Study Board is undertaking a comprehensive 5-year study (2000-2005) for the International Joint Commission (IJC) to assess the current criteria used for regulating water levels on Lake Ontario and in the St. Lawrence River.
The overall goals of Environment/Wetlands Working Group of the IJC study are (1) to ensure that all types of native habitats

(floodplain, forested and shrubby swamps, wet meadows, shallow and deep marshes, submerged vegetation, mud flats, open water, and fast flowing water) and shoreline features (barrier beaches, sand bars/dunes, gravel/cobble shores, and islands) are represented in an abundance that allows for the maintenance of ecosystem resilience and integrity over all seasons, and (2) to maintain hydraulic and spatial connectivity of habitats to ensure that fauna have access, temporally and spatially, to a sufficient surface of all the types of habitats they need to complete their life cycles.

The environment/wetlands component of the IJC study provides a major opportunity to improve the understanding of past water-regulation impacts on coastal wetlands. The new knowledge will be used to develop and recommend water level regulation criteria with the specific objective of maintaining coastal wetland diversity and health. Also, continued monitoring of water levels in all of the Great Lakes is vital to understanding coastal wetland dynamics and the ability to assess wetland health on a large scale. Fluctuations in water levels are the driving force behind coastal wetland biodiversity and overall wetland health. Their effects on wetland ecosystems must be recognized and monitored throughout the Great Lakes basin in both regulated and unregulated lakes.

**Acknowledgments**
Author: Duane Heaton, U.S. Environmental Protection Agency, Great Lakes National Programs Office, Chicago, IL.

Much of the information and discussion presented in this summary is based on work conducted by the following: Douglas A. Wilcox, Ph.D. (U.S. Geological Survey / Biological Resources Division); Todd A. Thompson, Ph.D. (Indiana Geological Survey); Steve J. Baedke, Ph.D. (James Madison University).

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**Authors' Commentary**
Human-induced global climate change could be a major cause of lowered water levels in the Lakes in future years. Further study is needed on the impacts of water level fluctuations on other nearshore terrestrial communities. Also, an educated public is critical to ensuring wise decisions about the stewardship of the Great Lakes basin ecosystem are made, and better platforms to getting understandable information to the public are needed.

**Last Updated**
*State of the Great Lakes 2003*

## Coastal Wetland Plant Community Health
Indicator #4862

**Overall Assessment**

Status: **Mixed**
Trend: **Undetermined**

**Lake-by-Lake Assessment**

**Lake Superior**

| | |
|---|---|
| Status: | Good |
| Trend: | Unchanging |
| Primary Factors Determining Status and Trend | Degradation around major urban areas |

**Lake Michigan**

| | |
|---|---|
| Status: | Mixed |
| Trend: | Unchanging |
| Primary Factors Determining Status and Trend | High quality wetlands in north part of lake |

**Lake Huron**

| | |
|---|---|
| Status: | Mixed |
| Trend: | Deteriorating |
| Primary Factors Determining Status and Trend | Plowing, raking, and mowing on Saginaw Bay wetlands during low water causing degradation. Northern wetlands high quality |

**Lake Erie**

| | |
|---|---|
| Status: | Mixed |
| Trend: | Unchanging |
| Primary Factors Determining Status and Trend | Generally poor on US shore with some restoration at Metzger marsh – Presque Isle, PA and Long Pt, Ontario high quality wetlands |

**Lake Ontario**

| | |
|---|---|
| Status: | Poor |
| Trend: | Unchanging |
| Primary Factors Determining Status and Trend | Degraded by nutrient loading and water level control. Some scattered Canadian wetlands of higher quality. |

**Purpose**

•To assess the level of native vegetative diversity and cover for use as a surrogate measure of quality of coastal wetlands which are impacted by coastal manipulation or input of sediments.

**Ecosystem Objective**
Coastal wetlands throughout the Great Lakes basin should be dominated by native vegetation, with low numbers of invasive plant species that have low levels of coverage. (Great Lakes Water Quality Agreement, United States and Canada 1987).

**State of the Ecosystem**
Background
To understand the condition of the plant community in coastal wetlands it is necessary to understand the natural differences that occur in the plant community across the Great Lakes basin. The characteristic size and plant diversity of coastal wetlands vary by wetland type, lake, and latitude, due to differences in geomorphic and climatic conditions. Major factors will be described below.

Lake: The water chemistry and shoreline characteristics of each Great Lake differ, with Lake Superior being the most distinct due to its low alkalinity and prevalence of bedrock shoreline. Nutrient levels also increase in the lake basins further to the east, that is, in Lake Erie, Lake Ontario, and in the upper St. Lawrence River.

Geomorphic wetland type: There are several different types of wetland based on the geomorphology of the shoreline where the wetland forms. Each landform has its characteristic sediment, bottom profile, accumulation of organic material, and exposure to wave activity. These differences result in differences in plant zonation and breadth, as well as species composition. All coastal wetlands contain different zones (swamp, meadow, emergent, submergent), some of which may be typically absent in certain geomorphic wetland types. All Great Lakes wetlands have recently been classified and mapped (Albert et al. In Press).
http://glc.org/wetlands/inventory.html

Latitude: Latitudinal differences in temperature result in floristic differences between the southern and northern Great Lakes. Probably more important is the increased agricultural activity along the shoreline of the southern Great Lakes, resulting in increased sedimentation and non-native species introductions.

There are characteristics of coastal wetlands that make usage of plants as indicators difficult in certain conditions. Among these are:

Water level fluctuations: Great Lakes water levels fluctuate greatly from year to year. Either an increase or decrease in water level can result in changes in numbers of species or overall species composition in the entire wetland or in specific zones. Such a change makes it difficult to monitor change over time. Changes are great in two zones, the wet meadow where grasses and sedges may disappear in high water or new annuals may appear in low water, and in shallow emergent or submergent zones, where submergent and floating plants may disappear when water levels drop rapidly.

Lake-wide alterations: For the southern lakes, most wetlands have been dramatically altered by both intensive agriculture and urban development of the shoreline. For Lake Ontario, water level control has resulted in major changes to the flora. For both of these cases, it is difficult to identify base-line high quality wetlands for comparison to degraded wetlands.

There are several hundred species of plant that occur within coastal wetlands. To evaluate the status of a wetland using plants as indicators, several different plant metrics have been suggested. Several of these are discussed briefly here.

Native plant diversity: The number of native plant species in a wetland is considered by many as a useful indicator of wetland health. The overall diversity of a site tends to decrease from south to north. Different hydrogeomorphic wetland types support vastly different levels of native plant diversity, complicating the use of this metric.

Non-native species: Non-native species are considered signs of wetland degradation, typically responding to increased sediment, nutrients, physical disturbance, and seed source. The amount of non-native species coverage appears to be a more effective measure of degradation than number of non-native species, except in the most heavily degraded sites.

Submergent species: Submergent plants respond to high levels of sediment, nutrient enrichment, and turbidity, and plant species have been identified that respond to each of these changes. Floating species, such as Lemna spp., are similarly responsive to nutrient enrichment. While submergents are valuable indicators whose response to changing environmental conditions is well documented, they also respond dramatically to natural fluctuations in the water level, making them less dependable as indicators in the Great Lakes than in other wetland settings.

Nutrient responsive species: Several species from all plant zones are known to respond to nutrient enrichment. Cattails (Typha spp.) are the best known responders.

Salt tolerance: Many species are not tolerant to salt, which is introduced along major coastal highways. Narrow-leaved cattails are known to be very tolerant to high salt levels.

Floristic Quality Index (FQI): Many of the states and provinces along the Great Lakes have developed indices based on the “conservatism” of all plants growing there. A species is considered conservative if it only grows in a specific, high quality environment. FQI has proved effective for comparing similar wetland sites. However, FQI of a given wetland can change dramatically in response to a water level change, limiting its usefulness in monitoring the condition of a given wetland from year to year without development of careful sampling protocols. Another problem associated with FQIs is that the conservatism values for a given plant vary between states and provinces.

Status of Wetland Plant Community Health

The state of the wetland plant community is quite variable, ranging from good to poor across the Great Lakes basin. The wetlands in individual lake basins are often similar in their characteristics because of water level controls and lake-wide near-shore management practices. There is evidence that the plant component in some wetlands is deteriorating in response to extremely low water levels in some of the Great Lakes, but this deterioration is not seen in all wetlands within these lakes. In general, there is slow deterioration in many wetlands as shoreline alterations introduce non-native species. However, the turbidity of the southern Great Lakes has reduced with expansion of zebra mussels, resulting in improved submergent plant diversity in many wetlands.

Trends in wetland health based on plants have not been well established. In the southern Great Lakes (Lake Erie, Lake Ontario, and the Upper St. Lawrence River), almost all wetlands are degraded by either water level control, nutrient enrichment, sedimentation, or a combination of these factors. Probably the strongest demonstration of this is the prevalence of broad zones of cat-tails, reduced submergent diversity and coverage, and prevalence of non-native plants, including reed (Phragmites australis), reed canary grass (Phalaris arundinacea), purple loosestrife (Lythrum salicaria), curly pondweed (Potamogeton crispus), Eurasian milfoil (Myriophyllum spicatum), and frog bit (Hydrocharis morsus-ranae). In the remaining Great Lakes (Lake St. Clair, Lake Huron, Lake Michigan, Georgian Bay, Lake Superior, and their connecting rivers), intact, diverse wetlands can be found for most geomorphic wetland types. However, low water conditions have resulted in the almost explosive expansion of reed in many wetlands, especially in Lake St. Clair and southern Lake Huron, including Saginaw Bay. As water levels rise, the response of reed should be monitored.

One of the disturbing trends is the expansion of frog bit, a floating plant that forms dense mats capable of eliminating submergent plants, from the St. Lawrence River and Lake Ontario westward into Lake Erie. This expansion will probably continue into all or many of the remaining Great Lakes.

Studies in the northern Great Lakes have demonstrated that non-native species like reed, reed canary grass, and purple loosestrife have established throughout the Great Lakes, but that the abundance of these species is low, often restricted to only local disturbances such as docks and boat channels. It appears that undisturbed marshes are not easily colonized by these species. However, as these species become locally established, seeds or fragments of plant may be able to establish when water level changes create appropriate sediment conditions.

**Pressures**
There are several pressures that lead to degradation of coastal wetlands.

Agriculture: Agriculture degrades wetlands in several ways, including nutrient enrichment from fertilizers, increased sediments from erosion, increased rapid runoff from drainage ditches, introduction of agricultural non-native species (reed canary grass), destruction of inland wet meadow zone by plowing and diking, and addition of herbicides. In the southern lakes, Saginaw Bay, and Green Bay, agricultural sediments have resulted in highly turbid waters which support few or no submergent plants.

Urban development: Urban development degrades wetlands by hardening shoreline, filling wetland, adding a broad diversity of chemical pollutants, increasing stream runoff, adding sediments, and increased nutrient loading from sewage treatment plants. In most urban settings almost complete wetland loss has occurred along the shoreline.

Residential shoreline development: Along many coastal wetlands, residential development has altered wetlands by nutrient enrichment from fertilizers and septic systems, shoreline alterations for docks and boat slips, filling, and shoreline hardening. While less intensive than either agriculture or urban development, local physical alteration often results in introduction of non-native species. Shoreline hardening can completely eliminate wetland vegetation.

Mechanical alteration of shoreline: Mechanical alteration takes a diversity of forms, including diking, ditching, dredging, filling, and shoreline hardening. With all of these alterations non-native species are introduced by construction equipment or in introduced sediments. Changes in shoreline gradients and sediment conditions are often adequate to allow non-native species to become established.

Introduction of non-native species: Non-native species are introduced in many ways. Some were purposefully introduced as agricultural crops or ornamentals, later colonizing in native landscapes. Others came in as weeds in agricultural seed. Increased sediment and nutrient enrichment allows many of our worst aquatic weeds to out-compete native species. Most of our worst non-native species are either prolific seed producers or reproduce from fragments of root or rhizome. Non-native animals have also been responsible for increased degradation of coastal wetlands. One of the worst invasive species has been Asian carp, who's mating and feeding result in loss of submergent vegetation in shallow marsh waters.

**Management Implications**

While plants are currently being evaluated as indicators of specific types of degradation, there are limited examples of the effects of changing management on plant composition. Restoration efforts at Coots Paradise, Oshawa Second, and Metzgers marsh have recently evaluated a number of restoration approaches to restore submergent and emergent marsh vegetation, including carp elimination, hydrologic restoration, sediment control, and plant introduction. The effect of agriculture and urban sediments may be reduced by incorporating buffer strips along streams and drains. Nutrient enrichment could be reduced by more effective fertilizer application, reducing algal blooms. However, even slight levels of nutrient enrichment cause dramatic increases in submergent plant coverage. For most urban areas it may prove impossible to reduce nutrient loads adequately to restore native aquatic vegetation. Mechanical disturbance of coastal sediments appears to be one of the primary vectors for introduction of non-native species. Thorough cleaning of equipment to eliminate seed source and monitoring following disturbances might reduce new introductions of non-native plants.

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