Interactions Between Marsh Bird Population Indices and Great Lakes Water Levels: A Case Study of Lake Ontario Hydrology

Prepared for: International Joint Commission Environmental Technical Working Group

G. Eoin Craigie[1], Steven T.A. Timmermans[1] and Joel W. Ingram[2]

[1]Bird Studies Canada
P.O. Box 160
Port Rowan, Ontario
N0E 1M0

[2]Canadian Wildlife Service – Ontario Region
Environment Canada
4905 Dufferin Street
Downsview, Ontario
M3H 5T4

February 2003

Abstract: Seasonal and annual hydrologic variability is necessary for maintenance of suitable nesting and foraging habitats for a variety of wetland dependent bird species, especially at wetlands associated with large water bodies. Lake Ontario hydrology has been altered by water regulation controls in the St. Lawrence River since 1959. This has resulted in reduced within- and among-year amplitude and variability in Lake Ontario water levels and has altered temporal water level patterns. In 2000, the Lake Ontario – St. Lawrence River Study Board began a five-year study for the International Joint Commission to review the current water regulation criteria, and if deemed appropriate, alter the current criteria to better meet the diversity of interests that occur within this region. Water regulation criteria as it relates to and influences environmental values and specifically coastal wetland biotic communities have been identified as a priority aspect of the five year study. Seven years of Marsh Monitoring Program (MMP) data were used to compare 1) how occurrence and abundance of marsh bird species at Lake Ontario coastal marshes differ from those at non-Lake Ontario coastal marshes, 2) correlations of annual Great Lakes water level indices with annual wetland bird species abundance indices during the breeding period, 3) patterns of agreement between direction of annual changes of lake levels and those of species abundance indices, and 4) temporal patterns of basin-wide and basin-specific annual lake levels and proportional marsh habitat indices. Marsh bird species route occurrence and mean abundance indices for all survey years were lower at Lake Ontario coastal routes than at Great Lakes basin coastal routes combined. Several marsh nesting bird species' annual abundance indices for Great Lakes basin coastal routes correlated positively with water level indices, either directly or with the previous year's water level indices (American Bittern, Black Tern, Common Moorhen, Forester's Tern, Least Bittern, Marsh Wren, Pied-billed Grebe, Sora and Virginia Rail). Conversely, annual abundance indices of some marsh bird species known to inhabit dryer marsh edges or that nest on dry ground correlated negatively with Great Lakes basin water level indices (Common Yellowthroat, Song Sparrow, Willow Flycatcher and Yellow Warbler). Temporal proportional habitat coverage did not appear to track lake levels, however, MMP habitat collection techniques are basic and may not lend themselves to temporal comparison of overall habitat diversity and spatial heterogeneity. Because changes to natural hydrologic regimes could have marked effects on wetland dependent bird species richness and/or regional species-specific population status, results are discussed as they pertain to how Lake Ontario water level regulation may be influencing coastal marsh bird communities.

INTRODUCTION

Water levels of the Laurentian Great Lakes and associated wetlands have been fluctuating in their current post-Pleistocene hydrologic regime for about 3,500 years (Keddy 2000, Quinn 2002). Such temporal changes in lake levels, shoreline land feature formation, ground water hydrology and annual weather patterns in the Great Lakes region have resulted in a vast coverage and array of unique and dynamic shoreline wetlands (Herdendorf 1992, Wilcox 1995, Mitsch and Gosselink 2000). For instance, an estimated 1,200 km^2 of wetlands occur in the United States portion of the Great Lakes, while greater proportions have been estimated to occur in the Canadian occupied portion of the Great Lakes shoreline (Mitsch and Gosselink 2000). Vegetation characteristic to marshes provides diverse community structure for mammals, amphibians and birds that occupy these systems. Likely the most influential abiotic attribute sustaining such wetland characteristics and the diverse faunal and floral communities of Great Lakes shoreline (hereafter coastal) marshes is hydrology (Wilcox 1995, Wilcox and Whillans 1999, Keddy 2000).

Great Lakes coastal marshes provide important breeding, migrating and foraging habitats for a variety of wetland dependent bird species (Prince et al. 1992). These marshes support high densities of breeding Red-winged Blackbird (*Agelaius phoeniceus*), Common Yellowthroat (*Geothlypis trichas*) and Marsh Wren (*Cistothorus palustris*) (Picman et al. 1993) and moderate densities of breeding rails (*Rallidae*) and bitterns (*Botaurus spp*.) (Melvin and Gibbs 1996, Gibbs et al. 1992a). Pied-billed Grebe (*Podilymbus podiceps*), American Bittern (*Botaurus lentiginosus*), American Coot (*Fulica americana*) and Common Moorhen (*Gallinula chloropus*) use robust emergents for both breeding and summer habitat (Herendorf 1992), while millions of waterfowl and various other water birds use Great Lakes marshes for essential migratory staging habitat (Prince et al. 1992). Under natural conditions, Great Lakes shoreline hydrology and plant community structure varies seasonally and annually in response to lake level variation (Keough et al. 1999). This functions to sustain diverse wetland plant communities (Wilcox and Meeker 1991, Wilcox et al. 1992). Such seasonal and annual hydrologic variability helps create suitable nesting and foraging habitats for a variety of marsh dependent species, and each species has adapted to occupy specific niches within diverse marsh habitat structure (Riffell et al. 2001).

Of the five Laurentian Great Lakes, water levels of Lakes Superior and Ontario have been regulated since 1920 and 1959, respectively, through anthropogenic control of outflow according to regulation plans determined by the International Joint Commission (IJC) (Quinn 2002). Regulation of Lake Ontario water levels has resulted in a measurable reduction in amplitude of seasonal water level changes, has decreased year-to-year hydrologic variability, and has resulted in lower spring water levels (Wilcox and Whillans 1999). Reduced year-to-year lake level variation leads to reduction in wetland size, diversity and resilience to environmental perturbation (Keddy and Reznicek 1986, Wilcox et al. 1992). Such hydrologic moderation has increased monotypicity of emergent marsh vegetation (Keddy and Reznicek 1986, Wilcox et al. 1992), which may be reflective in the avian community structure. Keddy (2000) suggested that further reduction to such amplitude of hydrologic variability could cause losses of up to 30% of Lake Ontario's remaining wetlands. Determining how such hydrologic changes relate to relative abundance and occurrence of wetland dependent bird species will improve the understanding about how lake hydrology functions to maintain diverse marsh systems and associated avifauna communities.

This study is part of a large collaborative project that has been supported by the IJC to evaluate economic, social and environmental consequences of Lake Ontario water level regulation. In particular, study objectives were to evaluate 1) how occurrence and abundance of marsh bird species at Lake Ontario coastal marshes differ from those at non-Lake Ontario coastal marshes, 2) correlations of annual Great Lakes water level indices with annual wetland bird species abundance indices during the breeding period, 3) patterns of agreement between direction of annual changes of lake levels and those of species abundance indices, and 4) temporal patterns of basin-wide and basin-specific annual lake levels and proportional marsh habitat indices.

Because specific wetland dependent bird species require permanent and healthy coastal marsh habitats, and habitat requirements vary considerably among species (Fairbairn and Dinsmore 2001, Timmermans et al. *in prep*.), any reduction of natural marsh habitat diversity, loss of certain habitat components, or loss of natural hydrologic regimes could have marked effects on wetland dependent bird species richness and/or regional species-specific population status. The Marsh Monitoring Program (MMP) is a binational, long-term program that coordinates volunteers in monitoring birds and calling amphibians of coastal and inland marshes of the Great Lakes basin. The MMP was launched in 1995 to: monitor populations of marsh birds and amphibians over a variety of spatial scales; investigate habitat associations of marsh birds and amphibians; contribute to wetland conservation initiatives; and help increase awareness of conservation issues. Seven years of data have demonstrated significant temporal changes in annual indices at both basin-specific basin and basin-wide scales (see Timmermans and Craigie 2002). This report covers 1) how occurrence of marsh bird species at Lake Ontario coastal marshes differ from those at non-Lake Ontario coastal marshes, 2) correlations of Great Lakes water level annual indices (basin-specific and basin-wide) with wetland bird species annual abundance indices during the breeding period (May through July), and 3) patterns of agreement between direction of annual changes in lake levels and that of species abundance indices. Results are discussed in context of understanding how lake hydrology relates to marsh bird communities that utilize coastal marshes. Ultimately, results will contribute to the IJC environmental technical working group's goal of understanding how various hydrologic attributes and water regulation criteria may be affecting ecological integrity of its coastal marshes.

METHODS

Data for this study were gathered by MMP volunteers who monitored marsh bird relative abundance and occurrence throughout marshes of the Great Lakes basin between 1995 and 2001. The Great Lakes basin encompasses more than 534,000 km^2 of total land area and more than 247,000 km^2 of total fresh water surface area (Quinn 2002). This basin encompasses five recognized distinct Great Lakes; Ontario, Erie, Huron, Michigan, and Superior and is bounded by one Canadian province (Ontario) and eight U.S. states (New York, Pennsylvania, Ohio, Michigan, Indiana, Illinois, Wisconsin and Minnesota).

Volunteers received training kits that included protocol instructions, field and summary data forms, instructional cassette tapes with examples of songs and calls of marsh birds, and a call broadcast tape used to elicit calls from normally secretive marsh bird species (Virginia Rail (*Rallus limicola*), Sora (*Porzana carolina*), Least Bittern (*Ixobrychus exilis*), Common Moorhen, American Coot and Pied-billed Grebe). MMP volunteers established survey routes in marshes greater than 1 ha in size and each route consisted of one to eight survey stations. Each marsh bird point count survey station was separated by at least 250 m to minimize duplicate counts of individuals. MMP survey stations were defined as a 100 m radius semicircle with emergent marsh vegetation covering at least 50% of the semicircle area. Marsh habitat was defined as habitat regularly or periodically wet or flooded to a depth of up to two metres where non-woody vegetation was predominant. Marsh bird counts were conducted from a focal point at each station that was marked with a stake and metal tag to facilitate relocation within and between years. Marsh bird survey visits were conducted twice annually between 20 May and 5 July, beginning after 18 00 h under appropriate survey conditions (i.e., 16 ºC or warmer, no precipitation and wind no greater than a score of three on the Beaufort scale) with at least 10 days separation between visits. A five minute call broadcast tape was played at each station during the first half of each 10 minute survey visit. The call back tape included calls of normally secretive marsh bird species (mentioned above) separated by 30 seconds of silence. Observers recorded all birds heard and/or seen within the survey station area onto a field map and data form during the call playback period and during a five minute silent period following call playback. Aerial foragers that occurred within the station area to a height of 100 m, other species flying through the station area, or those detected outside the station were recorded separately. Marsh bird species that were recognized as important faunal indicators of wetland health and condition in the Great Lakes basin were identified *a priori* and listed in Appendix 1.

MMP surveyors conducted annual assessments of habitat characteristics for each of their survey stations during mid- to late-June, when most emergent plant zones could be readily identified. Observers provided information about coverage of five habitat types: herbaceous emergent plants; open water; exposed mud, rock or sand; trees; and shrubs. Observers also recorded percent coverage of four dominant emergent plant types found within a survey station and sketched a map illustrating general habitat characteristics of each station. Additional information about sampling methodology can be found in Anonymous (2001) and Weeber and Valliantos (2000).

'Coastal' and 'non-coastal' MMP routes and their locations were identified according to whether the marsh where the route(s) occurred were connected directly to any Great Lakes water body. Marsh bird annual indices and occurrences were only calculated for coastal routes. Basin-specific annual indices were calculated only for those species that occurred in 10 or more routes over the seven-year period. Basin-specific and basin-wide occurrence indices were calculated based on counts of species inside the MMP station boundary and were defined relative to 2001 values. General models (PROC GENMOD; SAS Institute Inc. 2001) were developed to generate annual indices for each marsh bird species. Indices were scaled to correct for over-dispersion prior to transformation for regression analyses. Analyses to test overall effect of year as a class variable or as a continuous variable were done using likelihood ratio tests (PROC GENMOD; SAS Institute Inc. 2001) to compare deviance of these models to models with no year variable. For each species, annual percent change in annual indices and their upper and lower 95% confidence limits were calculated. Because raw counts of marsh birds approximate a Poisson distribution of observations, Poisson regression was used to evaluate year-to-year variance of annual indices and overall direction and strength of trends across years. Due to revisions in the proportional habitat assessment protocols that occurred prior to the 1997 survey season, habitat annual indices were calculated for herbaceous emergent plants, exposed substrate, open water, trees, shrubs, grasses and cattails occurring at coastal routes from 1997 to 2001. Assessments were made to determine how marsh bird abundance indices and plant species proportional indices related to changes in Great Lakes water levels. Water level data were derived and measured relative to the 1985 International Great Lakes Datum from the Canadian Hydrographic Service between 1994 and 2001. Mean annual water levels for the months of May, June and July were calculated. These water level indices were related to marsh bird indices derived from MMP data collected during the same three-month period. Because Lakes Michigan and Huron constitute a contiguous water body and are subject to similar water level changes (Quinn 2002) results will be discussed for Lake Michigan-Huron as one water body. Annual number of MMP routes surveyed was insufficient to calculate reliable indices or trends in the Lake Superior basin, thus data from this basin were excluded from analyses.

Number of stations surveyed per route and marsh bird species route occurrence was calculated for Lake Ontario coastal routes and Great Lakes coastal routes combined and was calculated and compared using a paired t-test (PROC CORR; SAS Institute Inc. 2001). Route occurrence was defined as total number of coastal routes where species were observed in a basin divided by total number of routes surveyed in that basin. Mean abundance indices across all survey years were compared for Lake Ontario and non-Lake Ontario MMP routes for each species that were detected at both Lake Ontario and non-Lake Ontario routes (PROC GENMOD; SAS Institute Inc. 2001). For each species, Pearson's product-moment correlation coefficients (PROC CORR; SAS Institute Inc. 2001) were used to assess correlations between mean water levels and annual abundance indices at coastal routes. For several marsh dependent bird species, parallelism in the direction of between-year water level changes and species annual abundance indices were compared, and assigned a ' + ' to year-pairs when the changes paralleled (e.g., increase vs. increase) and a ' - ' when the changes were opposed (e.g., decrease vs. increase).

The MMP was designed and implemented to monitor marsh bird abundance and amphibian occurrence at a Great Lakes basin-wide scale using a volunteer survey network. Survey route placement is non-random and volunteer survey expertise varies. These two aspects of the MMP increase potential of introducing spatial biases and increasing variance in sampling error into the MMP dataset, which can reduce accuracy and precision of results derived from analyses. This becomes a more significant issue when subsets of MMP data are used for "custom" analyses at smaller spatial scales, as is the case for some aspects of this report. However, the MMP does constitute an extensive marsh bird database that contains valuable temporal species occurrence and abundance information related to the Great Lakes coastal wetlands. The scale and temporal aspect of the MMP data provides a unique opportunity to investigate correlations between annual species occurrence and abundance indices and annual Great Lakes water level indices. Results of this MMP analysis and report aids to validate and compare in a broader sense conclusions from other short-term intensive IJC specific studies, and existing relevant published literature. Potential influences of the MMP survey design on results will be identified within the discussion of this report.

RESULTS

Marsh bird route occurrence and abundance

For several species, when considering strictly coastal marsh routes, route occurrence was inadequate in certain individual basins (i.e., less than ten routes) to calculate reliable annual indices. In total, MMP volunteers surveyed 88 coastal routes (Lake Ontario - $n = 30$, Lake Erie - $n = 36$, Lake Michigan-Huron - $n = 22$) from 1995 through 2001. There was no difference ($t = 2.45$, df = 6, $P = 0.36$) in number of stations surveyed per route when compared between years and when compared between Lake Ontario coastal routes and Great Lakes coastal routes combined (Table 1). Route occurrence of marsh bird species at Lake Ontario coastal routes were at least 10 % lower than at Great Lakes coastal routes combined for seven species (Bank Swallow (*Riparia riparia*), Common Yellowthroat, Eastern Kingbird (*Tyrannus tyrannus*), Least Bittern, Pied-billed Grebe, Swamp Sparrow (*Melospiza geogiana*), Yellow Warbler (*Dendroica petechia*)) (Table 2). Among all species, marsh bird route occurrence on Lake Ontario was significantly lower ($t = 1.70$, df = 29, $P = 0.02$) than non-Lake Ontario (Lakes Michigan-Huron and Erie) marsh bird species coastal route occurrence.

Mean marsh bird abundance indices across all survey years for species that were detected in both Lake Ontario and non-Lake Ontario coastal routes differed significantly for five of 19 species (Bank Swallow, Common Grackle (*Quiscalus quiscula*), Common Yellowthroat, moorhen/coot, Tree Swallow (*Iridoprocne bicolor*)) (Table 3). However, when compared across all species, Lake Ontario marsh bird abundance indices were significantly lower ($X^2 = 11.93$, df = 18, $P < 0.001$) than non-Lake Ontario marsh bird abundance indices.

Marsh bird population indices and basin-wide water levels

Product-moment correlations between annual marsh bird population indices and mean May-July Great Lakes basin water level indices are presented in Table 4. For several marsh dependent species, population indices among coastal routes were positively correlated with basin-wide water level indices (American Bittern – $r = 0.66$, $P = 0.11$; American Coot – $r = 0.72$, $P = 0.07$; Forster's Tern (*Sterna forsteri*) – $r = 0.92$, $P = 0.004$; Least Bittern – $r = 0.93$, $P = 0.002$; Marsh Wren (*Cistothorus palustris*) - $r = 0.80$, $P =$

0.03; Pied-billed Grebe – $r = 0.71$, $P = 0.07$; Sora – $r = 0.85$, $P = 0.01$; Virginia Rail – $r = 0.53$, $P = 0.22$, Figure 1, Table 4). Similarly, inter-annual directional changes of four marsh dependent species' indices most often paralleled those of basin-wide water level indices, as denoted by a preponderance of year-pair comparisons that were each assigned a ' + ' (American Bittern - $n = 4/6$; Forster's Tern - $n = 4/6$; Least Bittern – $n = 5/6$, Table 5). Annual indices for several marsh birds that prefer marsh edge habitat were weakly negatively correlated to mean annual basin-wide water level indices (Common Yellowthroat – $r = -0.57$, $P = 0.18$; Song Sparrow (*Melospiza melodia*) – $r = -0.50$, $P = 0.25$; Willow Flycatcher (*Empidonax traillii*) – $r = -0.45$, $P = 0.31$; Yellow Warbler – $r = -0.32$, $P = 0.48$, Figure 2, Table 4). Directional agreement in inter-annual change between marsh bird population and water level indices were most often opposed for two edge species, as denoted by a preponderance of year-pairs assigned a ' - ' (Willow Flycatcher – $n = 4/6$; Yellow Warbler – $n = 4/6$, Table 5).

For marsh bird species monitored across all Great Lakes coastal routes combined, and that occurred at Lake Ontario basin coastal routes, Common Yellowthroat (b = 5.3 % / year, $P = 0.02$) was the only species that showed a significant increase over the seven-year monitoring period (Table 6). However, seven species (Common Moorhen - b = -9.9 % / year, $P = 0.04$; Marsh Wren - b = -4.5 % / year, $P = 0.02$; moorhen/coot - b = -13.1 % / year, $P < 0.01$; Red-winged Blackbird - b = -4.3 % / year, $P < 0.01$; Sora - b = -14.5 % / year, $P < 0.01$; Tree Swallow - b = -9.8 % / year, $P < 0.01$; Virginia Rail - b = -7.2 % / year, $P = 0.03$) showed significant declines across all Great Lakes coastal routes combined.

Marsh bird population indices and Lake Ontario water levels

Absolute changes in Lake Ontario's water levels were less than other lake basins considered (Timmermans 2002). Further, although Lake Ontario's water levels peaked during the same year as other basins (i.e., 1997), a unique rebound in Lake Ontario water levels occurred between 1999 and 2001 (Figure 3). Because coastal route occurrence was low for many species (less than 10 routes), coastal route indices were calculated for only five of the nine candidate marsh dependent species. Only two of these species' indices at Lake Ontario coastal routes correlated positively with temporal patterns of mean Lake

Ontario water level indices (Marsh Wren - *r* = 0.56, *P* = 0.19; Virginia Rail – *r* = 0.58, *P* = 0.17, Figure 4, Table 4). There was high directional agreement in inter-annual changes between marsh bird population indices and water level indices for three marsh dependent species (Marsh Wren – *n* = 4/6; Sora – *n* = 5/6; Virginia Rail – *n* = 4/6, Table 7). For two marsh bird species that prefer marsh edge habitat, temporal patterns of annual population indices were weakly negatively correlated to that of mean May-July Lake Ontario water level indices (Common Yellowthroat – *r* = -0.57, *P* = 0.18; Willow Flycatcher – *r* = -0.44, *P* = 0.32, Figure 5, Table 4). Directional agreement in inter-annual change between population indices and water level indices were most often opposed for three marsh edge species in Lake Ontario coastal routes (Common Yellowthroat – *n* = 5/6; Eastern Kingbird – *n* = 4/6; Willow Flycatcher – *n* = 5/6, Table 7).

For marsh bird species monitored at Lake Ontario coastal routes, Canada Goose (*Branta canadensis*) (b = 32.1 % / year, *P* = 0.03) was the only species that showed a significant increase, while no species showed significant declines over the seven-year monitoring period (Table 8).

Marsh habitat

Comparisons of annual marsh vegetation indices in relation to mean May - July Great Lakes water level indices are presented in Figure 6. While indices of Great Lakes water levels decreased between 1997 and 2001 annual proportional indices of emergent vegetation, open water, cattails, exposed substrate, trees and shrubs had less than a 10% net difference between high and low annual indices for the same period. However, annual proportional indices of grasses increased 16.6% between 1997 and 2001.

Comparisons of annual marsh vegetation indices to mean May – July Lake Ontario water level indices are presented in Figure 7. Annual proportional indices of open water, exposed substrate, trees, shrubs and grasses had a net difference of less than 5% between 1997 and 2001. Whereas net difference between high and low annual proportional indices was 9.8% for cattails and 25.3% for emergent vegetation between 1997 and 2001.

DISCUSSION

As identified in the methodology, volunteer-selected marshes are not randomly assigned and thus may not be entirely representative of wetlands throughout the Great Lakes basin. From a statistical perspective, the only way to ensure that MMP results are representative of the Great Lakes basin is through random sampling. However, even without random sampling, it is conceivable that the results might be representative, but this is unknown. The degree to which volunteer-selected marshes are representative of the Great Lakes basin depends on measurement criteria. Also, it is not known how representative indices derived from current MMP route coverage relate to actual populations within the Great Lakes basin. For example, it is probable that population densities may not be representative if there is geographical variation across the basin in densities, and if sampled marshes are concentrated in only certain parts of the basin. Yet population indices and their trends may be representative if they are relatively uniform across the basins (which is unlikely), or if selected marshes happen to adequately represent the range of variation in annual indices and their trends. In any case, complete randomization of MMP route assignment is not feasible, and may not be desirable. Further discussion and planning on this issue is required to determine the need for developing and conducting a parallel random sampling scheme. These potential biases are further identified and discussed below. Because the MMP is still intensifying its geographical coverage and because sample sizes for some species prevented calculation of reliable annual indices, especially when viewed at smaller spatial scales (i.e. less routes), summaries for certain species at smaller scales (e.g., Lake Ontario) are not provided.

Marsh bird route occurrence and abundance

Generally, coastal route occurrence and mean abundance indices of marsh bird species were lower at Lake Ontario coastal routes than at Great Lakes coastal routes combined. Obligate marsh nesting species common to Great Lakes basin marshes, such as American Coot, Least Bittern and Pied-billed Grebe, occurred at least 10% lower at Lake Ontario coastal routes than at Great Lakes coastal routes combined. Similarly, mean abundance indices of three marsh bird species (Common Yellowthroat, moorhen/coot, Tree Swallow) were significantly lower at Lake Ontario routes than at non-Lake Ontario routes. Of the 21 marsh bird species that were detected at both Lake Ontario coastal routes and at Great Lakes coastal routes combined, seven these species' indices showed significant declines across all Great Lakes coastal routes over the seven-year monitoring period. Conversely, there were no marsh bird species indices that showed significant declines at Lake Ontario coastal routes over the seven-year period. Lower route occurrence and abundance indices of marsh birds at Lake Ontario coastal routes may be attributed to basin-specific annual water level variation. For example, Lakes Michigan-Huron and Erie showed similar patterns of water level variation from 1995 through 2001, whereas Lake Ontario water level patterns showed distinct perturbations between 1999 and 2001 that did not occur in other lake basins. More importantly, the amplitude of annual water level change in Lake Ontario was considerably lower compared to that of non-Lake Ontario basins. For instance, from 1995 through 2001 the net difference between high and low water level indices of Lake Ontario was approximately 50 cm, while for both Lakes Michigan-Huron and Erie it was greater than 85 cm. Seasonal and annual hydrologic variability functions to sustain diverse marsh plant communities (Wilcox and Meeker 1991, Wilcox et al. 1992), while reduced water level variation can lead to increased monotypic wetlands and reduced wetland size (Keddy and Reznicek 1986, Wilcox et al. 1992). Further, anthropogenic regulation of seasonal and annual water level cycles can reduce diversity of marsh avifauna, which have adapted to natural water level fluctuations (Kushlan 1989). Regular cyclic temporal changes in population size are deemed essential for maintenance of thriving, diverse populations (Mitsch and Gosselink 2000). Findings for obligate marsh nesting bird species and those known to occur for many waterfowl species (Mitsch and Gosselink) clearly demonstrate that there are strong relationships between annual changes in water levels and relative annual population indices. Consequently, habitat suitability and in turn species richness (occurrence) and abundance of nesting and foraging wetland dependent bird species at Lake Ontario coastal routes may be negatively affected by decreased amplitude of water level fluctuations.

Marsh bird population indices and basin-wide water levels

In evaluating how temporal patterns of marsh bird species abundance indices at coastal marshes related to temporal patterns of hydrology in the Great Lakes basin, it was found that nine marsh dependent bird species indices were positively correlated with Great Lakes water level variability during the critical breeding period. Of these species, American Coot (Sutherland and Maher 1987), Forster's Tern (McNicholl et al. 2001), Least Bittern (Rodgers and Schwikert 1999), Marsh Wren (Verner 1965), Pied-billed Grebe (Muller and Storer 1999), Sora (Melvin and Gibbs 1996) and Virginia Rail (Conway 1995), often nest less than 1 meter above and forage exclusively in standing water in marshes. Subsequently, these wetland dependent bird species were expected to relate most directly to temporal water level changes. It was predicted that changes in annual indices of obligate marsh bird species that depend on flooded and healthy emergent vegetative structure would closely track changes in mean annual Great Lakes water levels during the breeding season. Although hydrologic variability is important in maintaining healthy, diverse and interspersed herbaceous marsh vegetative communities (Keough et al. 1999, Keddy 2000), absence of standing water within emergent marsh communities reduces suitability of this habitat to marsh dependent species. American Bittern often nest in dryer adjacent upland habitat (Gibbs et al. 1992b) and would be less expected to follow this trend. However, this species relies heavily on emergent marsh habitat with standing water during foraging and brood rearing periods, which may explain why MMP data for this species showed close correlations between annual indices and Great Lakes water level indices.

For some species (American Bittern, Least Bittern, Marsh Wren, and Virginia Rail) there appeared to be a one-year lag in the relation between annual abundance indices and annual Great Lakes basin water level indices from 1994 through 1997, but this apparent lag was not evident thereafter. If there is a real lag effect, such an effect may be more evident during periods of increasing water levels than during periods of sharp decline. Such lags may be due to a lag in response to shifts in vegetation composition when areas become inundated with higher water levels. However, more direct relations between annual abundance indices and water level indices may occur during declines of water levels due to lack of standing water for species that only nest in, and most commonly forage in standing water within emergent vegetation.

Annual changes in abundance indices for several marsh bird species that are less dependent on marsh habitat, showed either negative or no correlation with annual changes in Great Lakes basin water level indices. For example, annual indices of Bank Swallow, Eastern Kingbird and Swamp Sparrow showed virtually no correlation to indices of Great Lakes water levels. Annual abundance indices of four species (Barn Swallow (*Hirundo rustica*), Common Yellowthroat, Song Sparrow and Willow Flycatcher) were negatively correlated to Great Lakes water levels during the breeding season. Aerial foragers (i.e., Barn Swallow) most often forage over dry terrestrial habitat, which some marshes most resemble when they become dry (Brown and Brown 1999). Common Yellowthroat and Song Sparrow are considered “ground nesters” and nest in drier areas of marsh habitat (Bent 1968, Guzy and Ritchison 1999), while Willow Flycatcher often nest in dry, woody vegetation (Sedgwick 2000).

Several wetland dependent marsh bird species of the Great Lakes basin showed patterns of agreement between year-to-year changes in abundance indices and annual changes in Great Lakes water levels. For three of the nine obligate marsh nesting species, direction of between-year annual index changes agreed with that of Great Lakes water level indices. For example, agreement in direction of change for Least Bittern abundance indices and that of Great Lakes water level indices agreed in all but one year-to-year interval.

Marsh bird population indices and Lake Ontario water levels

Probably the most intriguing aspects of the study results were numerous correlations between species-specific annual abundance indices at coastal routes and temporal changes in Lake Ontario water level indices. Lake Ontario’s controlled water level regimes have no effect on hydrology regimes of other Great Lake basins because the Niagara Escarpment provides a vertical separation of approximately 70 meters (Lee et al. 1998). Due to this and Lake Ontario’s controlled hydrology, Lake Ontario’s water level regimes are unique from those of other Great Lakes basins. Thus, Lake Ontario’s controlled hydrologic nature offers an opportunity to compare how relative annual abundance and occurrence of various bird species differ from those of non-Lake Ontario basins.

Results showed that annual route occurrence for several marsh bird species (i.e., American Bittern, American Coot, Black Tern, Least Bittern, Pied-billed Grebe) at Lake Ontario coastal routes was insufficient to calculate reliable population indices with which to compare to Lake Ontario's water level indices. However, among those species for which adequate data were available, several obligate marsh birds were directly correlated with variations in Lake Ontario water levels. During the seven-year monitoring period, Marsh Wren and Virginia Rail indices closely followed annual patterns of Lake Ontario water levels. Further, direction of between-year water level changes for Lake Ontario showed high agreement with direction of between-year annual population changes for three of five obligate marsh nesting species examined. Annual indices for Sora agreed with Lake Ontario water level indices in all but one year-to-year interval. The moderate to low correlation coefficients between marsh bird species annual indices and Lake Ontario water level indices may be attributed to an apparent lag observed in the comparisons. There appeared to be a one-year lag in the pattern of annual population indices for several obligate marsh nesters (Common Moorhen, moorhen/coot and Virginia Rail) and that of annual water level indices of Lake Ontario. Such a lag obscured the ability to detect correlations that examined similarities of change assuming a direct (i.e., same year) relation. Further, reduced year-to-year water level variation has suppressed natural flooding and drawdown events of marshes, thereby reducing significant water level changes. Both are critical in maintaining diversity and nutrient availability in marshes (Weller, 1978, Harris et al. 1981, Lyon 1979, Lyon et al. 1986). Consequently, many coastal marshes along Lake Ontario's shoreline are known to have become overgrown with dense, monotypic stands of cattail, which uptake vast amounts of water in their vascular systems and reduce local areas of open water within emergent zones (Keddy and Reznicek 1986, Wilcox et al. 1992). An example of this occurs within the Bay of Quinte region of Lake Ontario, where monotypic cattail stands have become so dense that artificial channels have been created to augment loss of open water patches. Thus, decreased water level fluctuation and cattial dominance in coastal marshes may suppress changes to marsh bird species occurrence and abundance, thereby reducing their temporal correlations with Lake Ontario water levels.

Temporal patterns of six obligate marsh nesting bird species' annual indices in Lake Erie (nearest to Lake Ontario and at a similar latitude) are highly correlated with Lake Erie annual water level changes (see Timmermans 2002). Five of these species (American Bittern, Black Tern, Forster's Tern, Least Bittern, Pied-billed Grebe) were not adequately detected at Lake Ontario coastal routes to calculate annual indices. This alone indicates that hydrologic control of Lake Ontario may reduce suitability of marsh habitat for several obligate species.

Marsh Habitat

Proportional annual indices of most marsh habitat components did not appear to pattern annual water level changes as expected. Annual indices of Great Lakes water levels decreased considerably from 1997 to 2001, but four of seven marsh habitat types recorded (percent emergent vegetation, percent trees, percent shrubs, percent cattail) increased only moderately. Only percent grasses increased considerably during basin-wide water level declines. Percent open water decreased very slightly during the 1997 through 2001 water level declines. Increases in proportional annual indices of certain marsh plants (e.g., grasses and cattails) would be expected to occur after multiple years of declining water levels (Keddy and Reznicek 1986, Wilcox et al. 1992).

Lake Ontario water level patterns from 1997 through 2001 were different from those of other Great Lakes during this period. Patterns of proportional annual indices of certain marsh habitat components (percent open water, percent exposed substrate, percent trees, percent shrubs) were quite similar to those for all Great Lake basins combined, indicating that patterns were similar across basins, despite differences in Lake Ontario's hydrology. It is important to recognize that MMP habitat data collection is basic, and may not lend itself well to such comparisons, or to ascertaining overall diversity and spatial heterogeneity. As well, estimating percent cover of habitat types within the survey area is very difficult and can be subject to significant observer bias. Although annual abundance data for marsh bird species evidently reflects how annual water level changes influence annual relative abundance within surveyed marshes (because birds utilize more habitat types and areas than what occurs within MMP boundaries), annual habitat proportion estimates recorded within MMP stations may no be adequate to use as indicators of hydrologic change within these Great Lakes coastal marshes. The lack of change of habitat components with bird population indices may also indicate the importance of standing water within various plant habitat types in dictating habitat suitability. Even though habitat cover components may not have changed much within the scale of MMP survey stations, the lack of standing water within these emergent zones during low water years nonetheless made this habitat less suitable for over-water nesting birds and more suitable for ground nesting species. Conversely, during high water years, larger areas of emergent communities will be flooded during the nesting season, which potentially increases suitable nesting area for over-water nesting species and decreases it for edge and ground nesting species. This phenomenon would likely occur only in the short term during changing water levels. Sustained higher or lower water levels would eventually result in expansion or contraction of emergent plant communities respectively, and a change in species composition over a long-term period.

The MMP was designed primarily for extensive purposes. Also, due to the volunteer nature of the program and because sample sizes become reduced when viewing only coastal routes at smaller spatial scales, some variation in annual population indices may be partly due to changes in route locations and/or volunteer surveyors. However, the strong and expected correlations between specific marsh bird species population indices and water levels in each of the Great Lake basins over several years, and lack of temporal change in relative amount of habitat components during this same period, indicate that results were not strongly influenced by potential bias associated with the MMP survey data.

CONCLUSIONS

In conclusion, evaluations using Marsh Monitoring Program data have demonstrated that annual water levels of Great Lakes during spring and early summer may be influencing relative abundance of certain obligate marsh specialist bird species at coastal marshes either during that same year (especially for species that nest over standing water), or for some species during the following year, which may be indicative of a lag in response to water level changes by either certain marsh habitat components and/or by individuals of certain species. Had only direct correlations between temporal patterns of bird species annual indices and annual lake level indices been evaluated, important lag response relations that appear to occur for certain species would have been missed.

In Lake Ontario, annual hydrology is controlled at its outlet and has resulted in reduced water level variability and a unique annual water level pattern distinct from other lake basins. This unique water level pattern was reflected in annual patterns of occurrence and abundance for certain bird species and demonstrates that anthropogenic control of Lake Ontario has the ability to influence use of its coastal wetlands by certain bird species. Lake Ontario's moderate hydrologic regulation appears to have eliminated short-term population index declines of several wetland dependent species that occurred in the other Great Lakes during the same survey period. Initial conclusions could be that regulation is benefiting wetland bird populations by providing a stable supply of habitat, however the population stabilization appears to be to the determent of reduced habitat quality. Lake Ontario survey routes contained reduced species occurrence (diversity) and abundance (density) and were, on average, lower than those at routes within the other Great Lakes. These results indicate that natural cycling of Great Lakes water levels are necessary for maintaining habitat quantity and diversity to support healthy and diverse marsh bird communities. Overall, marsh species benefit from natural high and low water events through time. Marsh bird species have evolved to persist during periodically unfavourable hydrologic conditions. This cycling provides a diversity of habitat for many species, therefore any measure that reduces this variability and disrupts the nature of these processes, has the potential to affect the ecological integrity of freshwater coastal wetlands and their biotic communities.

MMP results for the Great Lakes basin and Lake Ontario coastal wetlands support this and indicate that regulation of lake levels may have had negative consequences to the integrity and health of coastal wetland bird communities. The Marsh Monitoring Program is a valuable extensive bird monitoring initiative that can contribute to knowledge of how hydrologic and climatic processes in large regions, such as the Great Lakes basin, may affect use of marsh environments by bird communities. The MMP is ongoing and also provides an excellent opportunity to incorporate an Adaptive Resource Management approach into the Water Regulation Review Study. Future MMP data can be used to evaluate if changes to regulation criteria have had expected results on wetland bird communities.

ACKNOWLEDGEMENTS

The Marsh Monitoring Program is delivered by Bird Studies Canada (BSC) in partnership with Environment Canada's Canadian Wildlife Service – Ontario Region, United States Environmental Protection Agency's Great Lakes National Program Office (U.S. EPA-GLNPO), and Great Lakes United. Development and implementation of the MMP has been funded by Canada's Great Lakes Sustainability Fund, Canadian Wildlife Service, U.S. EPA–GLNPO, U.S. EPA Lake Erie Team and the U.S. Great Lakes Protection Fund. The program has received important support from a variety of conservation partners, including Wildlife Habitat Canada, U.S. Geological Survey - Biological Resources Division, the Federation of Ontario Naturalists, Ducks Unlimited Canada, Ontario Ministry of Natural Resources, National Audubon Society and provincial agencies and regional conservation groups. The following organizations were particularly instrumental during early development of the MMP: Ashtabula River Public Advisory Committee, Citizens Advisory Committee for Rochester Remedial Action Plan, Hamilton Harbour Bay Area Restoration Council, International Joint Commission, Ontario Ministry of Natural Resources, Rochester Embayment Remedial Action Plan and the U.S. National Biological Service. We also appreciate support and input of the MMP's Science and Technical Advisory Committee: Lesley Dunn (CWS), Mike Cadman (CWS), Charles Francis (BSC), Jon McCracken (BSC), Kathy Jones (BSC) and Steve Timmermans (BSC). Amy Chabot, Natalie Helferty, Ron Ridout, Russ Weeber and Mary Valiantos coordinated the MMP during earlier program development. Special thanks to Mike Cadman, Christine Bishop, and Jon McCracken for their leadership in developing the bird and amphibian survey protocols. Thank you to all MMP participants for your invaluable contributions and dedication to the program. Implementation and success of the Marsh Monitoring Program is made possible only by participation of these Great Lakes basin volunteer citizen scientists.

LITERATURE CITED

Anonymous. 2001. The Marsh Monitoring Program - Training Kit and Instructions for Surveying Marsh Birds, Amphibians and Their Habitats. Bird Studies Canada in cooperation with Environment Canada and the U.S. Environmental Protection Agency. 40 pp.

Bent, A.C. 1968. Life Histories of North American Cardinals, Grosbeaks, Buntings, Towhees, Finches, Sparrows and allies. Part Three. *Ed* O.L Austin Jr. Dover Publications Inc., New York. pp. 1512-1556.

Brown, C.R., and M.B. Brown. 1999. Barn Swallow (*Hirundo rustica*). *In* The Birds of North America, No. 452. *Eds* A. Poole and F. Gill. The Birds of North America, Inc., Philadelphia, PA.

Conway, C.J. 1995. Virginia Rail (*Rallus limicola*). *In* The Birds of North America, No. 173. *Eds* A. Poole and F. Gill. The Birds of North America, Inc., Philadelphia: The Academy of Natural Sciences; Washington, DC: The American Ornithologists' Union.

Fairbain, S.E., and J.J. Dinsmore. 2001. Local and landscape-level influences on wetland bird communities of the prairie pothole region of Iowa, USA. Wetlands. 21:41-47.

Gibbs, J.P., Reid, F.A., and S.M. Melvin. 1992a. Lest Bittern. *In* The Birds of North America, No. 17. *Eds* A. Poole and F. Gill. The Birds of North America, Inc., Philadelphia: The Academy of Natural Sciences; Washington, DC: The American Ornithologists' Union.

Gibbs, J.P., Melvin, S., and F.A. Reid. 1992b. American Bittern. *In* The Birds of North America, No. 18. *Eds* A. Poole and F. Gill. The Birds of North America, Inc., Philadelphia: The Academy of Natural Sciences; Washington, DC: The American Ornithologists' Union.

Guzy, M.J., and G. Ritchison. 1999. Common Yellowthroat (*Geothlypis trichas*). *In* The Birds of North America, No. 448. *Eds* A. Poole and F. Gill. The Birds of North America, Inc., Philidelphia, PA.

Harris, H., Fewless, G., Milligan, M., and W. Johnson. 1981. Recovery process and habitat quality in a freshwater coastal marsh following a natural disturbance. *In* Selected Proceedings of the Midwest Conference on Wetland Values and Man, Freshwater Society, St. Paul, MN, pp. 363-379.

Herdendorf, C.E. 1992. Lake Erie coastal wetlands: an overview. Journal of Great Lakes Research. 18:533-551.

Keddy, P.A. 2000. Wetland Ecology: Principles and Conservation. Cambridge University Press, Cambridge, United Kingdom. 614 pp.

Keddy, P.A., and A.A. Reznicek. 1986. Great Lakes vegetation dynamics: the role of fluctuating water levels and buried seeds. Journal of Great Lakes Research. 12:25-36.

Keough, J.R., Thompson, T.A., Guntenspergen, G.R., and D.A. Wilcox. 1999. Hyrdogeomorphic factors and ecosystem responses in coastal wetlands of the Great Lakes. Wetlands. 19:821-834.

Kushlan, J.A. 1989. Avian use of fluctuating wetlands. *In* Freshwater Wetlands and Wildlife. *Eds* R.R. Sharit and J.W. Gibbons. Department of Energy Symposium Series 61. Office of Scientific and Technical Information, Department of Energy, Oak Ridge TN. pp. 593-604.

Lee, D. H., Quinn, F. H., and A. H. Clites. 1998. Effect of the Niagara river Chippawa Grass Island Pool on water levels of Lakes Erie, St. Clair, and Michigan-Huron. J. Great Lakes Res. 24(4):936-948.

Lyon, J. 1979. The influence of Lake Michigan water levels on wetland soils and distribution of plants in the Straits of Mackinac, MI. Doc. diss., Univ. Michigan, Ann Arbor, MI.

Lyon, J., Drobney, R. D., and C. E. Olson, Jr. 1986. Effects of Lake Michigan water levels on wetland soil chemistry and distribution of plants in the Straits of Mackinac. J. Great Lakes Res. 12:175-183.

McNicholl, M.K., Lowther, P.E., and J.A. Hall. 2001. Forster's Tern (*Sterna forsteri*). *In* The Birds of North America, No. 595. *Eds* A. Poole and F. Gill. The Birds of North America, Inc., Philidelphia, PA.

Melvin, S.M., and J.P. Gibbs. 1996. Sora (*Porzana Carolina*). *In* The Birds of North America, No. 250. *Eds* A. Poole and F. Gill. The Academy of Natural Sciences, Philadelphia, PA, and the American Ornithologists' Union, Washington, D.C.

Mitsch, W.J., and J.G. Gosselink. 2000. Wetlands. 3rd Ed. John Wiley and Sons, Inc., New York, New York. 920 pp.

Muller, M.J., and R.W. Storer. 1999. Pied-billed Grebe (Podilymbus podiceps). *In* The Birds of North America, No. 410. *Eds* A. Poole and F. Gill. The Birds of North America, Inc., Philidelphia, PA.

Pickman, J., Milks, M.L., and Leptich, M. 1993. Patterns of predation on passerines nests in marshes: effects of water depth and distance from edge. The Auk. 110:89-94.

Prince, H.H, Padding, P.I., and R.W. Knapton. 1992. Waterfowl use of the Laurentian Great Lakes. Journal of Great Lakes Research. 18:673-699.

Quinn F.H. 2002. Secular changes in Great Lakes water level seasonal cycles. Journal of Great Lakes Research. 28:451-465.

Riffell, S.K., Keas, B.E., and T.M. Burton. 2001. Area and habitat relationships of birds in Great Lakes coastal wet meadows. Wetlands. 21:492-507.

Rodgers, J.A. Jr., and S.T. Schwikert. 1999. Breeding ecology of the Least Bittern in central Florida. Florida Field Naturalist. 27:141-149.

Sedgwick, J.A. 2000. Willow Flycatcher (*Empidonax traillii*). *In* The Birds of North America, No. 533. *Eds* A. Poole and F. Gill. The Birds of North America, Inc., Philidelphia, PA.

Sutherland, J.M., and W.J. Maher. 1987. Nest-site selection of the American Coot in the aspen parklands of Saskatchewan. The Condor. 89:804-810.

Timmermans, S.T.A., Kirk, D.A., and C.M. Francis. *In preparation*. Habitat associations of breeding marsh birds monitored through the Great Lakes basin Marsh Monitoring Program. Manuscript in preparation.

Timmermans, S.T.A. 2002. Temporal relationships between Marsh Monitoring Program derived wetland bird and amphibian annual population indices and average annual Great Lakes water levels. Published by Bird Studies Canada in cooperation with Environment Canada and the U.S. Environmental Protection Agency. 84 pp.

Timmermans, S.T.A., and G.E. Craigie. 2002. The Marsh Monitoring Program 2002 Report: monitoring the Great Lakes wetlands and their amphibian and bird inhabitants. Published by Bird Studies Canada in cooperation with Environment Canada and the U.S. Environmental Protection Agency. 51 pp.

Verner, J. 1965. Breeding biology of the Long-billed Marsh Wren during the breeding season. Condor. 67:6-30.

Weeber, R. C., and M. Valliantos. 2000. The Marsh Monitoring Program 1995-1999: Monitoring Great Lakes wetlands and their amphibian and bird inhabitants. Published by Bird Studies Canada in cooperation with Environment Canada and the U.S. Environmental Protection Agency. 47 pp.

Weller, M. W. 1978. Management of freshwater marshes for wildlife. *In* Freshwater wetlands: ecological processes and management potential. *Eds* R. E. Good, R. L. Simpson, and D. F. Whigham. Academic Press, New York, New York, USA. pp. 267-284.

Wilcox, D.A., and J.E. Meeker. 1991. Disturbance effects on aquatic vegetation in regulated and unregulated lakes in northern Minnesota. Canadian Journal of Botany. 69:1542-1551.

Wilcox, D.A., Meeker, J.E., and J. Elias. 1992. Impacts of water-level regulation on wetlands of the Great Lakes. Phase 2 Report to Working Committee 2, IJC Water-Level Reference Study.

Wilcox, D.A. 1995. Wetland and aquatic macrophytes as indicators of anthropogenic hydrologic disturbance. Natural Areas Journal. 15:240-248.

Wilcox, D.A., and T.H. Whillians. 1999. Techniques for restoration of disturbed coastal wetlands. Wetlands. 19:835-857.

TABLES

Table 1. Number of stations surveyed per route in each year for marsh birds at Lake Ontario and basin-wide basin coastal routes.

	Ontario* (30)	Basin-wide (88)
1995	4.0	4.3
1996	4.1	4.2
1997	3.8	3.7
1998	3.5	3.7
1999	3.9	3.8
2000	3.4	3.6
2001	3.6	3.7
All years	3.8	3.8

* - values in parentheses are number of routes surveyed across the seven year period

Table 2. Route occurrence of marsh birds at Great Lakes coastal MMP routes between 1995 and 2001.

	Ontario* (30)	Basin-wide (88)
Alder Flycatcher	0.20	0.16
American Bittern	0.13	0.19
Amercian Coot	0.07	0.24
Bank Swallow	0.53	0.43
Barn Swallow	0.77	0.75
Black Tern	0.30	0.38
Blue-winged Teal	0.17	0.19
Canada Goose	0.43	0.50
Chimney Swift	0.30	0.30
Cliff Swallow	0.13	0.14
Common Grackle	0.73	0.75
Common Moorhen	0.43	0.42
Common Yellowthroat	0.60	0.74
Eastern Kingbird	0.43	0.57
Least Bittern	0.23	0.33
Mallard	0.77	0.75
Marsh Wren	0.73	0.74
Moorhen/Coot	0.50	0.55
Mute Swan	0.40	0.23
N. Rough-winged Swallow	0.33	0.31
Pied-billed Grebe	0.17	0.36
Purple Martin	0.40	0.43
Red-winged Blackbird	1.00	1.00
Sora	0.40	0.45
Song Sparrow	0.87	0.90
Swamp Sparrow	0.70	0.80
Tree Swallow	0.97	0.94
Virginia Rail	0.67	0.66
Willow Flycatcher	0.40	0.39
Yellow Warbler	0.70	0.80

* - values in parentheses are number of routes surveyed across the seven year period.

Table 3. Comparisons of species abundances for Lake Ontario and non-Lake Ontario coastal MMP routes averaged between 1995 and 2001. For each species and among all species, Least Square (LS) means are presented to show relative differences between Lake Ontario and non-Lake Ontario species abundance indices

	Lake Ontario LS mean	non-Lake Ontario LS mean	X^2	P - value
Bank Swallow	2.03	1.41	7.15	0.008
Barn Swallow	1.40	1.82	2.95	0.086
Canada Goose	1.22	1.23	0.00	0.970
Chimney Swift	-0.16	-0.35	0.10	0.750
Common Grackle	1.96	0.58	19.17	< 0.001
Common Yellowthroat	0.55	1.55	8.77	0.003
Eastern Kingbird	-0.20	0.14	0.39	0.533
Mallard	1.13	0.55	2.65	0.104
Marsh Wren	1.49	1.65	0.40	0.525
Moorhen/Coot	0.71	1.99	18.14	< 0.001
N. Rough-winged Swallow	-0.09	-0.02	0.02	0.901
Red-winged Blackbird	3.02	3.08	0.20	0.656
Sora	-0.02	-0.03	0.00	0.985
Song Sparrow	0.99	0.97	0.01	0.943
Swamp Sparrow	1.86	1.74	0.30	0.586
Tree Swallow	2.07	2.98	33.06	< 0.001
Virginia Rail	0.82	0.59	0.35	0.550
Yellow Warbler	1.36	1.48	0.21	0.650
All species	1.46	1.65	11.93	< 0.001

Table 4. Pearson's product-moment correlation coefficients between annual marsh bird abundance indices and mean annual basin water levels (averaged for May, June and July) for coastal MMP routes between 1995 and 2001

	Ontario*	Basin-wide
Alder Flycatcher	——	-0.32 (0.48)
American Bittern	——	0.66 (0.11)
Amercian Coot	——	0.72 (0.07)
Bank Swallow	-0.17 (0.72)	-0.01 (0.97)
Barn Swallow	-0.01 (0.98)	-0.61 (0.15)
Black Tern	——	0.43 (0.33)
Blue-winged Teal	——	0.49 (0.27)
Canada Goose	0.02 (0.97)	0.17 (0.71)
Chimney Swift	-0.47 (0.29)	-0.26 (0.57)
Cliff Swallow	——	-0.35 (0.44)
Common Grackle	0.29 (0.53)	0.37 (0.42)
Common Moorhen	-0.02 (0.97)	0.15 (0.75)
Common Yellowthroat	-0.57 (0.18)	-0.57 (0.18)
Eastern Kingbird	-0.48 (0.27)	-0.06 (0.89)
Forster's Tern	——	0.92 (0.004)
Least Bittern	——	0.93 (0.002)
Mallard	-0.25 (0.58)	-0.13 (0.79)
Marsh Wren	0.56 (0.19)	0.80 (0.03)
Moorhen/Coot	0.17 (0.72)	0.59 (0.16)
Mute Swan	-0.17 (0.72)	-0.61 (0.14)
N. Rough-winged Swallow	——	-0.29 (0.53)
Pied-billed Grebe	——	0.71 (0.07)
Purple Martin	——	0.37 (0.41)
Red-winged Blackbird	0.32 (0.48)	0.30 (0.51)
Sora	0.26 (0.57)	0.85 (0.01)
Song Sparrow	0.13 (0.79)	-0.50 (0.25)
Swamp Sparrow	-0.32 (0.48)	0.18 (0.70)
Tree Swallow	-0.04 (0.93)	0.26 (0.57)
Virginia Rail	0.58 (0.17)	0.53 (0.22)
Willow Flycatcher	-0.44 (0.32)	-0.45 (0.31)
Yellow Warbler	0.13 (0.78)	-0.32 (0.48)

* - values in parentheses are p-values for each species-lake level indices correlations

Table 5. Sign agreements between year-to-year directional change in annual abundance indices of select marsh birds and year-to-year change in annual Great Lakes water levels (averaged between May, June and July) for Great Lakes basin-wide coastal MMP routes between 1995 and 2001. See text for further details of how values were assigned.

	1995-1996	1996-1997	1997-1998	1998-1999	1999-2000	2000-2001
Marsh Nesters						
American Bittern	-	+	-	+	+	+
Black Tern	-	-	+	+	+	-
Common Moorhen	-	-	-	+	+	-
Forster's Tern	+	+	+	+	-	-
Least Bittern	+	+	-	+	+	+
Marsh Wren	-	+	-	+	-	+
Pied-billed Grebe	+	-	-	+	-	+
Sora	-	+	+	+	-	-
Virginia Rail	-	+	-	+	-	+
Edge Species						
Common Yellowthroat	+	-	-	-	+	+
Eastern Kingbird	+	-	-	+	+	-
Willow Flycatcher	+	+	-	-	-	-
Yellow Warbler	+	-	+	-	-	-
Aerial Foragers						
Bank Swallow	-	+	+	-	-	-
Barn Swallow	+	-	-	+	+	-
Chimney Swift	-	+	+	-	+	+
N. Rough-winged Swallow	-	-	+	-	-	+
Tree Swallow	-	-	-	+	+	+
Other						
Canada Goose	+	-	-	+	+	-
Common Grackle	-	+	-	+	-	+
Mallard	-	-	-	+	-	-
Red-winged Blackbird	+	-	+	-	+	+
Song Sparrow	-	+	-	+	+	+
Swamp Sparrow	+	-	-	+	+	+

Table 6. Annual marsh bird abundance indices and trends at coastal MMP routes throughout the Great Lakes basin, 1995-2001.

	Annual Abundance Indices [3]								Trend	Lower	Upper	
Species Routes	**1995 (64)**	**1996 (64)**	**1997 (69)**	**1998 (60)**	**1999 (62)**	**2000 (53)**	**2001 (48)**	***P*[1]**	**(%/yr)**	**95% C.I.**	**95% C.I.**	***P*[2]**
ALFL	0.000	0.230	0.274	0.257	0.602	0.583	0.222	0.3681	18.6	-8.5	53.7	0.2087
AMBI	0.261	0.201	1.076	1.365	0.230	0.618	0.444	**0.0073****	-3.9	-20.0	15.6	0.6596
AMCO	0.708	10.39	5.573	16.18	0.474	1.857	0.400	**0.0010****	-16.7	-34.7	6.3	0.1882
BANS	12.55	2.985	5.833	3.617	5.784	1.521	4.880	**0.0003****	-10.8	-21.3	1.2	0.0543
BARS	5.398	5.508	4.701	5.725	5.264	5.485	7.079	0.6232	3.4	-2.9	10.1	0.2951
BLTE	11.25	11.17	6.162	5.095	2.004	2.386	3.143	**0.0000****	-24.7	-31.7	-17.1	**0.0000****
BWTE	1.273	0.976	0.879	1.535	0.110	0.744	0.917	0.3071	-6.9	-20.1	8.5	0.3861
CAGO	1.449	3.546	3.286	5.449	2.314	4.161	4.391	0.1232	1.3	-4.6	27.6	0.1705
CHSW	0.597	0.592	0.722	0.656	1.016	1.042	0.529	0.5030	9.6	-4.6	26.0	0.2098
CLSW	0.272	0.078	0.368	1.116	0.899	1.426	0.750	0.3385	33.6	0.3	78.1	0.0850
COGR	2.061	1.409	2.206	12.15	3.700	2.127	2.028	**0.0000****	0.0	-11.9	13.5	0.9971
COMO	2.338	1.527	1.267	1.625	0.722	0.802	1.727	**0.0178***	-9.9	-18.7	-0.1	**0.0401***
COYE	2.970	3.937	3.157	3.705	3.971	4.484	4.086	0.0919	5.3	1.0	9.8	**0.0155***
EAKI	0.769	1.176	0.941	1.364	0.988	1.100	1.333	0.6722	5.0	-5.2	16.2	0.3502
FOTE	0.782	1.375	2.729	1.228	0.265	0.202	0.333	**0.0418***	-18.2	-38.2	8.1	0.1123
LEBI	0.637	0.708	0.865	1.079	0.396	0.395	0.273	0.0698	-13.0	-24.3	0.0	**0.0487***
MALL	2.651	1.842	1.670	3.256	2.159	1.862	2.806	0.1392	2.3	-7.1	12.7	0.6393
MAWR	5.407	4.815	5.450	6.414	4.641	4.506	3.657	**0.0027****	-4.5	-8.1	-0.7	**0.0197***
MOOT	7.368	6.622	4.884	6.780	1.951	3.692	3.536	**0.0005****	-13.1	-20.3	-5.3	**0.0009****
MUSW	0.739	0.748	0.786	0.654	0.987	0.932	0.800	0.9915	3.5	-11.7	21.4	0.6782
NRWS	1.210	0.899	0.304	1.159	1.802	0.784	0.500	**0.0324***	2.8	-14.0	22.8	0.7650
PBGR	3.636	4.305	2.716	3.792	1.643	1.156	0.667	**0.0001****	-23.0	-31.6	-13.4	**0.0000****
PUMA	4.922	3.054	5.178	2.876	2.879	2.310	3.750	0.2936	-7.0	-18.1	5.5	0.2442
RWBL	22.02	27.30	20.93	19.33	18.58	20.52	19.23	**0.0015****	-4.3	-7.1	-1.3	**0.0044****
SORA	0.779	0.710	1.963	1.320	0.786	0.344	0.565	**0.0001****	-14.5	-24.1	-3.8	**0.0078****
SOSP	3.272	2.286	2.399	2.373	2.137	3.524	3.167	**0.0005****	3.0	-1.6	7.8	0.1855
SWSP	5.890	6.156	5.416	5.842	5.328	6.484	5.057	0.3683	-2.0	-5.7	1.9	0.3115
TRES	24.09	17.75	14.65	15.92	13.24	14.26	11.44	**0.0164***	-9.8	-15.1	-4.2	**0.0008****
VIRA	2.694	1.588	2.093	2.539	1.778	1.720	1.276	**0.0212***	-7.2	-13.4	-0.6	**0.0310***
WIFL	0.930	1.186	1.272	1.357	1.428	1.334	1.778	0.6989	8.2	-1.0	18.3	0.0877
YWAR	3.686	5.145	3.947	3.877	4.745	4.354	4.330	0.1339	1.3	-2.5	5.2	0.5003

***P*[1]** - probability that significant year-to-year variation in population index occurred.

***P*[2]** - probability that population index trend between 1995-2001 differed from zero.

[3] - maximum number of routes surveyed enclosed in parentheses

* - statistically significant at $P < 0.05$.

** - statistically significant at $P < 0.01$.

Table 7. Sign agreements between year-to-year directional change in annual abundance indices of select marsh birds and year-to-year change in annual Lake Ontario water levels (averaged between May, June and July) for Lake Ontario coastal MMP routes between 1995 and 2001. See text for further details of how values were assigned.

	1995-1996	1996-1997	1997-1998	1998-1999	1999-2000	2000-2001
Marsh Nesters						
Common Moorhen	-	+	-	+	-	-
Marsh Wren	-	+	-	+	+	+
Moorhen/Coot	-	+	-	+	-	-
Sora	-	+	+	+	+	+
Virginia Rail	-	+	-	+	+	+
Edge Species						
Common Yellowthroat	+	-	-	-	-	-
Eastern Kingbird	+	-	+	-	-	-
Willow Flycatcher	+	-	-	-	-	-
Yellow Warbler	+	-	-	+	-	+
Aerial Foragers						
Bank Swallow	-	+	+	-	-	-
Barn Swallow	-	+	-	+	-	-
Chimney Swift	-	+	+	-	+	-
N. Rough-winged Swallow	-	+	-	+	-	-
Tree Swallow	+	+	+	-	-	-
Other						
Canada Goose	+	+	-	+	-	-
Common Grackle	-	+	-	+	-	+
Mallard	-	+	-	+	-	-
Red-winged Blackbird	+	+	+	-	-	+
Song Sparrow	-	-	+	+	+	+
Swamp Sparrow	-	+	-	-	+	+

Table 8. Annual marsh bird abundance indices and trends at coastal MMP routes within the Lake Ontario basin, 1995-2001.

	Annual Abundance Indices [3]								Trend	Lower	Upper	
Species Routes	**1995 (26)**	**1996 (25)**	**1997 (25)**	**1998 (22)**	**1999 (20)**	**2000 (15)**	**2001 (12)**	***P*** [1]	**(%/yr)**	**95% C.I.**	**95% C.I.**	***P*** [2]
BANS	15.61	2.318	14.27	5.985	6.512	3.112	5.375	**0.0002****	-10.8	-23.8	4.4	0.1104
BARS	4.471	3.014	4.169	4.966	3.615	3.606	4.545	0.7299	0.5	-9.2	11.2	0.9251
CAGO	0.817	1.850	3.697	4.406	2.471	1.800	8.800	0.1482	32.1	0.9	72.8	**0.0274***
CHSW	0.796	0.631	0.764	0.475	1.057	1.101	1.143	0.6748	9.7	-7.3	29.7	0.3273
COGR	3.336	1.104	3.226	31.35	4.754	3.190	2.909	**0.0000****	-2.2	-22.0	22.8	0.7761
COMO	1.396	0.806	1.420	1.524	1.109	0.779	1.125	0.5209	-3.2	-13.8	8.6	0.5757
COYE	1.523	1.548	1.441	1.722	2.189	1.855	1.909	0.7674	6.6	-2.4	16.4	0.1597
EAKI	0.581	1.163	0.700	0.500	1.215	0.409	1.143	0.5154	3.4	-14.6	25.2	0.7208
MALL	3.577	1.241	3.066	4.342	3.496	2.717	3.273	0.3674	4.1	-11.1	22.0	0.6018
MAWR	3.926	3.158	5.957	6.005	4.156	4.777	3.200	0.0704	0.4	-7.2	8.7	0.9155
MOOT	2.231	1.639	2.479	2.875	1.859	1.330	1.800	0.5234	-4.2	-14.6	7.6	0.4662
MUSW	0.469	0.690	0.762	0.443	1.035	0.952	0.667	0.7851	8.9	-9.6	31.2	0.3794
NRWS	1.367	0.170	0.528	2.179	0.867	0.286	1.000	**0.0147***	0.7	-21.3	28.9	0.9437
RWBL	16.22	22.23	23.66	19.00	22.98	21.45	18.50	0.2559	1.0	-4.2	6.6	0.6930
SORA	1.234	0.221	1.987	0.981	0.779	0.974	0.667	0.8860	-2.8	-20.5	18.8	0.7809
SOSP	2.896	2.699	2.622	2.349	2.289	3.109	2.917	0.8126	0.2	-6.2	7.0	0.9576
SWSP	6.718	4.681	5.359	5.807	6.471	8.119	7.667	0.2612	6.3	-0.5	13.5	0.0726
TRES	6.034	6.693	10.22	5.730	9.077	8.210	9.417	0.3310	5.9	-5.5	18.6	0.3096
VIRA	2.352	1.412	2.549	3.623	1.270	2.749	1.889	**0.0116***	0.5	-9.4	11.4	0.9259
WIFL	1.977	2.360	2.004	2.660	3.723	2.313	2.000	0.7506	2.7	-9.3	16.4	0.6842
YWAR	3.922	4.599	3.622	4.141	4.063	3.797	3.091	0.7731	-2.7	-8.3	3.2	0.3652

P [1] - probability that significant year-to-year variation in population index occurred.

P [2] - probability that population index trend between 1995-2001 differed from zero.

[3] - maximum number of routes surveyed enclosed in parentheses

* - statistically significant at $P < 0.05$.

** - statistically significant at $P < 0.01$.

FIGURES

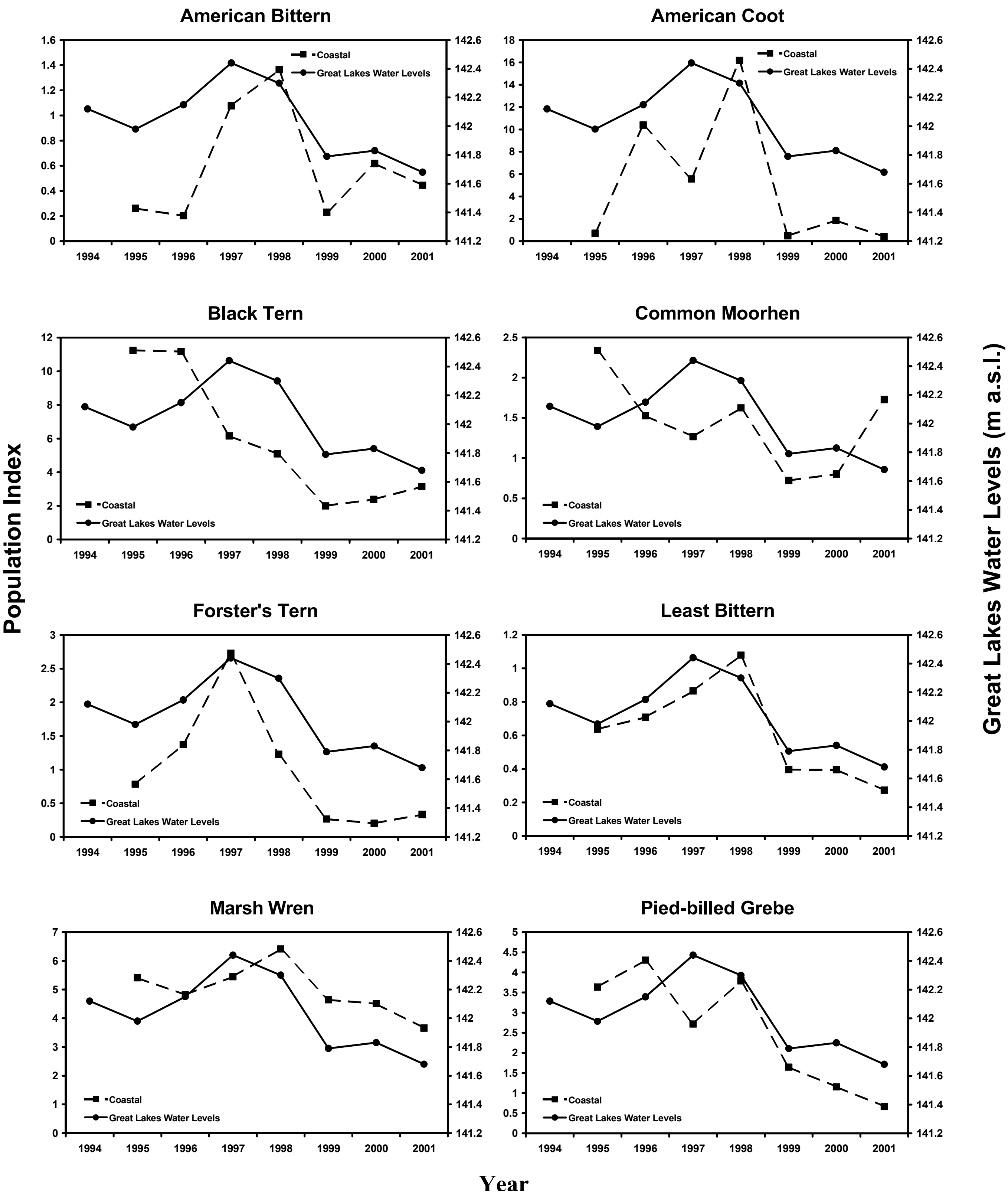

Figure 1. Annual abundance indices of select marsh bird species at coastal MMP routes across the Great Lakes (Lakes Michigan-Huron, Erie and Ontario combined) compared to mean annual water levels of these lakes (May, June and July), 1994-2001. Population indices are based on counts of individuals inside MMP boundaries and are defined relative to 2001 values. 1994 water levels are shown to maximize evaluation of potential lag effects.

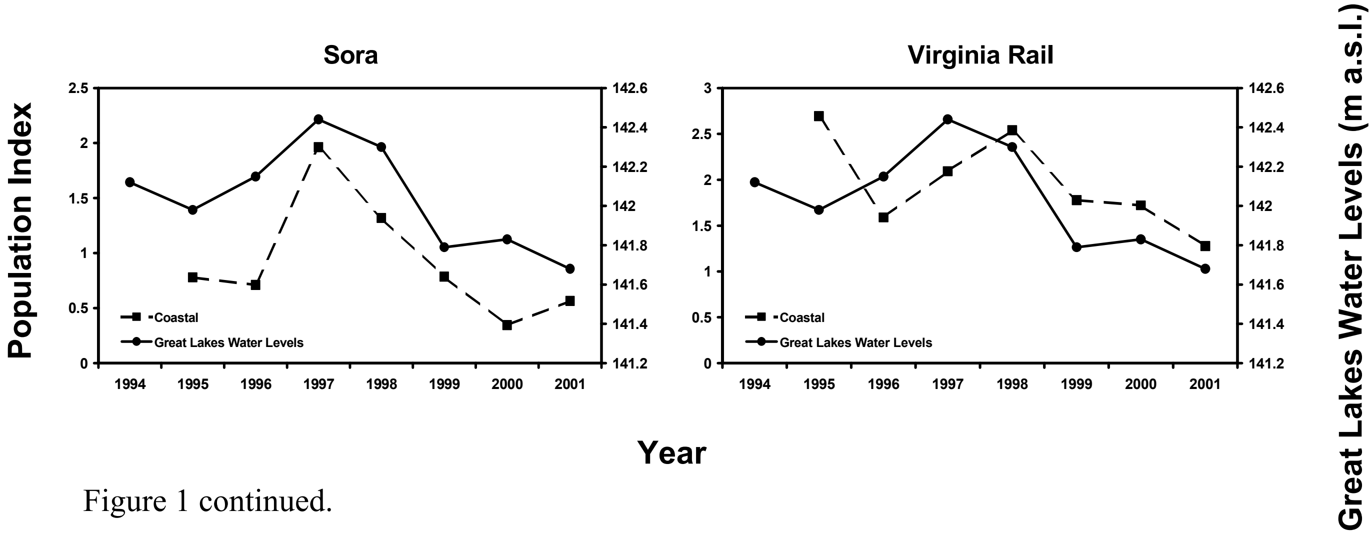

Figure 1 continued.

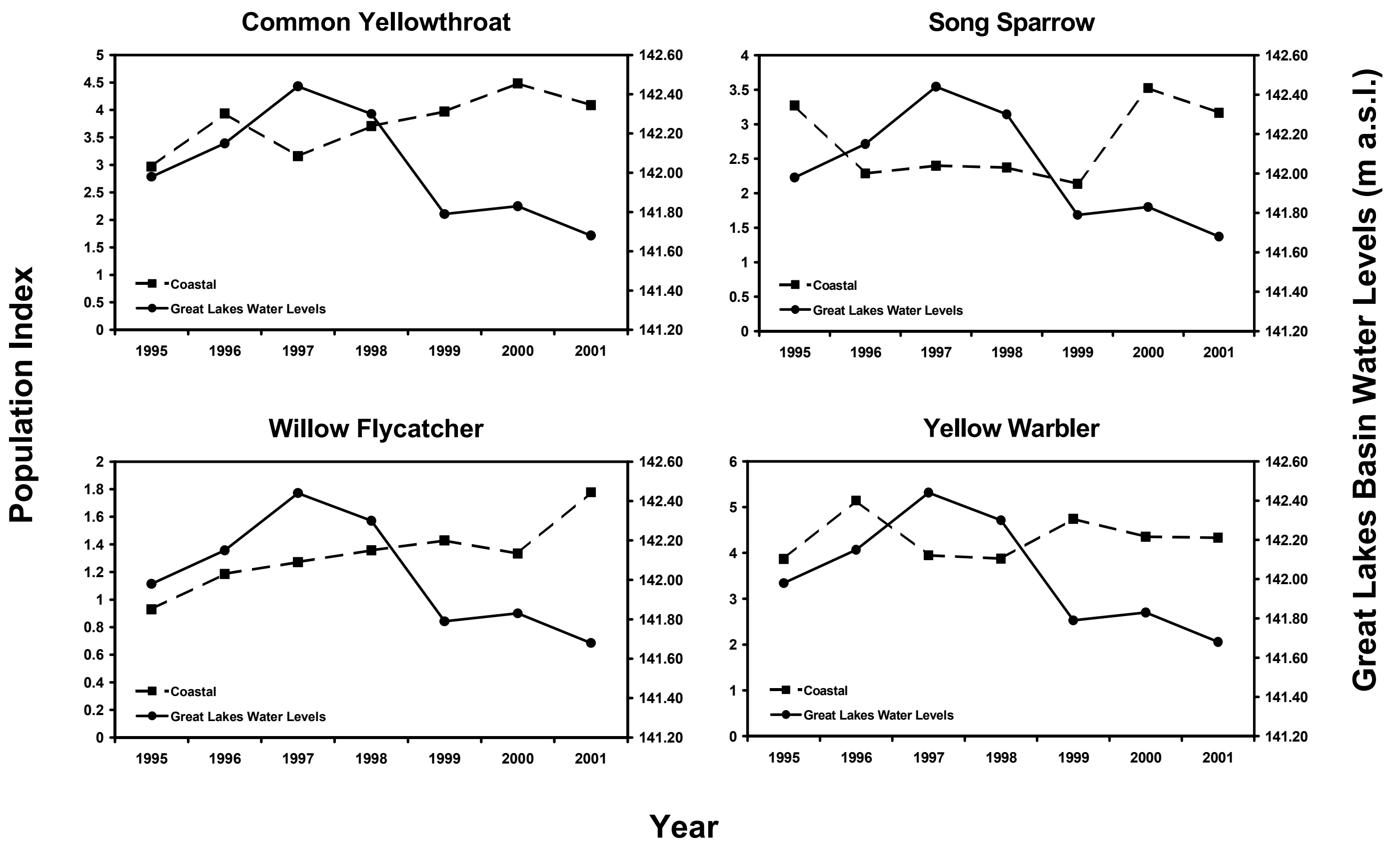

Figure 2. Annual abundance indices of select marsh bird species at coastal MMP routes across the Great Lakes (Lakes Michigan-Huron, Erie and Ontario combined) compared to mean annual water levels of these lakes (May, June, and July), 1995-2001. Population indices are based on counts of individuals inside MMP boundaries and are defined relative to 2001 values.

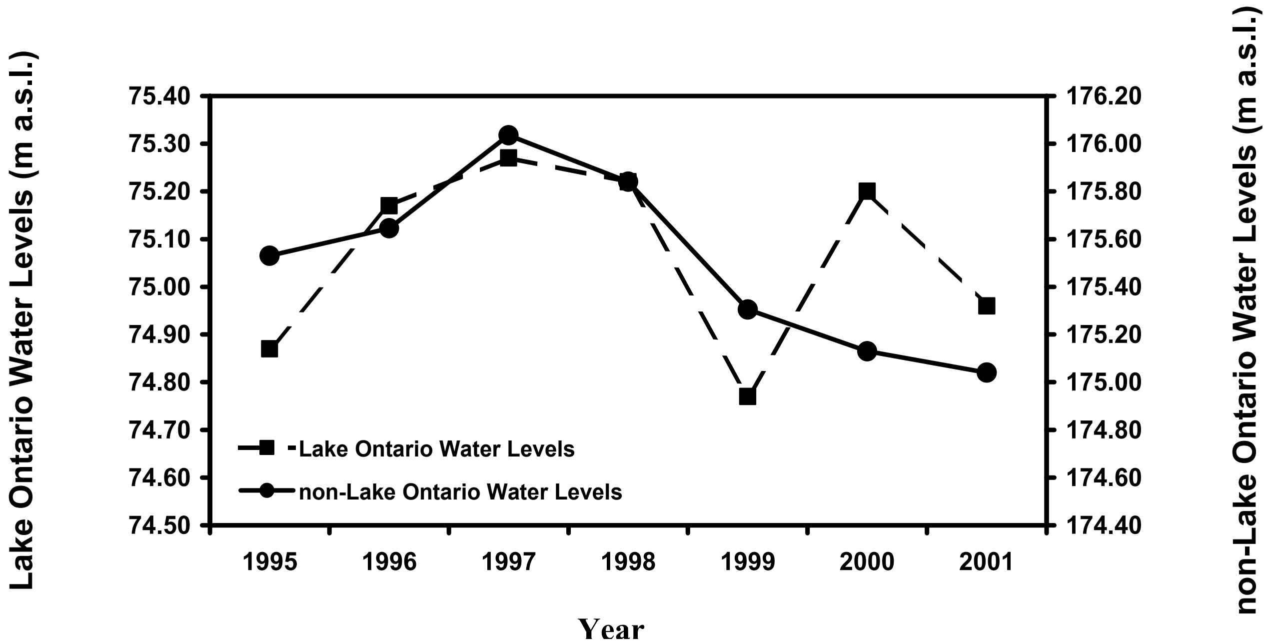

Figure 3. Annual indices of Lake Ontario and non-Lake Ontario (Lakes Michigan-Huron and Erie combined) water levels averaged between May, June and July, 1995-2001.

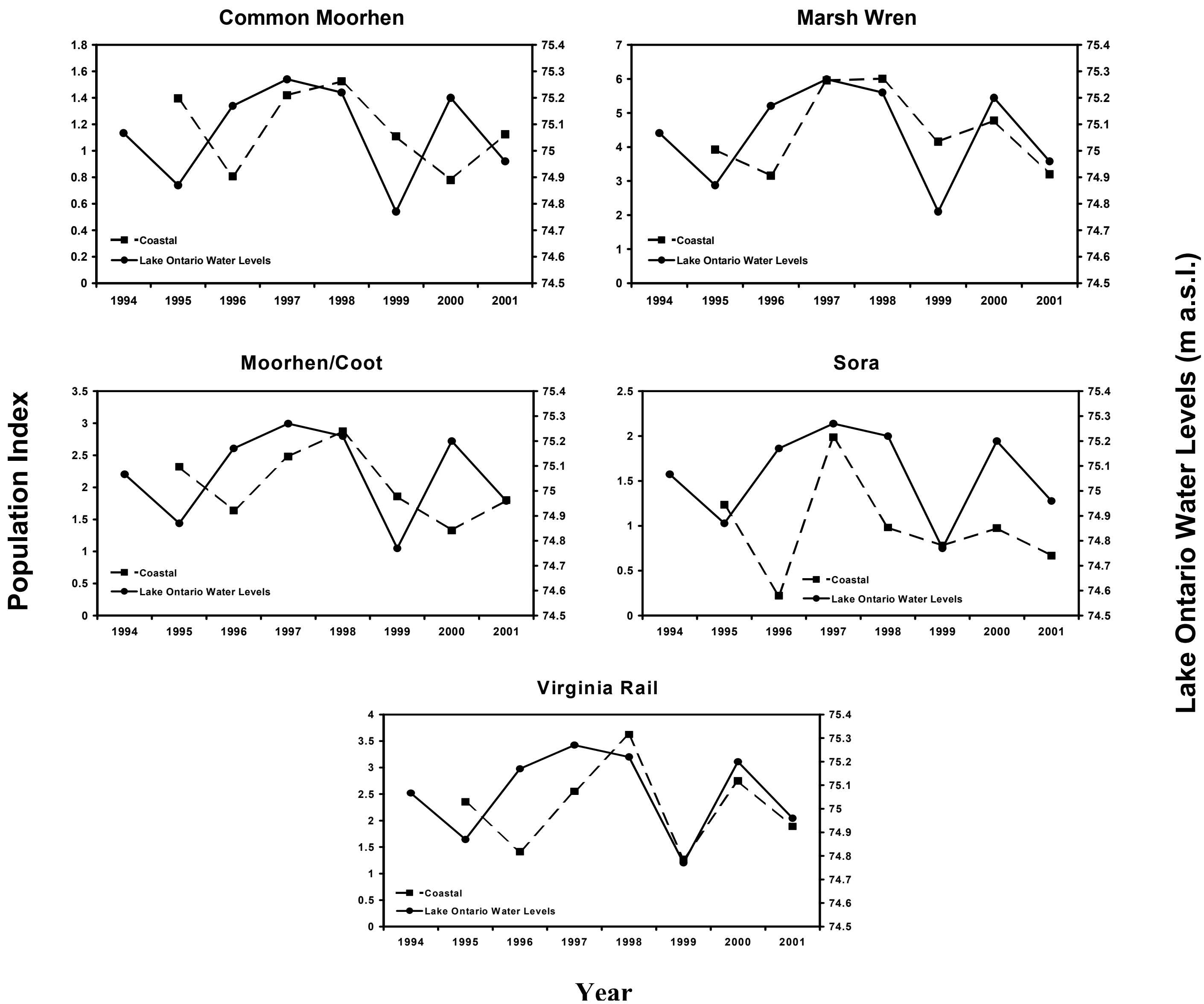

Figure 4. Annual abundance indices of select marsh bird species at Lake Ontario coastal MMP routes compared to mean Lake Ontario water levels (May, June and July), 1994-2001. Population indices are based on counts of individuals inside MMP boundaries and are defined relative to 2001 values.

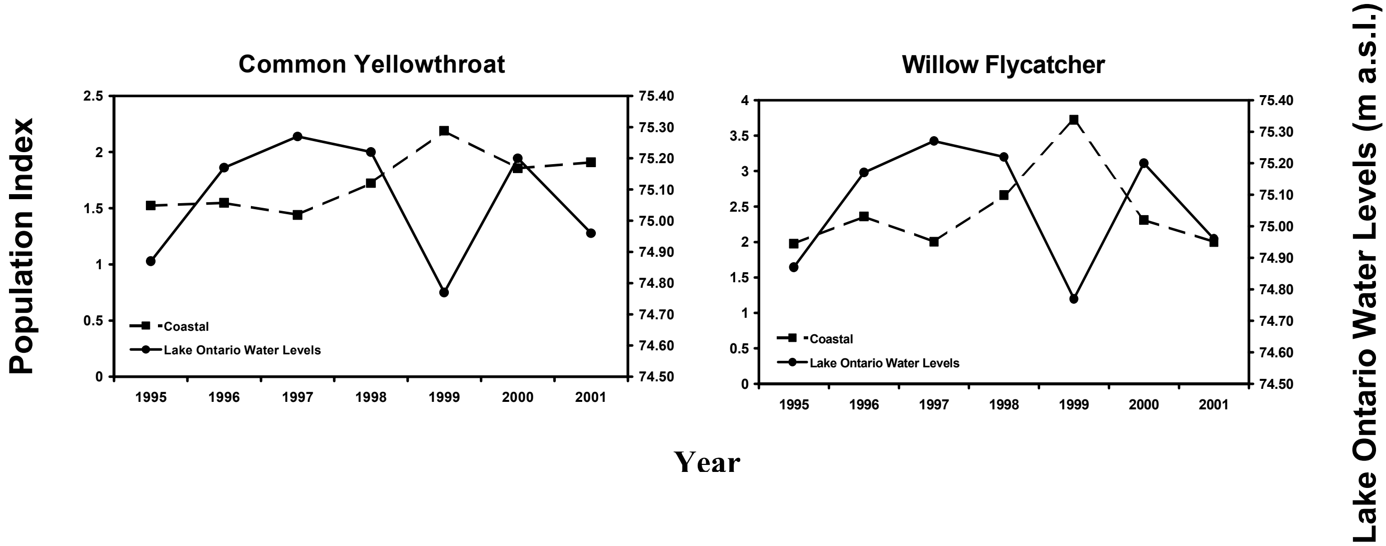

Figure 5. Annual abundance indices of select marsh bird species at Lake Ontario coastal MMP routes compared to mean Lake Ontario water levels (May, June and July), 1994-2001. Population indices are based on counts of individuals inside MMP boundaries and are defined relative to 2001 values.

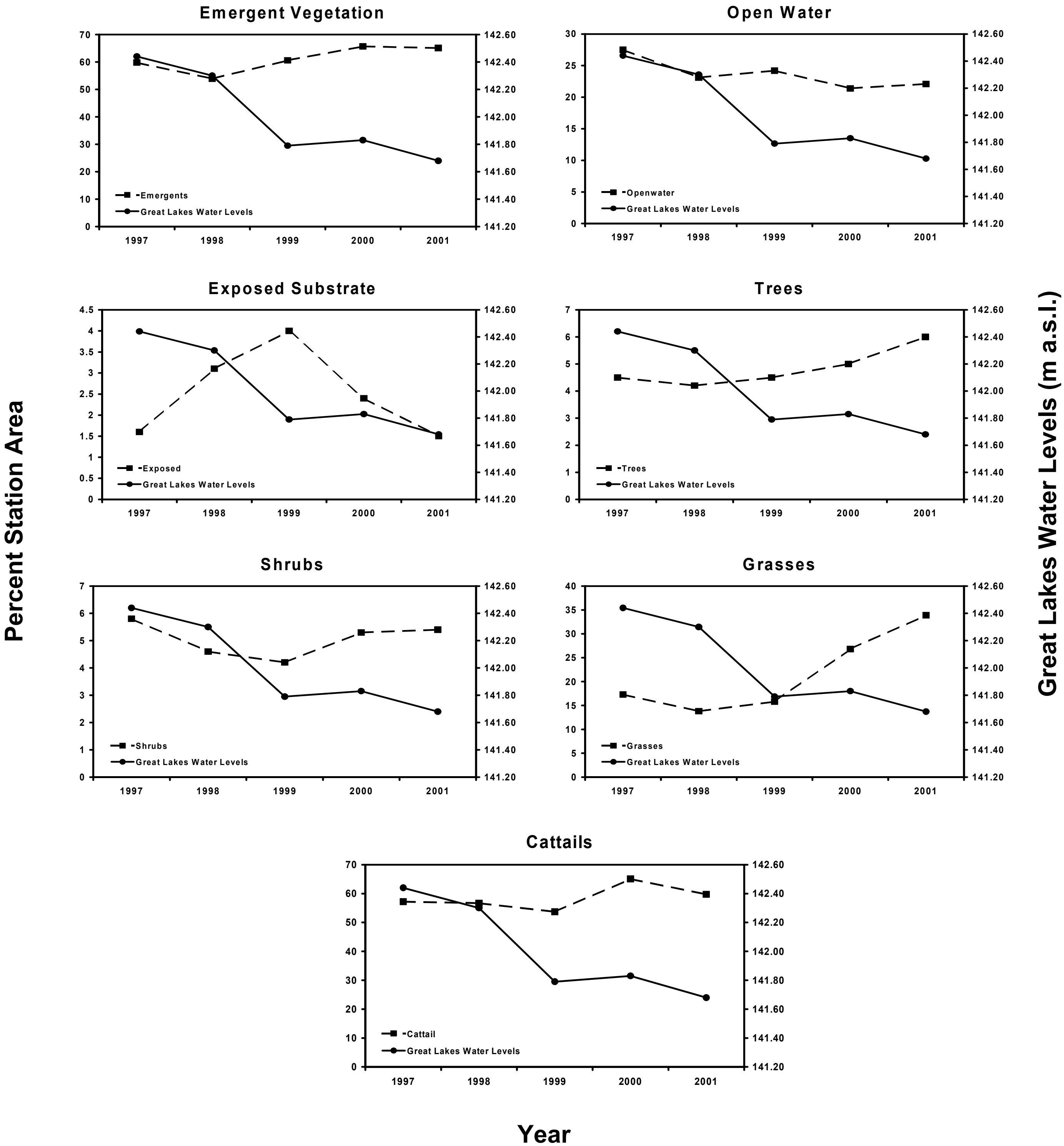

Figure 6. Annual indices of marsh habitat cover type at coastal Great Lakes basin-wide MMP routes compared to mean Great Lakes basin water levels (May, June and July), 1997-2001. Indices are proportion of survey station occupied by habitat cover types. Habitat data were collected in this manner beginning in 1997, therefore data are not available for 1995 or 1996.

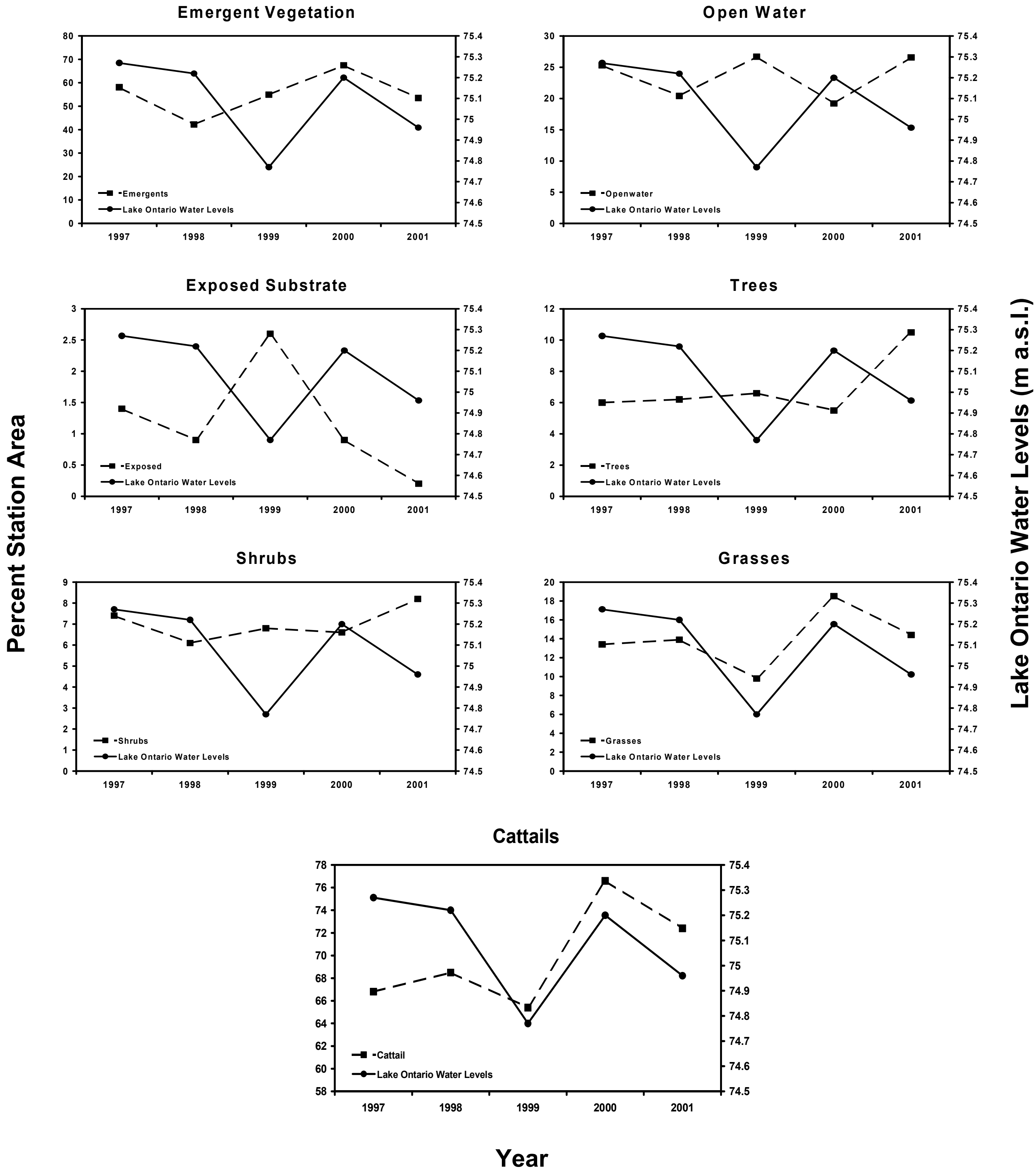

Figure 7. Annual indices of marsh habitat cover type at coastal Lake Ontario MMP routes compared to mean Lake Ontario water levels (May, June and July), 1997-2001. Indices are proportion of survey station occupied by habitat cover types. Habitat data were collected in this manner beginning in 1997, therefore data are not available for 1995 or 1996.

APPENDICES

Appendix 1

Species Name	Latin
American Bittern	*Botaurus lentiginosus*
American Coot	*Fulica americana*
Black Tern	*Chilidonias niger*
Blue-winged Teal	*Anas discors*
Common Moorhen	*Gallinula chloropus*
Common Snipe	*Capella gallinago*
Least Bittern	*Ixobrychus exilis*
Marsh Wren	*Cistothorus palustris*
Undifferentiated moorhen/coot	
Pied-billed Grebe	*Podilymbus podiceps*
Sora	*Porzana carolina*
Virginia Rail	*Rallus limicola*