Temporal Relations Between Marsh Bird and Amphibian Annual Population Indices and Great Lakes Water Levels: A Case Study from the Marsh Monitoring Program

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MARSH MONITORING PROGRAM

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EXECUTIVE SUMMARY

Wetland loss in some areas of the Great Lakes basin has exceeded 80% since European settlement (Snell 1987, Dahl 1990). Marshes are one of the most ubiquitous and important wetland types (Weller 1981). Marshes occur at both isolated inland and exposed lakeshore contexts throughout much of the Great Lakes basin. Marshes support the highest diversity and biomass of floral and faunal species than any other wetland type (Weller 1978, Weller 1981), and are perhaps the most important natural mechanism for maintaining water quality to support life, including human life.

Many birds and amphibians frequent and rely heavily on marshes to support their annual life cycle (Weller 1999). With continual degradation and loss of marsh habitat, there has long been a recognized need to monitor populations of avian and amphibian species that rely on these sensitive wetland environments. In 1995, a bi-national Great Lakes basin-wide effort was launched in a multi-partner effort to establish the Marsh Monitoring Program, a program whose primary goal is to monitor populations of marshbirds and calling amphibians across wetlands in this globally unique and water-rich region. Since 1995, through a unique partnership between Bird Studies Canada, United States Environmental Protection Agency, Environment Canada, Great Lakes United, the Great Lakes Protection Fund, and hundreds of citizen scientists, the Marsh Monitoring Program has succeeded in capturing important and meaningful population and wetland habitat information from hundreds of wetlands throughout the Great Lakes basin.

In 2000, the Marsh Monitoring Program released its first five-year report (Weeber and Valliantos 2000) summarizing information it has gained during its first five years of operation. During this time (and including 2000), the Great Lakes have undergone a dramatic period of water level fluctuation, with the last three years (1997-2000) having undergone relatively dramatic rates of water level decreases. This report provides updated information about numerous MMP avian and amphibian species-specific population indices and trends within marsh habitat and how patterns of index changes relate to those of annual Great Lakes water level, at both lake-specific and basin-wide scales. Relations between annual indices of several avian and amphibian species and those of water levels elucidate how long-term hydrologic dynamics of the Great Lakes may influence bird and amphibian populations occupying and breeding in marshes throughout the basin.

Temporal patterns of many species' annual indices, as measured by MMP surveyors, in many instances have been closely related (positively or negatively) to changes in mean annual water levels of Great Lakes. Unique patterns of water level change in Lake Ontario offered an opportunity to examine how species' index responses to water level changes differ from those of other Great Lakes that are not under significant anthropogenic operating regimes. Results herein provide an impetus to continue studying these relations and demonstrate a need for additional research to complement and increase our understanding of marshes, their avian and amphibian occupants, and sources of marsh ecosystem health and integrity. The success of the Marsh Monitoring Program demonstrates the value in multi-partner ventures and the need to continue building and

strengthening the current partnership that supports this invaluable wetland conservation initiative.

INTRODUCTION

The Marsh Monitoring Program (MMP) has been monitoring trends in marsh bird and calling amphibian population indices for six years. As such, this report summarizes results of data collected throughout the Great Lakes basin from 1995-2000 by describing trends in relative abundance and occurrence of marsh birds and calling amphibians (frogs and toads). Many of the marsh bird and amphibian species that are monitored by MMP volunteer participants are recognized as important faunal indicators of wetland health and condition. Efforts to evaluate the relative status of marsh birds and amphibians across the Great Lakes basin are essential to understanding how well marshes within and across the basin are functioning to maintain ecological integrity. Marshes that support abundances of a diversity of wetland dependent species are considered to be healthy and functioning at an optimal state.

MMP data are being used to assist efforts to conserve and rehabilitate wetlands for the benefit of wetland-dependent wildlife and people. Local citizen groups use MMP data to better understand and maintain wetlands in their locales. Regional government use MMP data for planning, and MMP data contribute to management plans at the individual lake basin scale and to assess wetland health at the Great Lakes basin-wide scale (e.g. State of the Lakes Ecosystem Conference).

In this report, both basin-wide and within-basin summaries are provided for marsh birds and amphibians. Trends are presented for up to 9 of the 11 amphibian species encountered within the basin, and trends are presented for up to 34 marsh bird species, several of which have undergone significant increases or declines in annual population indices. Because the MMP is still expanding its geographical coverage, and because sample sizes sometimes prevent derivation of reliable trend data, summaries for certain species in some basins are not provided. Also, routes are non-random, however, we believe that representation is adequate to conduct the analysis. Although species summaries are not provided for Lake Superior at the basin level due to lack of route coverage, data from this basin contributed to basin-wide analysis of marsh bird and amphibian trends but will be removed for future analysis given the limited number of routes surveyed.

Variation in annual population indices result partly from sampling error, and presumably partly from natural extrinsic environmental factors. Assessing relations between such factors and variation in annual indices is possible if data are available for any given suspected variable. Thus, also included in this report is a comparison of Great Lakes basin-wide mean annual water levels with annual indices of marsh bird abundance and amphibian occurrence at both inland (≥ 5 km from any lake shore) and coastal (< 5 km from any lake shore) MMP routes. This distance delineation was used for simplicity and because precise locations of MMP route are currently poorly documented. Using this coarse measure most certainly resulted in misidentifying some near-shore isolated marshes and diked and managed coastal wetlands as coastal wetlands fully subject to water level influences. However, such wetlands are most likely to be more influenced by water levels (i.e., ground water connection and 'spill-over' effect) than those at greater distances from lake shorelines.

Composition and type of marsh habitat are associated with marsh water levels (Weller 1981). Thus, relative abundance and occurrence of marsh bird and amphibian species that are largely dependent on marshes and specific marsh habitat types should be associated with mean annual water levels in marshes; mean annual water levels of marshes within the Great Lakes basin presumably vary according to their influence by Great Lakes water levels. To some degree, changes in water levels of Great Lakes are influenced by precipitation received throughout the Great Lakes drainage basin, which validates comparing species indices at both coastal and inland marsh routes with changes in Great Lakes water levels.

This paper reports on general trends of several marsh dependent bird and calling amphibian (frogs and toads) species that occur with some regularity throughout the Great Lakes basin. These trends are assessed extensively across the entire Great Lakes basin, and less extensively at the individual lake basin level. Following this, species trends are assessed separately at coastal and inland monitoring route category levels, and annual indices of birds and amphibians within inland and coastal route locations are compared with Great Lakes water level annual indices to examine how water level variation relates to these species' annual population changes.

METHODS

Marsh Monitoring Program data are gathered by dedicated volunteer naturalists from Canada and the United States who contribute their valuable time to monitor abundance and occurrence of marsh birds and calling amphibians, respectively, throughout marshes of the Great Lakes basin. Key elements of MMP sampling methodology are reported herein, and additional detailed information about MMP protocol and methodology are reported in Weeber and Valliantos (2000).

Upon registering with the MMP, volunteers receive training kits that include detailed protocol instructions, field and summary data forms, instructional cassette tapes with examples of songs and calls of common marsh birds and of calling amphibians, and a broadcast tape used to elicit calls from secretive wetland bird species. MMP volunteers establish survey routes in minimum 1 ha marshes of their choice, so that route distribution is non-random. Each route consists of from one to eight monitoring stations, the number at each route depending on a variety of factors from time available to available marsh habitat. Each marsh bird survey station must be separated by at least 250 metres (275 yards) to minimize duplicate counts of individuals. Because judging distances and locations of calling amphibians can be difficult, stations surveyed for amphibians must be separated by at least 500 metres (550 yards).

An MMP station is defined as a 100-metre (110 yard) radius semicircle with more than 50% of the semicircle area covered by marsh habitat. Counts are conducted from a focal point at each station – the surveyor stands at the midpoint of the 200-metre (220 yard) base of the semi-circle and faces the arc of the station perimeter. Each focal point is permanently marked with a stake and metal tag to facilitate relocation in subsequent years.

Bird Survey Protocol

Survey visits for birds are conducted twice each year, at least 10 days apart, between May 20 and July 5. Visits must begin after 6:00 p.m. and are to be conducted in good survey conditions (i.e., warm, dry weather with little wind). A 5-minute broadcast tape is played at each station during the first half of each 10-minute survey visit. The broadcast tape helps elicit calls from several normally elusive bird species and contains calls of Virginia Rail, Sora, Least Bittern, Common Moorhen, American Coot and Pied-billed Grebe. During the count period, observers record all birds heard and/or seen within the survey station area and record their observations onto a field map and data form. Aerial foragers are also counted and are defined as those birds foraging within the station area to a height of 100 metres (110 yards). Bird species flying through or detected outside the station are also tallied separately.

Amphibian Survey Protocol

Amphibians surveyed by the MMP volunteer participants are those calling frogs and toads that typically depend on marsh habitat during spring and summer breeding. Males of several frog and toad species elicit distinctive calls. MMP routes are surveyed for these calling amphibians on three nights each year, with at least 15 days between visits. Because peak amphibian calling periods are closely associated with temperature and precipitation rather than date, visits are scheduled to occur three separate evenings according to night air temperatures of 5°C (41° F), 10° C (50° F), and 17° C (63° F), respectively.

Amphibian surveys begin one-half hour after sunset and end before midnight. Visits are conducted on evenings with little wind, preferably in moist conditions with one of the above corresponding temperatures. During three-minute survey visits, observers assign a Call Level Code to each species detected; for two of these levels, estimated numbers of individuals are recorded. Call Level Code 1 is assigned if calls do not overlap and calling individuals can be discretely counted. Call Level Code 2 is assigned if calls of individuals sometimes overlap, but numbers of individuals can still reasonably be detected. Call Level Code 3 is assigned is so many individuals of a species are calling that overlap among calls seems continuous; a count estimate is impossible for Code 3 and is not required by the protocol.

Starting in 1999, MMP participants were asked to use their best judgement to distinguish whether each species detected was calling from inside the station boundary only, from outside the station boundary only, or from both inside and outside. Combined with habitat information provided for each station by MMP surveyors, this modification will provide better information about amphibian habitat associations.

Habitat Assessments

Habitat associations for many species of Great Lakes wetland birds and amphibians are not well known. A good understanding of these relationships is critical to designing effective wetland management and conservation practices. When combined with information about trends in species occurrence or abundance, data quantifying and describing vegetation and other wetland characteristics help to identify those wetland habitats that are at most risk of losing their capacity to support a diversity and abundance and marsh birds and amphibians. Using standard protocol, MMP surveyors conduct an annual assessment of habitat characteristics for each of their MMP stations. Volunteers are encouraged to conduct habitat surveys during mid- to late June, when plants can readily be identified.

Observers provide information about coverage of five general habitat types: herbaceous emergent plants; open water; exposed mud, rock or sand; trees; and shrubs. Percent coverage of the four most dominant types of emergent plants is also recorded, providing more detailed assessment of this important component of wetland habitat. Observers record coverage of floating plants and estimate wetland size and permanency, and adjacent land use. Observers also sketch a map illustrating general habitat characteristics of each station.

Population Trend Analysis

Population indices were derived for each species in each survey year. For marsh birds, population indices were based on counts of individuals inside the MMP station boundary and were defined relative to 2000 values. General models (PROC GENMOD; SAS Institute Inc. 1999) were developed to generate annual parameter estimates (indices) for each marsh bird species. Parameter estimates 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. 1999) to compare deviance of these models to models with no year variable. For each year, 95% confidence limits around each annual index were calculated. Presented in each figure and table herein are estimated annual percent changes (trends) in abundance of each marsh bird species and the associated upper and lower extremes of the 95% confidence limits for each species trend. Because actual counts of marsh birds provide a Poisson distribution of observations, Poisson regression was used to evaluate year-to-year variance of annual indices and overall direction of trends across years.

For calling amphibians, population indices were based on annual proportion of survey stations with each species present and were defined relative to 2000 values. Similarly, general models (PROC GENMOD; SAS Institute Inc. 1999) were developed to generate annual parameter estimates (indices) for each amphibian species. Parameter estimates 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. 1999) to compare deviance of these models to models with no year variable. For each year, 95% confidence limits around each annual index were calculated and both estimated annual percent change (trends) in occurrence of each amphibian species, and the associated upper and lower extremes of the 95% confidence limits for each species trend are presented herein. Because indices were derived based on presence or absence of a given species at a given station, this produced a binomial distribution of observations, thus logistic (or binary) regression was used to evaluate year-to-year variance of annual indices and overall direction of trends in amphibian occurrence across years.

Statistically testing for year-to-year variance of population indices provides knowledge about whether population indices for a given species were similar or different among years, whereas statistically testing for overall magnitude and direction of trends across years evaluates whether temporal trends differed from a slope of zero (i.e., no change). It is important to emphasize that the most meaningful interpretation of results is done by assessing both year-to-year variance in annual indices as well as overall magnitude and direction of trends. For example, a species may have exhibited high year-to-year variance in population indices, yet the overall trend may not have differed from a slope of zero. Similarly, for example, a significant positive or negative trend over time may have occurred for a given species, but such a trend may have been driven by a single year-specific index value having differed considerably from those of all other years combined. In the latter example, significant year-to-year variance in indices may not have occurred, and such a scenario is less meaningful than if both year-to-year variance *and* overall direction of a trend had occurred (i.e., each or most years having contributed to overall increase or decline in trends).

To assess how species population indices have related to changes in Great Lakes water levels, mean annual water levels for each of the Great Lakes since 1995 were derived from the Canadian Hydrographic Service's internet website, Burlington, Ontario. These water level data were measured relative to the 1985 International Great Lakes Datum. Data were pooled across lakes within years to derive basin-wide annual means in water levels for each of these six years. For each species, Spearman's Correlation Coefficients (PROC CORR; SAS Institute Inc. 1999) were used to assess correlations between basin-wide indices of mean annual water levels and species annual indices at both coastal and inland routes. To portray these relations, mean annual population indices for coastal and inland routes, and mean annual water levels of the Great Lakes were plotted together to observe how annual population indices compared with water levels during the six-year monitoring period.

Hydrologically, Lake Huron and Michigan constitute a contiguous water body. Thus, because these lakes share the same hydrologic regimes, they are subject to similar water level changes. Consequently, water level indices and species annual indices were combined for Lakes Huron and Michigan, and for the purposes of comparing species indices with water level indices, results are presented for 'Lake Huron-Michigan' as a contiguous water body.

RESULTS

This report focuses on results of MMP surveys conducted within the Great Lakes basin (Figure 1) and emphasizes results for marsh birds and calling amphibian species believed to be most closely associated with marshes and other wetland and aquatic habitats. Routes are not distributed randomly, however, it is believed that there is adequate representation to conduct these analyses.

Marsh Bird Population Indices

Basin-wide

With only six years of data collected across the Great Lakes basin, the MMP is still in its infancy as a marsh bird population monitoring program. Bird species occurrence and numbers, their activity, and likelihood of being observed vary naturally among years and within seasons. Thus, large numbers of observations, collected over many years at the same locations are required to reliably estimate population indices.

Trends in population indices (i.e., average annual percent change in population index) are presented graphically for several commonly observed marsh bird species, 1995 through 2000 (Figure 2) and tabulated in Appendix 1, Table 1A. Species that have undergone significant steady year-to-year basin-wide declines include American Coot, Black Tern, Common Moorhen, undifferentiated moorhen/coot, Pied-billed Grebe, Red-winged Blackbird, Sedge Wren and Sora (Table 1A). A significant negative trend occurred for Blue-winged Teal, but this decline was not consistent over the six-year period. Although a steady year-to-year decline in Virginia Rail was less certain (P = 0.08), the trend for this species indicates cause for concern. Rails are highly marsh dependent, therefore evidence of decline in their relative abundance merits close scrutiny.

Statistically significant year-to-year basin-wide increases in annual indices occurred for Chimney Swift, Cliff Swallow, Common Yellowthroat and Mallard. All marsh bird species indices that have declined are those species that depend almost exclusively on marsh habitat with some standing water during breeding (i.e., American Coot, Black Tern, Common Moorhen, Pied-billed Grebe, Sedge Wren, and Sora), whereas all species indices that have increased (i.e., Cliff Swallow, Chimney Swift, Common Yellowthroat, and Mallard) do not require standing water throughout marshes during breeding and some even occupy non-marsh habitats during at least part of the breeding season.

The most notable trend in marsh birds was the strong negative decline for Black Tern, a colonial marsh nesting species that is drawing considerable attention by water bird specialists throughout North America. Not only has the estimated annual percent decline of 21.9 percent been the highest for this species than for all other marsh bird species monitored by the MMP, but virtually all but one year (1998) had a lower annual index than that of the previous year.

Three general population trend patterns have occurred among marsh birds monitored by MMP; 1) generally steady increases, 2) generally steady decreases, and 3) cyclic patterns.

Basin-specific

Basin-specific indices for marsh bird species that were detected in at least 15 routes are presented in Appendix 1, Tables 1B - 1E. For many bird species, changes in population indices varied among lake basins. For example, significant basin-wide declines in Black Tern and Pied-billed Grebe relative abundance is attributable largely to significant declines that occurred in Lake Ontario and Lake Huron basins, whereas, a significant basin-wide increase in Common Yellowthroat abundance was driven primarily by strong year-to-year increases in Lake Huron and Lake Michigan basins, even though trends in all basins showed similar patterns. Similar to that for basin-wide marsh bird indices, increasing, decreasing and cyclic patterns dominated the trend types observed among the suite of marsh birds species monitoring within each lake basin.

<u>Amphibian Population Trends</u>

Basin-Wide

During the period from 1995-2000, Marsh Monitoring Program surveyors recorded 14 species of calling amphibians. All of these species, except the Great Plains Toad, were recorded within the Great Lakes basin.

Trends in station occurrence were assessed for calling amphibian species most commonly detected during Great Lakes MMP route surveys. Because natural variability can be substantial and station occupancy is a relatively coarse measure (i.e., does not detect changes in absolute numbers of individuals), trend estimates for amphibians should be regarded as preliminary until additional years of data have been collected.

For each amphibian species, trends in annual proportion of stations with each species present were assessed first on a by-route basis. Such route level trends were combined for overall species-specific trend assessments. Although notable trends are apparent for some species (e.g., American toad and bullfrog) only the declining trend for chorus frog and green frog, and the increasing trend for pickerel frog could be resolved with statistical confidence at $\alpha = 0.05$ (i.e., confidence limits around the trend did not encompass zero; $P < 0{,}05$) (Appendix 2, Table 2A; Figure 3). However, regardless of statistical significance, general increases, decreases and, most commonly, cyclic patterns (peak in annual indices usually occurring in 1998) dominated the trends for these nine most commonly occurring amphibian species.

Basin-Specific

Overall decline in chorus frog station occupancy resulted from strong basin specific declines within the Huron and Michigan lake basins (Appendix 2, Tables 2B – 2D). Further, basin-wide decline in trends of green frog annual indices have resulted largely from strong annual declines in the Huron and Michigan lake basins, 1999 and 2000 being years with considerably lower station occupancy than previous years. It is notable that lakes Michigan and Huron (hydrologically the same water body) have experienced considerably low water levels during 1999 and 2000, which may account for these basins' relatively large contribution to overall basin-wide decline in both chorus frog and green frog. This phenomenon was assessed and results are reported for this later in this section.

Overall increase in pickerel frog station occupancy is based on small sample sizes, so even a small trend increase results in a statistically significant increase. Also, this trend increase resulted from considerably higher station occupancy during 1999 and 2000 than in all previous years combined (i.e., year-to-year decline had relatively less influence on overall decline).

As demonstrated, year-to-year fluctuations were apparent for many calling amphibian species monitored by MMP surveyors. In addition to natural variation and fluctuation of local populations, calling amphibians may have been present at a monitoring station but not been detected for a variety of reasons (e.g., temperature and/or moisture). In addition to such environmentally derived variability, six years of MMP survey data represent a relatively short timeframe; low resolution of trends in amphibian station occupancy will improve with time. Additional years of monitoring data, particularly if augmented with intensive studies of individual species, will better refine our efforts to identify relative trend changes in species-specific occupancy of Great Lakes basin marshes.

Our five-year *Marsh Monitoring Program, 1995 – 1999: Monitoring Great Lakes Wetlands and Their Amphibian and Bird Inhabitants* report [http://www.bsc-eoc.org/mmpreport.html] describes the extent to which additional years of data might be expected to provide better resolution of amphibian trends, and how the Marsh Monitoring Program will improve its ability to provide trend estimates for several amphibian species, including species of conservation and management concern such as Northern leopard frog and bullfrog. Nonetheless, it is possible to evaluate possible sources of variation in current trend data. Such an evaluation was done and is reported in the following section.

Coastal and Inland Marsh Bird Indices and Mean Annual Great Lake Water Levels

Because sample sizes are reduced when considering MMP data at individual lake basins, and are further reduced when categorizing data into coastal and inland marsh routes within each basin, adequate route occurrences of some species were too low to generate reliable annual indices for either inland, coastal, or both marsh route categories. Thus, in some cases, species annual indices for either only inland or only coastal marsh routes (or sometimes neither) were available to compare with that of lake-specific mean annual water level indices.

Basin-wide

Comparisons of coastal and inland marsh bird indices in relation to indices of mean annual water levels across the Great Lakes basin are presented for select marsh bird species in Figure 4. It is notable that for several species that depend on marsh habitat, population indices at coastal marsh routes were more positively correlated to indices of mean annual water levels than were those at inland marsh routes (e.g., American Bittern - r = 0.85, P = 0.03; Least Bittern - r = 0.72, P = 0.11; Sora - r = 0.77, P = 0.07; Black Tern - r = 0.61, P = 0.20; and Coot/Moorhen - r = 0.60, P = 0.20; Table 1, Figure 4). Similarly, at coastal marsh routes, annual indices for marsh bird species that prefer drier marsh edges were notably more negatively correlated to indices of mean annual water levels than were those at inland marsh routes (e.g., Common Yellowthroat - r = -0.67, P = 0.15; Table 1). For some marsh bird species, peak station abundance either coincided with, or occurred one year after peak mean annual water levels of the Great Lakes (1997); the latter suggesting a lag response of species specific station abundances to changing water levels. Those species whose annual indices at coastal marsh routes correlated with indices of mean annual water levels appeared to do so best from 1997 to 2000, when steady year-to-year water level decreases occurred.

Lake Michigan–Huron

Figure 5 portrays species-specific patterns of marsh bird indices and those of mean annual water levels in Lake Huron-Michigan, and Table 2 provides corresponding correlations between species annual indices and mean annual water level indices for each species considered. Interestingly, for certain species inland routes population indices were more strongly positively correlated with water level changes than were they at coastal routes (e.g., Pied-billed Grebe - *r* = 0.44, *P* = 0.24; Sora - *r* = 0.70, *P* = 0.12; Table 2). Indices at coastal routes for Black Tern (*r* = 0.52, *P* = 0.29), Coot/Moorhen (*r* = 0.68, *P* = 0.14), and Virginia Rail (*r* = 0.53, *P* = 0.28) were more positively correlated with water level changes than were they at inland routes, similar to that for basin-wide comparisons.

Lake Erie

Mean annual water level indices of Lake Erie were quite positively correlated with Black Tern (*r* = 0.78, *P* = 0.07), Least Bittern (*r* = 0.80, *P* = 0.06), Marsh Wren (*r* = 0.70, *P* = 0.13), Coot/Moorhen (*r* = 0.53, *P* = 0.28), Pied-billed Grebe (*r* = 0.51, *P* = 0.30) and Sora (*r* = 0.90, *P* = 0.01) at coastal marshes (Table 3, Figure 6). For several species, indices at inland routes could not be calculated because of their low route occurrences. For those species where information was sufficient to calculate indices at inland routes, most did not correlate at all or did so only moderately with Lake Erie water level changes (Table 3, Figure 6).

Lake Ontario

Absolute changes in Lake Ontario's water levels were comparatively less than were they for any other lake basins considered. Further, although Lake Ontario's water levels peaked during the same year as did other Great Lakes' (i.e., 1997), a marked flux in water levels occurred between 1998 and 2000. Because coastal route occurrences were too low for many species, coastal route indices were calculated for only four of the nine marsh bird species selected for water level comparisons (Table 4). Among those species where sample sizes were sufficient to calculate coastal route indices, Marsh Wren correlated positively well (*r* = 0.84, *P* < 0.05), Virginia Rail correlated moderately positive (*r* = 0.54, *P* = 0.27), and Coot/Moorhen correlated poorly (*r* = 0.28, *P* = 0.59) with Lake Ontario water level changes (Table 4, Figure 7). Coastal route annual indices for Common Yellowthroat were moderately negatively correlated with Lake Ontario water level indices (*r* = -0.53, *P* = 0.27). A strong positive correlation occurred between American Bittern inland route indices and those of Lake Ontario's water levels (*r* = 0.77, *P* = 0.07), and a moderate positive correlation between Virginia Rail inland indices and Lake Ontario's water levels (*r* = 0.53, *P* = 0.28). Inland route Black Tern indices correlated highly negative with Lake Ontario water levels (*r* = -0.85, *P* = 0.03), and that for Least Bittern was moderately so (*r* = -0.53, *P* = 0.28).

<u>Coastal and Inland Amphibian Indices and Mean Annual Water levels</u>

Basin-wide

Figure 8 portrays basin-wide comparisons of amphibian occurrence indices at both coastal and inland MMP routes to mean annual water level indices of the Great Lakes. Basin-wide indices for several marsh dependent amphibian species that breed almost exclusively in marsh habitats (e.g., bullfrog, green frog), and for chorus frog (less marsh dependent), were more strongly positively correlated with mean annual water levels than were those for amphibian species that can be considered less dependent upon marsh habitat *per se* (e.g., northern leopard frog, American toad and Wood frog)(Table

5). Interestingly, basin-wide indices for American toad, northern leopard frog, grey treefrog and spring peeper at *inland* routes were more strongly positively correlated with indices of mean annual water levels than were they at coastal routes (Table 5); the former three of these four species are commonly associated with terrestrial environments and are less dependent on marshes than are the three obligatory marsh amphibian species described previously, whereas spring peeper can also be considered less marsh dependent. Population indices for wood frog showed little or no correlation with that of mean annual water levels at either inland or coastal routes (Table 5). Further, wood frog annual indices at coastal and inland routes were positively correlated with each other (r = 0.78, P < 0.1).

Lake Michigan-Huron

Coastal route spring peeper, chorus frog, and green frog annual indices correlated positively (spring peeper r = 0.82, P < 0.05; chorus frog r = 0.73, P = 0.10; green frog r = 0.69, P = 0.12) with those of Lake Michigan-Huron water levels (Table 6, Fig. 9). Other notable water level – species indices correlations at coastal routes occurred for northern leopard frog and American toad (both positive), and for wood frog and bullfrog (both negative)(Table 6).

At inland routes, negative water level – species indices correlations occurred for bullfrog, (r = 0.8, P = 0.057). Both northern leopard frog and American toad inland indices correlated more positively with Lake Michigan-Huron water levels, but general patterns were more similar (except lagging by one year) between coastal route northern leopard frog indices and water levels than between those at inland routes for this species (Figure 9). Green frog annual indices correlated moderately positive (r = 0.52, P = 0.29) with water levels of this lake at inland routes.

Lake Erie

Contrary to what occurred for chorus frog in Lake Michigan-Huron coastal routes, there was a highly negative correlation between coastal route annual indices of chorus frog and Lake Erie water levels (r = -0.81, P < 0.05)(Table 7, Figure 10), even though Lake Erie's water level patterns and amplitude were similar to those of Lake Michigan-Huron. Moreover, a highly positive correlation between annual indices of bullfrog and water levels occurred at Lake Erie coastal routes, contrary to that that occurred for Lake Michigan-Huron. Moderately positive species – water level index correlations occurred for green frog (r = 0.60, P = 0.21) and northern leopard frog (r = 0.64, P = 0.17) at Lake Erie coastal routes.

At inland routes, the only notable relation was that of a strong positive correlation between northern leopard frog annual indices and those of Lake Erie water levels (r = 0.82, P = 0.05), and patterns of this relation for this species were notably similar at both coastal and inland routes (Table 7, Figure 10).

Lake Ontario

Several notable species – water level indices correlations occurred within Lake Ontario MMP routes (Table 8, Figure 11). Strong positive correlations between annual indices of wood frog (r = 0.96, P = 0.003) and green frog (r = 0.81, P = 0.05) occurrence occurred at coastal routes. Also at coastal routes, American toad and chorus frog annual indices were negatively correlated (American toad r = -0.80, P = 0.06; chorus frog r = -

0.72, *P* = 0.10) with those of Lake Ontario's water levels. Annual indices for coastal bullfrog were only weakly negatively correlated (*r* = -0.46, *P* = 0.36) with water levels of Lake Ontario, however patterns were similar, yet separated by 2-year lag period.

At inland routes, the only notable relation was a strong positive correlation between Lake Ontario water levels and green frog annual indices (*r* = 0.94, *P* = 0.005) (Table 8, Figure 11).

DISCUSSION AND SUMMARY OF CONCLUSIONS

Three dominant temporal patterns in population indices have occurred among marsh birds and amphibian species examined herein; 1) general steady increases, 2) general steady decreases, and 3) cyclic patterns. The latter was the most prevalent pattern observed for both marsh birds and amphibians, especially when patterns were examined separately at coastal and inland route locations. These patterns are important correlates of temporal patterns of Great Lakes water level indices, and in some (but not all) cases, the peak in such cyclic patterns for species annual indices lagged one year (or two for bullfrog) after that of peak water level indices. This could be due to a lag response of marsh vegetation to changes in water levels, or perhaps from a lag effect of individuals being recruited (or not) into the population the following year. Neither of these potential sources was examined but improved research and monitoring efforts may enable assessment of either or both of these phenomena.

Not only have temporal patterns in population indices among some marsh bird and amphibian species been similar to one other during the course of the Marsh Monitoring Program survey, but patterns of Great Lakes annual water level indices have proven to be important correlates and may explain a considerable amount of variation in many species' annual index patterns. This became especially apparent when survey data were separated according to whether routes were located in marshes with water levels most likely to have experienced significant water level effects (i.e., those in proximity to a Great Lake shoreline), or in marshes with water levels that have likely been under less influence by changing water level regimes *per se* (i.e., those routes greater than 5 km from a Great Lake). However, some caution is warranted when making inferences based simply on observed correlations. Such interpretations should be based on *a priori* hypotheses and bound to some understanding about how one factor may relate to another. Although such was the case when comparing indices of marsh bird abundance and amphibian occurrence with those of water levels of Great Lakes (i.e., a dramatic decrease in water levels over a short period of time results in marshes with reduced water coverage and depth that may affect species populations), other factors may interplay and could confound interpretations based on simple correlative comparisons. For example, depending on the shoreline gradient associated with a given marsh being sampled, lower water levels may simply result in prime marsh cover gradually progressing lake-ward in a broad front, and many species may simply reposition as optimal habitat moves with changing lakes levels. If new MMP sampling routes are not positioned within these 'prime' locations at the rate at which marshes advance (or recede during water level increases) lake-ward, then apparent population index declines may partly (or mostly) be an artifact of marsh habitat dynamics during changing water level regimes rather than a result of real population increases or decreases *per se*. Also, some bird species may readily move to better available marshes. For example, coastal and inland route Least Bittern indices patterns were inversely related to one another in some lake basins and their coastal indices often followed those of annual water levels, leading one to speculate possible movement of individuals to inland marshes when hydrologic conditions at coastal marshes are unfavourable for this species.

Although the above phenomena may have some bearing on results reported herein, it is also likely that some marsh vegetation could not regenerate in time, or that steep bottom profiles prevented plant regeneration further from shore, during rapid year-to-year water level declines that occurred during a relatively short period (e.g., 1 m decline in water level between 1997 and 2000 for Lake Michigan-Huron). Alternatively, in very flat areas, a 1 m decline in water levels could result in considerable lateral shifts of marsh vegetation and its associated avifauna communities. Thus, although some population indices changes probably partly reflected reduced productivity of individual marshes, thereby reducing individual reproductive success of marsh birds and/or amphibians at these sites, in certain cases it is also probable that surveying at permanent placed MMP routes (if not distributed throughout entire hydrologic regimes of marshes) were not able to detect repositioning of individuals as marsh vegetation communities moved with water level changes. Indeed, several areas (e.g., Long Point marshes, Tozer 2001) have suffered a net loss in suitable habitat for marsh dependent fauna during this period of water level decline; however at other locations (e.g., Lake St. Clair delta, J. Haggeman pers comm.) marsh vegetation communities have moved considerable lake-ward during recent low water levels. Some marshes in very flat areas may also have increased in size during low water levels, (Lyons et al. 1986). However, if mean water depth throughout marshes decreased substantially during steady year-to-year declines (e.g., 1997 – 2000), increased nest predation from terrestrial predators could offset any benefit of increased marsh area (Jobin and Picman 1997).

Despite the hypothesis that inland marshes are less influenced by water level changes *per se*, it was valid to compare both coastal and inland route marsh bird and amphibian indices to those of Great Lakes water levels. To a considerable degree, water levels of the Great Lakes are directly influenced by the amount of precipitation received within their catchment basins. This phenomenon may explain why some species' indices at *inland* routes correlated with water levels in some lake basins (i.e., some of the variation in Great Lakes water levels was directly caused by surface water runoff in any given year). However, other factors that affect water levels and their marshes probably have considerably less influence (or the opposite effect) on smaller inland marshes (e.g., bulk water removals and water diversions (Lyon et al. 1986), snow accumulation, whether a Great Lake freezes during winter, human-induced increased rate of surface/groundwater runoff). Also, a relatively little amount of short-term precipitation may provide ideal within-year water level conditions at smaller isolated inland marshes, but have negligible effects on annual water levels of an entire Great Lake and its marsh systems.

Probably the most intriguing and compelling aspect of our results was numerous positive and negative correlations between species-specific annual indices and water level variation of Lake Ontario during the latter part of the study period (1998 – 2000). Lake Ontario water level changes provide for an interesting, perhaps even post hoc, experiment with which to test whether year-to-year changes in water levels of the Great Lakes affected abundance and occurrence of marsh birds and amphibians, respectively, differently than in other lake basins. Interestingly, Lake Ontario's water levels are under considerable control of anthropogenic operating regimes at its outlet, where various hydroelectric power generation control structures span the St. Lawrence. The Niagara escarpment separates Lake Ontario from Lake Erie by more than a 50-metre drop where it intersects the Niagara river, and completely prevents Lake Ontario's controlled waters regimes from affecting hydrology regimes of the other Great Lakes (Lee et al. 1998). Thus, to a certain degree, Lake Ontario has water level regimes that are unique from those of other Great Lakes.

The pattern of water level variability for the other lake basins considered in this study (i.e., Lake Michigan-Huron and Lake Erie) were similar to each other, that is water levels increased from 1995 to 1997, followed by a steady and more rapid decrease from 1997 through to 2000. Although Lake Ontario's mean annual water level pattern was somewhat similar to those of the other Great Lakes, two key differences attributable to its human-induced control regimes are apparent: 1) the amplitude of water level change has been markedly reduced; and 2) a unique flux in mean annual water levels occurred between 1999 and 2000. This latter phenomenon provided the most compelling semi-experimental view into how water level changes have correlated with marsh bird and amphibian indices, and how these relations differed from those of other lake basins. In fact, during this unique period of water level flux from 1998 to 2000 in Lake Ontario, several species indices correlated strongly with Lake Ontario's mean annual water level indices, positively or inversely, depending on the species examined.

I also found that occurrence for many marsh bird and amphibian species at coastal routes were often lacking to calculate reliable population indices with which to compare to Lake Ontario's water level indices. The following may explain why occurrence of some bird and amphibian species was so low at Lake Ontario coastal MMP routes. Amplitude of annual water level fluctuation has been highly suppressed by water control activities along the St. Lawrence. Consequently, many coastal marshes along Lake Ontario's shoreline have become choked with dense, monotypic stands of cattail, which uptake vast amounts of water in their vascular systems (e.g., Bay of Quinte area, pers. obs.). Within some of these monotypic emergent tracks, available surface water can often become highly reduced, or even eliminated throughout much of the growing season, leaving little open water to support wetland dependent fauna. Further, reduced year to year water level variation also has suppressed natural flooding and draw-down of marshes, both that are critical in maintaining productivity and nutrient availability in marshes (Weller, 1978, Harris et al. 1981, Lyon 1981, Lyon et al. 1986).

Patterns of inland indices for many species of marsh birds and amphibians quite consistently inversely related to the pattern Lake Ontario mean annual water levels, again suggesting possible preference for inland marshes by individuals when lake Ontario water levels are low. One exception to this was the pattern of annual indices for American Bittern, which correlated positively with Lake Ontario's water levels at *inland* routes. Numerous strong correlations between species indices and Lake Ontario water levels (especially during the 1998 – 2000 flux period) provide two insights: 1) species indices at both inland and coastal routes (i.e., most amphibian species and two of four bird species where coastal routes sample sizes where sufficient) appear to be responsive to changes in Lake Ontario water level changes; and 2) hydrologic factors (e.g., annual precipitation) that occur at inland locations may be relatively more influential on Lake Ontario water level regimes than on those of other Great Lakes' water levels.

Several interesting results within Lake Ontario's basin occurred for most amphibian species examined. For example, patterns of indices for all species except tree frog were directly or inversely correlated with Lake Ontario water level changes during the water level flux that occurred from 1998 to 2000. Species indices that related positively to water level indices during this period occurred at coastal routes, and included species that are more aquatic in nature such as green frog, leopard frog, wood frog and spring peeper. Although this relation for bullfrog was negative as opposed to an expected positive relation, a greater lag period (i.e., two years) to changes in water levels for this species explains why the artificial negative correlation occurred. Bullfrogs usually require two years to reach maturity at higher latitudes, such as the Great Lake region (Behler and King 1979, Stebbins 1995). Thus, reproductive responses to water level changes (i.e., recruitment to breeding age) for this species wouldn't be expected until young produced during years in optimal water conditions for this species reached breeding age, when their breeding calls would have first been detected by MMP volunteers. If higher water levels do result in higher bullfrog productivity, young produced during a high water level year (e.g., 1997) wouldn't have been detected as calling adults until 1999. By 1999, water levels had rapidly decreased, which resulted in a negative correlation between the species' annual indices and that of Lake Ontario's water levels. Similar inverse correlations for American toad and chorus frogs might better be explained by real increases in occurrence in direct response to water level decreases. Both of these species frequently occur in aquatic environments with relatively little standing water, therefore breeding conditions may have been more favourable for these species when Lake Ontario's water levels were lower.

Concerns about population status of chorus frogs have increased in recent years and our data provide some support to legitimize these concerns. Although similar declining patterns of annual indices have occurred for chorus frog in both Lake Ontario and Erie basins, the trend for this species in the Lake Ontario basin was generally stable. Long term (1950s to 1990s) losses of Chorus Frog have been documented in the St. Lawrence River Valley just northeast of the Great Lakes basin, however this species is known to incur population fluctuations and even regional extirpations over short time intervals as a consequence of natural factors such as changes in annual weather conditions (Daigle 1997).

Despite having only six years of data to examine, basin-wide abundances and occurrences of obligate marsh dependent birds and amphibians were often more positively correlated with mean annual water levels at coastal routes than at inland routes, especially during recent years when water levels steadily declined (i.e., from 1998 – 2000). Similarly, indices of non-obligate marsh bird species that depend less on marshes with permanent standing water and more on drier marsh edge habitats (which would increase when marshes become drier) were more negatively correlated with mean annual water levels at coastal routes than at inland routes.

This initial investigation into how changing water levels relate to indices of marsh bird species abundance and amphibian species occurrence provides a preliminary view into how the dynamics of Great Lakes hydrology may influence population indices of marsh dependant fauna. Several factors not accounted for in this study likely interplay and account for residual variation in species' indices patterns. It is important to take such factors into consideration to better understand how wetland hydrology affects abundance and occurrence of marsh birds and amphibians. Nonetheless, data derived from volunteer marsh bird and amphibian monitoring initiatives such as the Marsh Monitoring Program are proving to be very useful for better understanding relative population status and changes at different spatial scales, and how populations may be responding to dynamics of their external environment.

RESEARCH NEEDS

Extensive monitoring and broad comparisons of species indices with components of their changing environment are important to maintain and to begin addressing questions about how to better direct conservation efforts of wetland ecosystems. Such approaches often benefit from intensive experimentation to determine if observed correlations are due to causal mechanisms. However, even improvement in extensive monitoring efforts and rigorous attempts to improve robustness of sampling design and comparative approaches can greatly improve confidence in correlative approaches. Improving selection of survey station placement by volunteers (i.e., random and area-based) would improve our ability to monitor populations and reduce how habitat and water level changes influence abundance and occurrence estimates. Also, obtaining geo-referenced locations of Marsh Monitoring Program survey stations would greatly aid our ability to use remote sensing and Geographic Information System modelling to examine how local influences and habitat regimes (including water conditions) relate to bird and amphibian occurrence and relative abundance. Such approaches would allow rigorous assessment of temporal and spatial patterns both within MMP surveyed marshes, and also throughout the adjacent landscapes, which can have marked affects on marsh community dynamics (Riffel 2001).

An evaluation of how changes in surveyed MMP route locations might confound apparent population indices and their trends, via differences in wetland type, size, morphology, habitat composition and other factors, would improve our certainty about how representative population data derived from the MMP are to real species population changes, both spatially and temporally. With some difficulty, due partly to within-route changes in habitat features, this could be done by comparing how various wetland associated features change with both species indices and with changes in MMP route coverage, to determine if changes in annual indices are independent of MMP route turnover.

Lastly, sampling precision and accuracy of marsh bird and amphibian population indices would also benefit from a comparison of results derived from intensive species- and site-specific sampling to those of the MMP. Such sampling could experimentally test how year-to-year changes in water level regimes of marshes affect populations by sampling at non-manipulated control sites and comparing results with those from experimental treatments under different degrees of water level control. Combining knowledge gained from such results with that gained from understanding specific habitat associations of marsh dependent birds and amphibians would greatly compliment our efforts to conserve and restore damaged and degraded wetland ecosystems for the benefit of entire marsh ecosystems throughout the Great Lakes region.

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