Changes in abundance of Least Bitterns in Ontario, 1995-2019

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Figure 1. Least Bittern female.
Photo: Andrew Chin

Abstract

Populations of many breeding marsh bird species continue to decline in the southern Great Lakes basin, although this is not the case for the threatened Least Bittern. Recent analysis based on data from the Great Lakes Marsh Monitoring Program of Birds Canada shows that its abundance has increased consistently since the mid-2000s throughout the lower Great Lakes in the U.S. and Canada, with the highest abundance occurring in recent years. In this study, we expanded on these findings by assessing patterns in abundance of Least Bitterns among different geographical locations in Ontario and across years from 1995 to 2019. We found that abundance was relatively consistent in Ontario from 1995 to 2016, but notably higher from 2017 to 2019, largely due to increases in abundance of Least Bitterns at Great Lakes coastal locations (i.e., those directly influenced by fluctuating Great Lakes water levels) compared to inland, particularly in the Lake Erie basin. We also found strong evidence that the increase in abundance was closely tied to increasing water levels during the breeding season on Lake Erie and Lake Ontario. Although this appears to be a good-news story for this species of priority conservation concern, it should be emphasized that Great Lakes water levels naturally fluctuate over time, so it is reasonable to expect a decline in abundance of Least Bitterns when water levels eventually begin to recede. It is also important to realize that the increase in abundance reported here may be due to a change in distribution of Least Bitterns moving into our study area during high water rather than an increase in the total size of the population. Nonetheless, the recent increase that we observed, if it represents a genuine increase in total population size, is encouraging for this species at risk in Ontario and Canada.

Introduction

The Least Bittern (*Ixobrychus exilis*) is a small, elusive heron whose breeding range in southern Canada includes parts of Manitoba, Ontario, Quebec, New Brunswick and possibly Nova Scotia (Poole *et al.* 2020, COSEWIC 2009) (Figure 1 and Figure 2). The Canadian breeding population was estimated at 1,500 pairs in 2009, with Ontario supporting the largest number of breeding pairs (COSEWIC 2009, Woodliffe 2007). The preferred breeding habitat of the Least Bittern includes marshes with dense emergent vegetation (primarily cattails) interspersed with pools of open water. Its small size, slender shape and secretive behavior make the species hard to detect visually, so it is more often detected by its soft, quiet, low-pitched song (*coo-coo-coo-coo*) or harsh call (*rick-rick-rick-rick*) (Sibley 2016, Poole *et al.* 2020).

In Canada, the Least Bittern is classified as a species at risk both provincially (in Ontario and Quebec) and federally (COSEWIC 2009). In Ontario, the species has been listed as *Threatened* on the *Species at Risk in Ontario List* since 2004 and has been regulated under the *Endangered Species Act* since 2008 (ESA 2007). Federally, it has been listed as *Threatened* under Schedule 1 of the

Species at Risk Act since 2003 (SARA 2002). Most recently, the species was assessed as *Threatened* by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 2009, based on evidence that the population was small and declining (by more than 30% in the 10 years before the time of the assessment) (COSEWIC 2009). This decline was attributed in large part to wetland loss and degradation, although the population faces many other threats, including impaired water quality and the spread of invasive plant species (Environment Canada 2014).

Populations of many breeding marsh bird species continue to decline in the Great Lakes basin. A recent report from Birds Canada summarizing the results of 25 years of the Great Lakes Marsh Monitoring Program (GLMMP) found a significant decrease in abundance for six marsh-dependent species that require healthy wetland conditions (Tozer 2020). These species were American Coot (*Fulica americana)*, Black Tern (*Chlidonias niger*), Common Gallinule (*Gallinula galeata*), Pied-billed Grebe (*Podilymbus podiceps*), Sora (*Porzana carolina*) and Virginia Rail (*Rallus limicola*). One marsh-dependent species that did not show a significant decrease in abundance, however, was the Least Bittern. The report showed that its abundance declined from 1995 to the mid-2000s, but increased consistently thereafter. In particular, the last two years reported (2017 and 2018) had the highest abundance of Least Bitterns across all years of the program (since 1995), roughly three times higher than the lowest abundance observed in 2004. These results are promising for conserving the Least Bittern in the Great Lakes basin.

In this study, our main objective was to expand on the 25-year GLMMP report by assessing patterns in Least Bittern abundance among different geographical locations in Ontario and across years from 1995 to 2019. To accomplish this objective, we used survey data from the GLMMP to map abundance over three time periods: 1) the beginning of the program from 1995 to 1997, 2) the period when Least Bittern abundance was lowest from 2003 to 2005 and 3) most recently when abundance was high from 2017 to 2019. To provide additional insight, we also explored differences in abundance among Great Lakes basins (e.g., Lake Erie, Lake Ontario) and between Great Lakes coastal wetlands (defined as wetlands within 1 km of a Great Lake or major connecting channel) and inland wetlands (defined as wetlands farther than 1 km from a Great Lake or major connecting channel). Furthermore, previous studies have shown that abundance of Least Bitterns was greater in years with higher Great Lakes water levels (e.g., Timmermans *et al.* 2008), and water levels of the Great Lakes have been on the rise since 2013, with many lakes experiencing record highs over the last few years. We therefore also investigated the relationship between these recent high water levels and abundance of Least Bitterns.

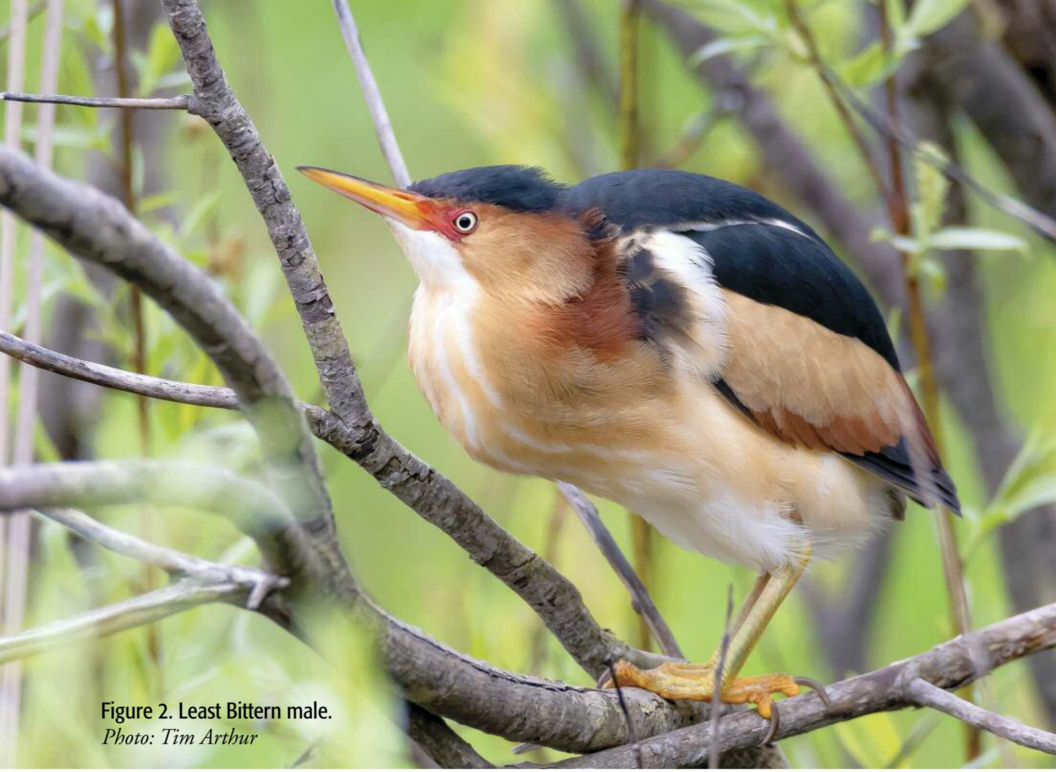


Figure 2. Least Bittern male.
Photo: Tim Arthur

Methods

Great Lakes Marsh Monitoring Program (GLMMP)

The GLMMP was initiated in 1995 by Birds Canada in partnership with Environment and Climate Change Canada and the United States Environmental Protection Agency. Operating annually on both the Canadian and U.S. sides of the Great Lakes basin, volunteers conduct surveys to collect data on bird presence and abundance, contributing to a long-term dataset tracking breeding marsh bird communities over time. The program places an emphasis on the detection of marsh-dependent species, especially American Bittern (*Botaurus lentiginosus)*, American Coot, Common Gallinule, King Rail (*Rallus elegans*), Least Bittern, Pied-billed Grebe, Sora, Virginia Rail and Yellow Rail (*Coturnicops noveboracensis*). Because many of these species are elusive, the GLMMP protocol requires standardized call broadcasts during each survey to elicit calls from a subset of these species, which ultimately improves detection (Tozer *et al.* 2017).

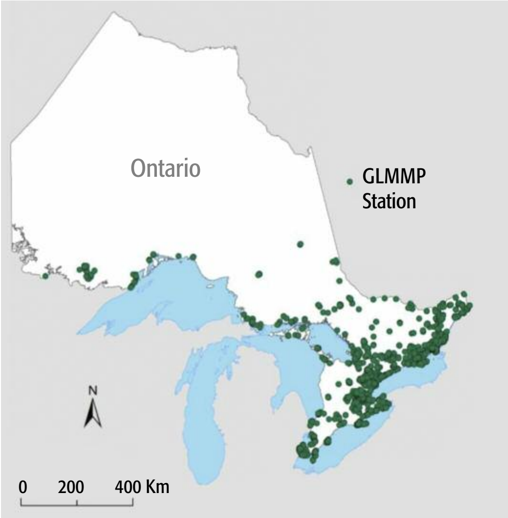
In general, surveyors visit GLMMP survey locations (stations) along survey routes (consisting of one to eight stations) two to three times per year during the marsh bird breeding season (between late-May and early-July). Prior to 2008, surveys were 10 minutes in length, consisting of five minutes of call broadcasts followed by five minutes of passive listening (with no broadcasts). In 2008, surveys were lengthened to 15 minutes and included an additional five-minute passive listening period before the broadcast period. During surveys, the surveyor records the number of individuals of all species detected visually and aurally.

Data preparation and analysis

To standardize survey results between stations that were surveyed twice as opposed to three times in a season, we excluded the second survey from all stations that were surveyed three times. Likewise, to compare survey results before and after 2008 (when the protocol changed from 10- to 15-minute surveys), we excluded the results from the first five minutes of 15-minute surveys. Removing the first five minutes meant that all survey data included in the analysis consisted of a broadcast period, followed by a passive listening period. From those data, we calculated the abundance of Least Bitterns at the station-level as the maximum number of Least Bitterns observed among surveys in a given year for each station.

We assessed patterns in abundance for three geographical scales: counties in Ontario, Great Lake basins and coastal versus inland station location. To visually assess patterns of abundance for counties over time, we calculated average annual abundance (the total number of Least Bitterns observed in a county divided by the number of stations surveyed over three years) for the three time periods previously described (1995-1997, 2003-2005 and 2017-2019). We note that the number and identity of stations that were surveyed in each county varied across years, which may have influenced the results in unknown ways; therefore, although we find the county-level visualizations useful for exploring broad changes in distribution, they should be treated with appropriate caution. To compare changes in abundance over the years at the level of Great Lakes basins, we modeled average annual abundance and associated error (95% confidence intervals) for stations situated in the Lake Erie, Lake Ontario, Lake Huron and upper St. Lawrence River basins (which included stations anywhere in southern Ontario in areas that drain into these lakes and along their shores for all years from 1995 to 2019; these stations cover the majority of the species range in Ontario). Likewise, to compare changes in abundance over the years between coastal and inland stations, we modeled average annual abundance and associated error for coastal stations (defined as stations within 1 km of a Great Lake or major connecting channel; e.g., St. Clair River) and inland stations (defined as stations farther than 1 km from a Great Lake or major connecting channel) for all years from 1995 to 2019. Average annual abundance was modeled using generalized linear models with a Poisson distribution and a log link function. We also report the average percentage of stations occupied, which we modeled using a generalized linear model with a binomial distribution and a logit link function. ArcGIS Desktop 10.6.1 was used to determine the county and basin in which each station was situated, whether each station was within 1 km of a Great Lake or major connecting channel and to produce the final maps.

Figure 3. Stations surveyed for the Great Lakes Marsh Monitoring Program (GLMMP), 1995-2019.



Lastly, to investigate the influence of water level on the abundance of Least Bitterns, daily water levels for lakes Erie, Ontario, Huron and the upper St. Lawrence River were averaged from May to July (corresponding to the GLMMP survey months) each year from 1995 to 2019. These average water levels were compared to average abundance values of Least Bittern for each lake basin across all years, and linear regression was used to determine whether the relationship was statistically significant. For this comparison, we only included coastal stations because these stations were expected to be directly influenced by Great Lakes water levels. Water-level data were retrieved from the Canadian Hydrographic Service (www.waterlevels.gc.ca/ eng) and the National Oceanic and Atmospheric Administration (www.tidesandcurrents.noaa.gov/water_level_info.html).

Results

The final dataset included 23,312 surveys at 2,506 stations, resulting in a total of 822 observations of Least Bitterns from 1995 to 2019. GLMMP stations used in the analysis were spread across southern Ontario, but were predominantly located in the Lake Erie and Lake Ontario basins (Figure 3). The number of stations surveyed varied each year, with an average of 466 stations surveyed annually (range = 217 to 655), and an average of 31 stations where Least Bitterns were observed (range = 5 to 75) (Figure 4). Both the number of stations surveyed and number of stations with Least Bitterns declined from 1995 to 2004, but generally increased thereafter, albeit at different rates. It is noteworthy that the increase in the number of stations surveyed occurred almost entirely in the Lake Ontario basin, where, as we show below, abundance of Least Bitterns remained relatively constant across years, which suggests that changes in Least Bittern abundance were not confounded with the number of stations surveyed (Figure 5). The percentage of stations occupied by Least Bitterns over the entire study period (1995-2019) was 6% (4%, 8%; lower, upper 95% confidence limits). From 1995 to 2016, the percentage of stations occupied ranged from a low of 2% (1%, 5%) in 2004 to a high of 9% (7%, 12%) in 2011 (average = 6%; 4%, 9%), and was highest at 14% (10%, 15%) in 2017, 13% (9%, 14%) in 2018, and 16% (11%, 17%) in 2019.

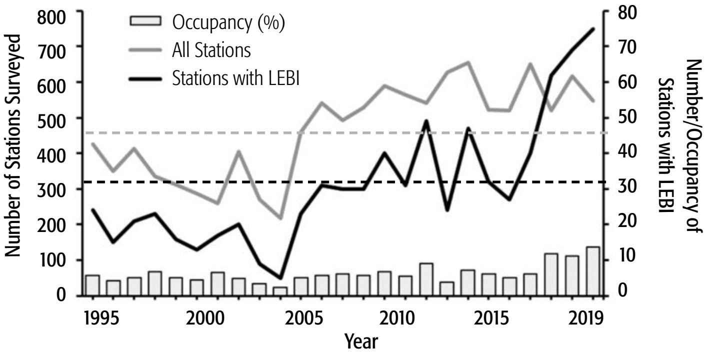


Figure 4. Stations surveyed for the Great Lakes Marsh Monitoring Program (GLMMP), 1995-2019 (grey solid line, left axis), the number of stations where Least Bitterns (LEBI) were observed (black solid line, right axis) and the percentage of stations occupied by Least Bittern (occupancy) (bars, right axis). The grey dashed line is the average number of stations surveyed per year (466) and the black dashed line is the average number of stations where Least Bitterns were detected (31).

Figure 5. Stations surveyed in the Lake Erie, Lake Huron, Lake Ontario and upper St. Lawrence River basins for the Great Lakes Marsh Monitoring Program (GLMMP), 1995-2019.

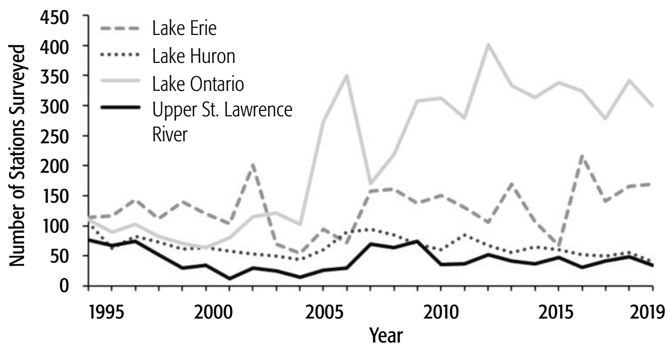


Figure 6. Abundance (maximum number of individuals among surveys per station) of Least Bitterns in Ontario, 1995-2019. Error bars are 95% confidence intervals.

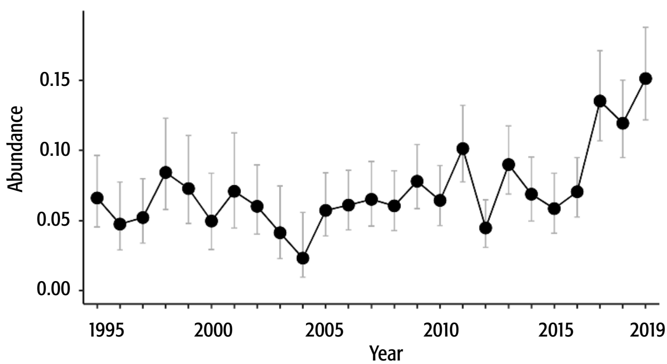
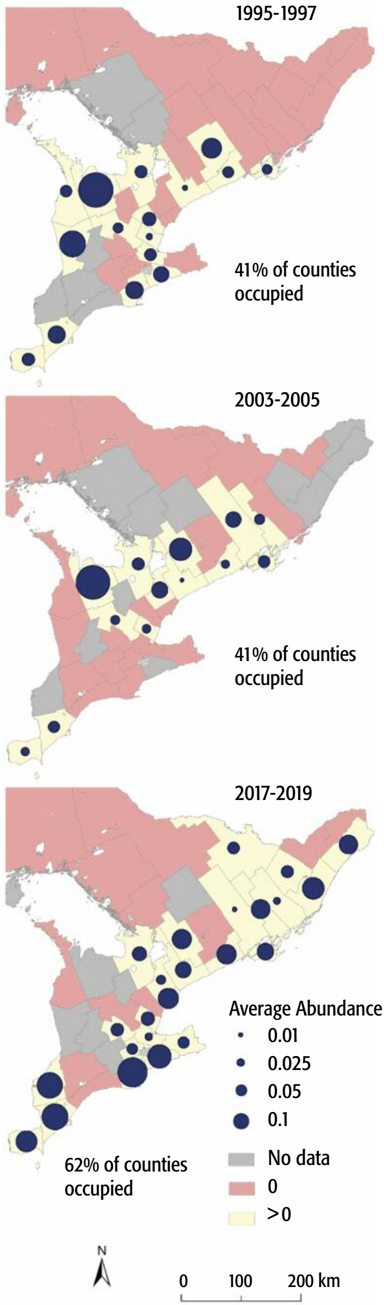


Figure 7. Abundance (maximum number of individuals among surveys per station per year) of Least Bitterns by county. The three time periods correspond to the beginning of the Great Lakes Marsh Monitoring Program (1995-1997), the period when Least Bittern abundance was lowest (2003-2005) and the period when abundance was highest (2017-2019).

Also shown is the percentage of counties occupied during each period. We note that the number and identity of stations that were surveyed in each county varied across years, which may have influenced the results in unknown ways; therefore, although we find the county-level visualizations useful for exploring broad changes in distribution, they should be treated with appropriate caution.



The maximum number of Least Bitterns detected at a station in a year ranged from zero to four, but rarely exceeded one; considering all stations where at least one Least Bittern was detected, only 9% had two or more (average = 1.1, standard deviation = 0.3). From 1995 to 2016, the average annual abundance of Least Bitterns (i.e., the average maximum number of individuals among surveys per station in a given year) was relatively consistent, ranging from a low of 0.02 (0.01, 0.06) in 2004 to 0.10 (0.08, 0.13) in 2011 (Figure 5). Average abundance was much higher at 0.14 (0.11, 0.17) in 2017, 0.12 (0.10, 0.15) in 2018 and 0.15 (0.12, 0.19) in 2019 compared to all years prior. The largest increase occurred between 2016 and 2017, when average abundance increased by 86%. Over the entire study period, the average annual abundance was 0.07 (0.04, 0.10) individuals per station per year.

By county

Least Bitterns were detected in 17 of 41 counties surveyed from 1995 to 1997, 14 of 34 from 2003 to 2005 and 24 of 39 from 2017 to 2019 (Figure 7). However, the percentage of counties with Least Bitterns was the same (41%) during the first two periods but increased to 62% during the 2017-2019 period. Of the 32 counties that were surveyed in both 1995-1997 and 2003-2005, eight counties increased in average abundance, 13 decreased and 11 did not change (where no Least Bitterns were observed in either timeframe). Likewise, of the 30 counties surveyed in both 2003-2005 and 2017-2019, 16 increased, five decreased and nine did not change, and of the 32 counties that were surveyed in both the first and last periods, 22 increased, six decreased and four did not change. In general, changes in average abundance were largest in counties with Lake Erie and Lake Ontario shorelines. There were nine counties along Lake Ontario and the upper St. Lawrence River where no Least Bitterns were detected during the 1995-1997 or 2003-2005 periods, but eight of those counties had average abundance values above zero in 2017-2019, with the one exception being Peel Region. For counties adjacent to Lake Erie, there was a decrease in average abundance in three counties between the first two periods followed by an increase in average abundance in four counties in 2017-2019. The change in average abundance was largest in Norfolk County, which also had the highest average abundance of all counties in the 2017-2019 period (0.36 individuals per station per year). Norfolk County was followed by the nearby counties of Chatham-Kent (0.28), Lambton (0.27) and Haldimand (0.23).

By basin

Average abundance of Least Bittern was highest in the Lake Erie basin in 14 of 25 years considered in this study; the Lake Huron, upper St. Lawrence River and Lake Ontario basins were highest in eight, two and one years, respectively (Figure 8). The average abundance in the Lake Erie basin declined from 1995 to 2004, and then increased from 2005 onward. Average abundance generally increased in the upper St. Lawrence River basin over time, but was relatively consistent in the Lake Ontario and Lake Huron basins. Across all years, the average abundance of Least Bittern for the Lake Erie, Lake Huron, Lake Ontario and upper St. Lawrence River basins was 0.12 (0.11, 0.13), 0.08 (0.07, 0.09), 0.06 (0.05, 0.06) and 0.05 (0.03, 0.06) individuals per station per year, respectively. Maximum annual values were 0.29 (0.21, 0.40) for Lake Erie in 2017, 0.11 (0.08, 0.16) for Lake Ontario in 2019, 0.16 (0.08, 0.32) for Lake Huron in 2017 and 0.18 (0.08, 0.39) for the upper St. Lawrence River in 2019.

Coastal vs. inland

Over the entire study period, average annual abundance of Least Bittern was 0.09 (0.08, 0.10) and 0.06 (0.05, 0.07) individuals per station per year for coastal stations and inland stations, respectively (Figure 9). Average annual abundance was very similar between coastal and inland stations from 1995 to 2016; however, from 2017 to 2019, coastal stations had an average abundance that was approximately 2.5 times that of inland stations, or about 0.10 more individuals

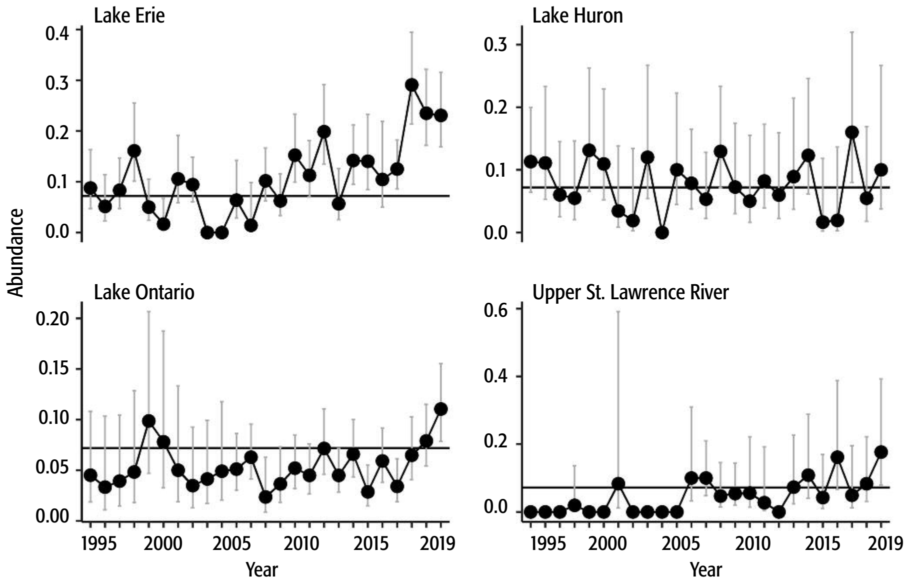


Figure 8. Abundance (maximum number of individuals among surveys per station) of Least Bitterns for the Lake Erie, Lake Ontario, Lake Huron and upper St. Lawrence River basins in Ontario, 1995-2019. Note the difference in the y-axis among lakes; a horizontal line is shown at the mean abundance across all lakes and years for reference. Error bars are 95% confidence intervals.

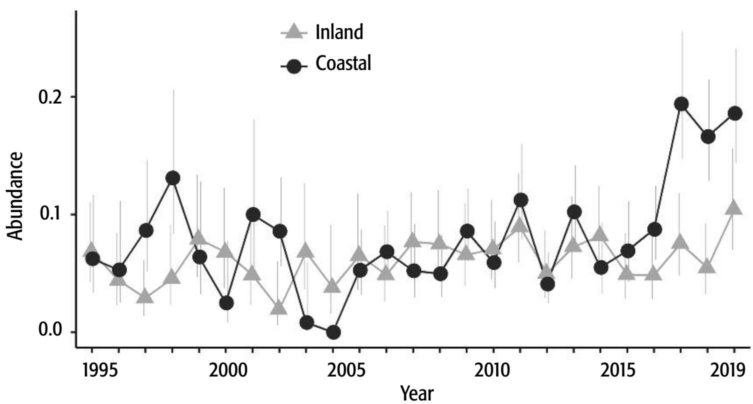


Figure 9. Abundance (maximum number of individuals among surveys per station) of Least Bitterns for coastal and inland survey stations in Ontario, 1995-2019. Error bars are 95% confidence intervals.

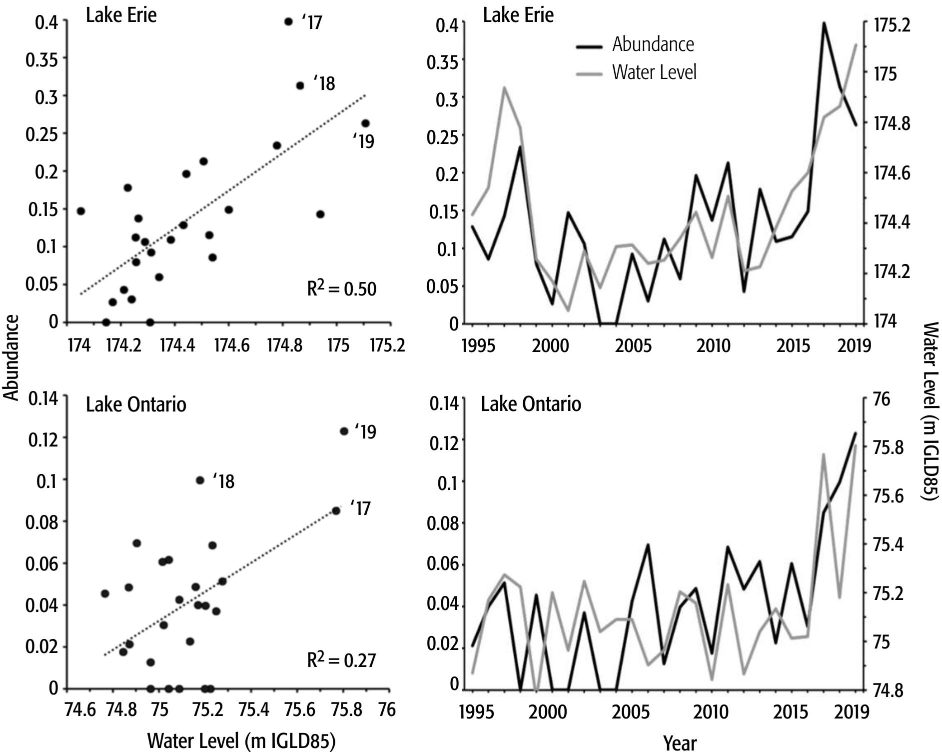


Figure 10. Relationship between the average abundance (maximum number of individuals among surveys per station) of Least Bitterns and water levels (m IGLD85) for Lake Erie and Lake Ontario, 1995-2019. Only coastal stations are included because these stations were expected to be directly influenced by lake water levels. For the panels on the left, each dot represents the abundance and water level in a given year. Note that the dots for 2017, 2018 and 2019 (which represent the recent high water years) are labelled. The panels on the right show average abundance and water level for each lake over time. Water levels were averaged from May to July (corresponding to the GLMMP survey months) using data from the Canadian Hydrographic Service (www.waterlevels.gc.ca/eng) and the National Oceanic and Atmospheric Administration (www.tidesandcurrents.noaa.gov/water_level_info.html).

per station each year. Average abundance at coastal stations was highest in 2017 at 0.19 (0.14, 0.24) and at inland stations in 2019 at 0.10 (0.07, 0.16), respectively. The lowest values, respectively, were zero individuals per station in 2004 for coastal stations and 0.02 (0.006, 0.06) individuals per station in 2002 for inland stations.

Relationship with water levels

Average abundance of Least Bittern had a significant positive relationship with water levels in Lake Erie ($R^2 = 0.50$, $P < 0.001$) and Lake Ontario ($R^2 = 0.27$, $P = 0.008$) (Figure 10). There was, however, no clear relationship between average abundance and water levels for Lake Huron and the upper St. Lawrence River ($R^2 < 0.1$, $P > 0.05$ for both). For Lake Erie, average abundance closely tracked water levels across the entire study period, declining with a decrease in water levels from 1995 to the mid-2000s, and then increasing with water levels thereafter. For Lake Ontario, average abundance and water levels were reasonably consistent from 1995 to 2016, but average abundance increased significantly in 2017 in the same year that water levels reached record highs on Lake Ontario. Average abundance further increased in 2018, despite a significant decrease in water levels compared to 2017 (but water levels were still above the long-term average), and then increased again in 2019, which was another record-breaking year for water levels on Lake Ontario (Figure 10).

Discussion

We found that the percentage of survey stations occupied by Least Bitterns (occurrence) and the maximum number of Least Bitterns observed per station (abundance) across southern Ontario was relatively consistent from 1995 to 2016, but was notably higher from 2017 to 2019. Furthermore, both the number of occupied counties and average abundance in many counties also notably increased during the most recent three years. In the federal recovery strategy, the primary objective regarding the population and distribution of Least Bittern is to "maintain and, where possible, increase the current population size and area of occupancy in Canada" (Environment Canada 2014). Although our results are specific to southern Ontario, they suggest this national objective may be on the right track, which is encouraging for this species at risk in Ontario and Canada. However, as we expand below, the increase in abundance that we observed may not represent a genuine increase in the total population, but rather a change in distribution.

It is not surprising that many of the counties with the highest abundance of Least Bittern in recent years (e.g., Norfolk, Essex, Chatham-Kent) were those with Important Bird Areas (Long Point Peninsula and Marshes, Greater Rondeau Area, Eastern Lake St. Clair, Point Pelee) and Wetlands of International Importance (Ramsar sites) (Long Point, St. Clair, Point Pelee). The importance of large, high quality marshes like those listed above was recognized in the first Ontario Breeding Bird Atlas as key habitat for Least Bitterns (Woodliffe 1987). Unfortunately, wetlands continue to be lost in Ontario, especially in the southern part of the province where roughly 6,000 hectares, or 0.6% of all remaining wetlands, were lost between 2000 and 2011 (OBC 2015). This may seem insignificant at face value, but consider that 6,000 ha equals the surface area of 7,360 Canadian football fields or 5.4 times the size of the marsh within Point Pelee National Park! As well, wetland quality continues to be degraded by pollution and invasion of aggressive exotic species — most notably, European Common Reed (*Phragmites australis* subsp. *australis*) (Robichaud and Rooney 2017). Despite this, we observed large increases in the average abundance of Least Bitterns in the third time period compared to the earlier time periods in some counties with large urban centers with high pollution runoff (e.g., Toronto), and across the Lake Erie basin where European Common Reed has become a dominant emergent plant species in most coastal wetlands (e.g., Jung *et al.* 2017). Wetland restoration efforts (such as European Common Reed management) by government and non-government organizations have contributed to improved habitat for Least Bitterns and other marsh-dependent bird species throughout southern Ontario (Tozer *et al.* 2018, Tozer and Mackenzie 2019); however, the changes among different counties and across years reported here most likely primarily reflect recent increases in water levels in the Great Lakes basin.

Two of our findings support our assertion that recent high water levels on the Great Lakes (but particularly on Lake Erie) is the primary factor responsible for the large increase in abundance of Least Bitterns that we documented from 2017 to 2019. Firstly, we found a strong positive relationship between abundance of Least Bitterns and water levels during the breeding season (i.e., May to July) for Lake Ontario and Lake Erie, and it is clear that the increase in abundance on Lake Erie was the primary influence on the increase in abundance for southern Ontario. Most apparent were the high abundance values in years when water levels were high on Lake Erie (in 1997, 1998, 2009, 2011, 2017, 2018 and 2019) (Figure 10). Secondly, we found that the abundance of Least Bitterns at coastal stations (i.e., those directly influenced by fluctuating Great Lakes water levels) mirrored the changes observed across years throughout southern Ontario, whereas abundance at inland stations was reasonably consistent across the entire study period (Figure 9). It has been suggested that inland wetlands in the Great Lakes basin may act as shelter for some marsh-associated bird species during low-water years in the Great Lakes (Gnass Giese *et al.* 2018); however, we did not observe a decrease in abundance at inland stations in high water years that would indicate that Least Bitterns preferentially relocate to coastal marshes from inland marshes when Great Lakes water levels are high. We also note that water levels at inland locations are unavailable, which would provide stronger justification for this interpretation. It is therefore possible that birds that might normally travel farther north to areas not sampled or less rigorously sampled by the GLMMP are utilizing coastal wetlands on Lake Erie that provided better habitat in high water years. In this scenario, it is likely that high water levels resulted in increased interspersion between emergent vegetation (cattails or European Common Reed) and open water, or increased the depth and/or the extent of standing water within dense, closed emergent vegetation patches, each of which ultimately improved the quality of nesting habitat for Least Bitterns (Jobin *et al.* 2009, Rehm and Baldassarre 2007). Under high-water scenarios, persistent emergent vegetation such as cattails may also expand landward (Smith *et al.* in press), which could create additional nesting habitat farther upland and enhance the quality of coastal habitat for Least Bitterns even further. Our results are also consistent with previous studies that identified similar links between abundance of Least Bitterns and fluctuating water levels (Timmermans *et al.* 2008, Jobin *et al.* 2009).

Interestingly, there was a modest, but consistent increase in the abundance of Least Bitterns in the upper St. Lawrence River basin over the study period that appeared to be unrelated to water levels (Figure 7 and Figure 8). It is possible that this trend reflects improvements in conservation-based land-use practices in the region, a range expansion as a result of climate change (Langham *et al.* 2015), or increased survivorship throughout migration and over-wintering, but these explanations require further investigation.

In this study, we used data collected for Birds Canada's GLMMP over two decades, primarily by volunteer citizen scientists, to assess changes in abundance among different geographical locations and across years for a provincially and federally *Threatened* species at risk, which speaks to the high conservation value of citizen science monitoring programs. We identified an increase in the abundance of Least Bitterns in southern Ontario (especially in coastal wetlands of Lake Erie) that appeared to primarily correspond to recent record-high water levels in the Great Lakes basin. Although this appears to be a good-news story for this species of priority conservation concern, it should be emphasized that Great Lakes water levels naturally fluctuate over time, going through extended periods of lows and highs, so it is reasonable to expect a

Least Bittern.
Photo: Gilles Bisson

decline in abundance of Least Bitterns when water levels eventually begin to recede. Furthermore, ongoing human-induced climate change is expected to cause more frequent climate extremes in the future, potentially with more frequent switching between low and high water periods across the Great Lakes, which adds even more uncertainty to predicting the future for Least Bitterns. It is also important to emphasize that the increase in abundance reported here may be due to a change in distribution of Least Bitterns moving into our study area during high water rather than an increase in the total size of the population. Nonetheless, the recent increase that we observed, if it represents a genuine increase in total population size, is encouraging for this species at risk in Ontario and Canada.

Acknowledgements

We are grateful for the dedication of participants in Birds Canada's GLMMP. In particular, we thank Tracy Barber, Catherine Jardine and Kathy Jones for their time scanning, organizing and proofing data. In addition, we are grateful to a large team of volunteer regional coordinators that assist and help motivate GLMMP participants in their local areas. We thank John Brett (Canadian Wildlife Service) and members of the Scientific Advisory Committee of Birds Canada's Long Point Waterfowl and Wetlands Research Program for comments that improved the paper. The GLMMP and our analysis received support from Birds Canada, Ducks Unlimited Canada, Eastern Habitat Joint Venture, Government of Canada, Government of Ontario, John and Pat McCutcheon Charitable Foundation, Nature Conservancy of Canada, SC Johnson, TD Friends of the Environment Foundation, The Bluff's Hunting Club and Wildlife Habitat Canada.

Literature Cited

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2009. COSEWIC assessment and update status report on the Least Bittern *Ixobrychus exilis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, ON. 36 pp.

ESA (Endangered Species Act). 2007. Endangered Species Act, 2007, S.O. 2007, c.6. https://www.ontario.ca/laws/statute/07e06. Retrieved 1 July 2020.

Environment Canada. 2014. Recovery strategy for the Least Bittern (*Ixobrychus exilis*) in Canada. Species at Risk Act Recovery Strategy Series. Environment Canada. Ottawa, ON. 41 pp.

Gnass Giese, E.E.G., R.W. Howe, A.T. Wolf and **G.J. Niemi.** 2018. Breeding birds and anurans of dynamic coastal wetlands in Green Bay, Lake Michigan. Journal of Great Lakes Research 44:950-959.

Jobin, B., L. Robillard and **C. Latendresse**. 2009. Response of a Least Bittern *(Ixobrychus exilis)* population to interannual water level fluctuations. Waterbirds 32:73-80.

Jung, J.A., D. Rokitnicki-Wojcik and **J.D. Midwood**. 2017. Characterizing past and modelling future spread of *Phragmites australis ssp. australis* at Long Point Peninsula, Ontario, Canada. Wetlands 37:961-973.

Langham, G.M., J.G. Schuetz, T. Distler, C.U Soykan and **C. Wilsey.** 2015. Conservation status of North American birds in the face of future climate change. PLOS One 10:e0135350.

OBC (Ontario Biodiversity Council). 2015. State of Ontario's biodiversity. Ontario Biodiversity Council, Peterborough, ON. http://sobr.ca/_biosite/wp-content/uploads/SOBR-2015_all-indicators_May-19-2015.pdf. Retrieved 9 April 2020.

Poole, A.F., P.E. Lowther, J.P. Gibbs, F.A. Reid and **S.M. Melvin**. 2020. Least Bittern (*Ixobrychus exilis*), version 1.0. In Birds of the World (A.F. Poole, ed.). Cornell Lab of Ornithology. Ithaca, NY.

Rehm, E.M. and **G.A. Baldassarre**. 2007. The influence of interspersion on marsh bird abundance in New York. Wilson Journal of Ornithology 119:648-654.

Robichaud, C.D. and **R.C. Rooney**. 2017. Long-term effects of a *Phragmites australis* invasion on birds in a Lake Erie coastal marsh. Journal of Great Lakes Research 43:141-149.

Sibley, D.A. 2016. Field guide to birds of eastern North America. Alfred A. Knopf. New York, NY. 466 pp.

Smith, I.M., G.E. Fiorino, G.P. Grabas and **D.A. Wilcox**. (in press). Wetland vegetation response to record-high Lake Ontario water levels. Journal of Great Lakes Research.

SARA (Species at Risk Act). 2002. Species at Risk Act (S.C. 2002, c. 29). https://laws.justice.gc.ca/eng/acts/S-15.3/. Retrieved 1 July 2020.

Timmermans, S.T.A., S.S. Badzinski and **J.W. Ingram**. 2008. Associations between breeding marsh bird abundances and Great Lakes hydrology. Journal of Great Lakes Research 34:351-364.

Tozer, D.C. 2020. Great Lakes Marsh Monitoring Program: 25 years of conserving birds and frogs. Birds Canada. Port Rowan, ON. https://www.birdscanada.org/glmmp25. Retrieved 1 October 2020.

Tozer, D.C. and **S.A. McKenzie**. 2019. Control of invasive *Phragmites* increases marsh birds but not frogs. Canadian Wildlife Biology and Management 8:66-82.

Tozer, D.C., C.M. Falconer, A.M. Bracey, E.E. Gnass Giese, G.J. Niemi, R.W. Howe, T.M. Gehring and **C.J. Norment**. 2017. Influence of call broadcast timing within point counts and survey duration on detection probability of marsh breeding birds. Avian Conservation and Ecology 12:8.

Tozer, D.C., O. Steele and **M. Gloutney.** 2018. Multispecies benefits of wetland conservation for marsh birds, frogs, and species at risk. Journal of Environmental Management 212:160-168.

Woodliffe, A.P. 1987. Least Bittern. In Cadman, M.D., P.F.J. Eagles and F.M. Helleiner (eds.). Atlas of the Breeding Birds of Ontario. University of Waterloo Press. Waterloo, ON.

Woodliffe, A.P. 2007. Least Bittern. In Cadman, M.D., D.A. Sutherland, G.G. Beck, D. Lepage and A.R. Couturier (eds.). Atlas of the Breeding Birds of Ontario, 2001-2005. Bird Studies Canada, Environment Canada, Ontario Field Ornithologists, Ontario Ministry of Natural Resources and Ontario Nature. Toronto, ON.

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