Least Bittern Occupancy Dynamics and Detectability in Manitoba, Ontario, and Québec

Author(s): Benoît Jobin , Marc J. Mazerolle , Nickolas D. Bartok , and Ron Bazin
Source: The Wilson Journal of Ornithology, 125(1):62-69. 2013.
Published By: The Wilson Ornithological Society
DOI: http://dx.doi.org/10.1676/12-046.1
URL: http://www.bioone.org/doi/full/10.1676/12-046.1

The Wilson Journal of Ornithology 125(1):62–69, 2013

LEAST BITTERN OCCUPANCY DYNAMICS AND DETECTABILITY IN MANITOBA, ONTARIO, AND QUÉBEC

BENOÎT JOBIN,[1,5] MARC J. MAZEROLLE,[2] NICKOLAS D. BARTOK,[3] AND RON BAZIN[4]

ABSTRACT.—We conducted 3,050 point counts from 2005–2009 (May–Jul) in 82 wetlands in three Canadian provinces (Ontario, Québec, and Manitoba) to quantify colonization and extinction dynamics of Least Bittern (*Ixobrychus exilis*) populations to detect geographic variations across provinces and to analyze effects of weather conditions, date, and survey methodology that may affect detection probability of Least Bitterns. Least Bitterns were detected at 773 (25%) of the 3,050 point counts with birds detected in 25, 26, and 28% of all point counts in Ontario, Québec, and Manitoba, respectively. Occupancy probability in the first year of the study was lower in Québec sites (0.26) compared to Manitoba sites (0.53). However, Québec sites had higher probabilities of colonization (0.67) than Ontario (0.32) and Manitoba (0.27). Probabilities of extinction did not differ across provinces but varied across years. Detection probability did not vary with weather variables (cloud cover, wind speed, air temperature – linear or quadratic effect) but decreased from mid-May (0.19) to mid-July (0.09). Detection probability was lower (0.13) for the first passive listening period than the call-broadcast period (0.28) and the second passive listening period (0.33). Observed differences in extinction and colonization probability between provinces and years show that occupancy dynamics vary both temporally and geographically, stressing the need to continue long-term monitoring of Least Bittern populations across the breeding range to detect geographic variation and changes in occupancy. We recommend Least Bittern surveys begin in mid-May at higher latitudes and use a second passive listening period following the call-broadcast period to increase detection of the species. *Received 20 March 2012. Accepted 21 June 2012.*

Key words: colonization, detection probability, extinction, *Ixobrychus exilis*, Least Bittern, occupancy dynamics.

The Least Bittern (*Ixobrychus exilis*) is a wetland-obligate bird that generally breeds from southern Canada to southern South America in wetlands with tall emergent vegetation such as cattail (*Typha* sp.), bulrush (*Scirpus* sp., *Schoenoplectus* sp.), and bur-reed (*Sparganium* sp.) interspersed with clumps of shrubs and open water (Bogner and Baldassarre 2002, Lor and Malecki 2006, Poole et al. 2009). Least Bittern are threatened in numerous states and Canada (SARA 2002, NatureServe 2011), primarily because of loss of wetlands in these regions (Dahl 2006, COSEWIC 2009, Ducks Unlimited Canada 2010). Although widely distributed in North America, Least Bittern population dynamics are still largely unknown. Geographic variation in extinction (an occupied site becoming unoccupied the next year) and colonization (an unoccupied site becoming occupied the next year) dynamics needs to be documented for efficient management of Least Bittern.

Some individuals are likely undetected during avian point count surveys. Thus, detection probability should be estimated to derive reliable estimates of occupancy and abundance (Thompson 2002, MacKenzie et al. 2002). Season, weather conditions, and survey methodology affect the detection probability of bird species detected primarily from auditory cues (Conway et al. 2004, Gonzalo-Turpin et al. 2008, Nadeau et al. 2008, Conway and Gibbs 2011). These effects need to be further studied for secretive species such as the Least Bittern and other marsh birds (Conway and Gibbs 2011).

Least Bitterns surveys were conducted in recent years in high-priority wetlands in three Canadian provinces which enabled us to quantify occupancy dynamics of Least Bittern and to analyze the effects of various factors on Least Bittern detection probability. Our objectives were to (1) quantify colonization and extinction dynamics of Least Bittern populations across provinces to detect geographic variations and (2) quantify the effects of weather variables, Julian date, and survey methodology on detection probability to provide recommendations for more efficient Least Bittern surveys.

[1] Canadian Wildlife Service, Environment Canada, 801-1550, avenue d'Estimauville, Québec, QC G1J 0C3, Canada.

[2] Centre d'étude de la forêt, Université du Québec en Abitibi-Témiscamingue, Rouyn-Noranda, QC J9X 5E4, Canada.

[3] Long Point Waterfowl, P. O. Box 160, 115 Front Street, Port Rowan, ON N0E 1M0, Canada.

[4] Canadian Wildlife Service, Environment Canada, 150-123 Main Street, Winnipeg, MB R3C 4W2, Canada.

[5] Corresponding author; e-mail: benoit.jobin@ec.gc.ca

METHODS

Least Bittern Surveys.—We conducted point count surveys in 82 wetlands in three provinces (47 in Ontario, 27 in Québec, 8 in Manitoba) where Least Bitterns breed in Canada (Fig. 1). Wetland size ranged from 1–980 ha (mean = 80 ha) and 18 wetlands (6 in Ontario, 8 in Québec, 4 in Manitoba) were man-made impoundments with water-control systems. Cattail was the primary vegetation at most survey stations with common reed (*Phragmites australis*), bur-reed, flowering rush (*Butomus umbellatus*), sedges (e.g., *Carex* sp.), buttonbush (*Cephalanthus occidentalis*) and willows (*Salix* sp.) dominating in only a few areas (Jobin et al. 2011a).

We conducted point count surveys from 2005–2009 (~14 May–22 Jul) using a standardized Least Bittern survey protocol (Jobin et al. 2011b). Point counts were 13 min long divided into three periods: 5 min of passive listening, 5 min of call broadcasts (each min consisting of 30 sec of the Least Bittern 'coo-coo' call followed by 30 sec of silence), followed by 3 min of passive listening. Surveys in 2005 consisted of 4 min of passive listening, 5 min of call broadcasts, and 4 min of passive listening. Survey stations were spaced ≥250 m and spot mapping was used to avoid double counting of the same individual from adjacent stations or within stations. Most surveys were performed by two observers (a few were conducted by a single observer) and Least Bittern detection at each station represents the combined efforts of all observers. We surveyed a few wetlands in each province up to five times in any given year with a minimum 10-day interval between visits to maximize detection during the nest initiation and egg laying period, which generally extends from early-May to early-August (Bogner and Baldassarre 2002). We visited some wetlands during two years, whereas others were only surveyed one year. We recorded air temperature, cloud cover, precipitation, and wind speed (Beaufort scale). Surveys were not conducted during adverse weather conditions including heavy rain, extreme heat (>30 °C), or strong winds (>19 km/hr or >3 on the Beaufort scale).

Multiple Season Occupancy Analyses.—We considered the three periods of the point count (i.e., first passive listening, playback, second passive listening) as separate visits for any given survey date and built detection histories for each station. We estimated the occupancy dynamics, namely colonization (γ) and extinction (ε) probabilities of Least Bitterns, at the survey station scale using multiple season occupancy models (MacKenzie et al. 2003, 2006). In cases where the probability of detection (P) is less than one, this type of model enables the distinction between non-detection and absence of a species at a station (MacKenzie et al. 2006). Multiple season occupancy models assume that survey stations are closed to changes in occupancy (ψ) within a given season (in this case a breeding season), whereas they allow changes in occupancy between seasons (years). Heterogeneity in occupancy, colonization, extinction, or detection probability was modeled with covariates (see below). Occupancy models accounted for Least Bittern presence within a survey station regardless of abundance, sex and type of detection (aurally or visually), as a single male Least Bittern was generally detected at any given station.

We considered two separate scenarios on the probability of occupancy in the first year, namely, an effect of water level control (regulated or not) and an effect of province. We considered three scenarios on extinction probability. First, we considered constant extinction probability for all stations, regardless of province (null model). Second, we considered constant extinction probability for stations in a given province but different across provinces (province model). Third, we considered a year effect on extinction probability (year model). Similarly, we formulated three identical scenarios on colonization probability, with a null model, province model, and year model.

Factors Affecting Detection Probability.—Based on recommendations by Conway and Gibbs (2011), we tested the effect of a number of factors on the detection probability of Least Bitterns by developing five scenarios: (1) weather variables (air temperature, cloud cover, wind speed), (2) same as 1) but with quadratic effect of air temperature, (3) sampling date (Julian date) and year, (4) province (to reflect geographical trends), and (5) constant detection (intercept only on detection) as a baseline. We included sampling effort (i.e., the product of number of observers and time surveying for each period) and sampling method (first passive listening period vs. call-broadcast period vs. second passive listening period) as covariates in all models.

We formulated 90 multiple season occupancy models based on combinations of our two scenarios on occupancy probability in the first year,

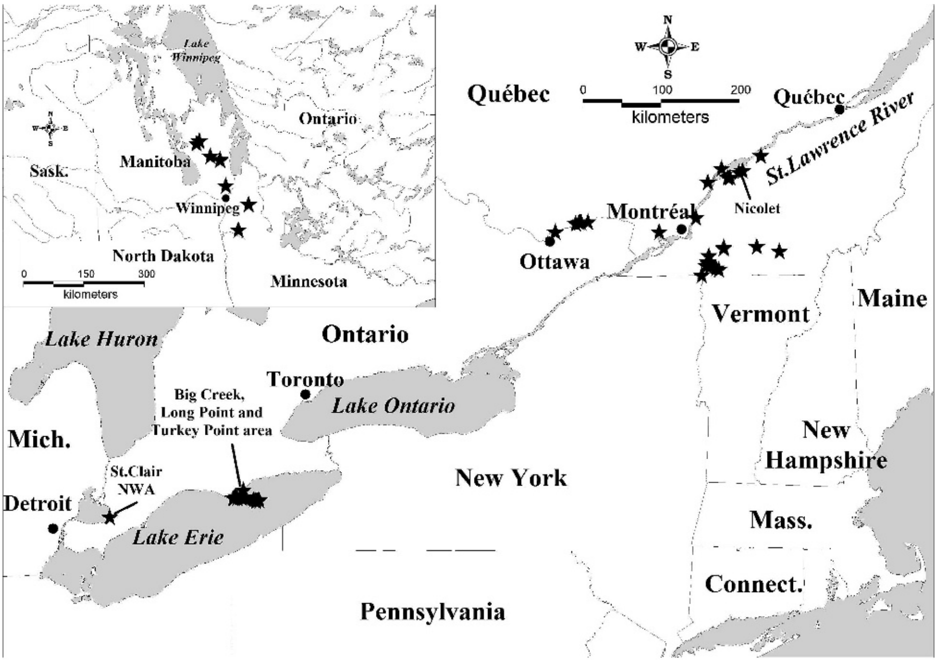

FIG. 1. Wetlands where Least Bitterns were surveyed in Ontario, Québec, and Manitoba from 2005–2009. Inset shows wetland locations in Manitoba.

three scenarios on extinction probability, three scenarios on colonization probability, and five scenarios on detection probability ($2 \times 3 \times 3 \times 5 = 90$). We also considered a null model with all parameters constant. All numeric covariates were centered prior to analysis and we discarded variables that were highly correlated (Pearson $r > |0.7|$) in the same model. Parameters were estimated with maximum likelihood in R 2.15.1 (R Development Core Team 2012) using the unmarked package (Fiske and Chandler 2011). We ranked multiple season models according to the AIC corrected for small sample sizes (AIC_c) with the number of survey stations as sample size, and computed associated measures to assess the support in favor of each model with the AICcmodavg package (Burnham and Anderson 2002; Mazerolle 2006, 2012).

RESULTS

We conducted a total of 3,050 point counts (Table 1). Specifically, we conducted 1,809 point counts at 380 survey stations in southern Ontario wetlands (mean = 8.1 stations/wetland; range = 1–12); 813 point counts at 263 survey stations in southern Québec wetlands (mean = 9.9 stations/wetland; range = 3–35); and 428 point counts at 122 survey stations in Manitoba wetlands (mean = 15.3 stations/wetland; range = 5–50). Overall, Least Bitterns were detected at 773 (25%) of the 3,050 point counts (Table 1) with birds detected in 25, 26, and 28% of all point counts in Ontario, Québec, and Manitoba, respectively. The top-ranked model had a weight of 0.64 (Table 2) and favored different initial occupancy for each province, different colonization probabilities for each province, different extinction probabilities for each year, and Julian date and year effects on detection probability. The second-ranked model ($w_i = 0.24$) had the same structure, except it supported a constant extinction probability throughout all years. The evidence ratio (0.69/0.23) between these two models suggested the highest-ranked model was 2.6 times more likely to be the most parsimonious model.

Occupancy Dynamics.—There was no support in favor of an effect of water level control on occupancy in the first year, as indicated by very low Akaike weights (Table 2). Least Bittern occupancy in 2005 did not vary with water level control as the 95% confidence interval around the model-averaged estimate largely included 0 ([−0.96, 0.48], Table 3). However, Least Bittern model-averaged occupancy probability in 2005

TABLE 1. Number of survey stations, point counts, Least Bittern surveys, and point count periods with Least Bittern detections in Ontario, Québec and Manitoba from 2005–2009.

Province	Year	No. of stations	No. of point counts*	Point counts with LEBI	
				No.	%
Ontario	2007	109	430	115	26.7
Ontario	2008	193	375	94	25.1
Ontario	2009	351	1,004	235	23.4
Total	All years	380	1,809	444	24.5
Québec	2005	100	306	33	10.8
Québec	2006	65	234	84	35.9
Québec	2007	22	34	7	20.6
Québec	2008	69	133	43	32.3
Québec	2009	51	106	43	40.6
Total	All years	263	813	210	25.8
Manitoba	2005	50	177	55	31.1
Manitoba	2006	39	117	21	17.9
Manitoba	2008	70	134	43	32.1
Total	All years	122	428	119	27.8
All provinces	2005	150	483	88	18.2
All provinces	2006	104	351	105	29.9
All provinces	2007	131	464	122	26.3
All provinces	2008	332	642	180	28.0
All provinces	2009	402	1,110	278	25.0
Total	All years	765	3,050	773	25.3

* Each point count yielded three distinct observation periods (passive listening before playback, playback, passive listening after playback).

was lower in Québec (model-averaged estimate: 0.26, 95% *CI*: 0.18, 0.36) than in Manitoba (model-averaged estimate: 0.53, 95% *CI*: 0.39, 0.66; no estimate for Ontario as no survey was conducted in 2005). Colonization probability did not vary across years, but Québec survey stations had a greater colonization probability (0.67) than Ontario (0.32) and Manitoba (0.27) (Fig. 2A). Extinction probability did not vary across provinces but varied weakly across years, with the greatest estimate in 2007 (0.44) (Fig. 2B).

Factors Affecting Detection Probability.— Weather variables (cloud cover range: 0–100%, wind speed range: 0–20 km/hr, air temperature range: 5–34 °C) had very weak support relative to year and Julian date, as all model including weather variables had very low Akaike weights (i.e., $w_i < 0.0001$, Table 2). Models with constant detectability (intercept only) had the lowest rankings of all models considered ($w_i < 0.0001$). The call-broadcast method affected detection probability. For a fixed sampling effort, detection probability was the lowest (0.13) for the first passive listening period of the point count relative to the call-broadcast period (0.28) and the second passive listening period (0.33) (Table 3;

TABLE 2. Top 6 multi-season occupancy models for the Least Bittern data from Ontario, Québec and Manitoba from 2005–2009, based on the AIC_c. Note that subscripts on each parameter indicate the variables assumed to influence the parameter. For instance, $\gamma_{Province}$ fits a different colonization probability for each province.

Model	Log-likelihood	K[1]	AIC_c	Δ AIC_c	Akaike weight (w_i)
$\psi_{Province}\ \gamma_{Province}\ \varepsilon_{Year}\ p_{Effort + Method + Year + Jday}$	−3,082.71	18	6,202.34	0	0.64
$\psi_{Province}\ \gamma_{Province}\ \varepsilon_{.}\ p_{Effort + Method + Year + Jday}$	−3,086.82	15	6,204.28	1.94	0.24
$\psi_{Province}\ \gamma_{Province}\ \varepsilon_{Province}\ p_{Effort + Method + Year + Jday}$	−3,085.93	17	6,206.68	4.34	0.07
$\psi_{Province}\ \gamma_{Year}\ \varepsilon_{Province}\ p_{Effort + Method + Year + Jday}$	−3,086.10	18	6,209.12	6.78	0.02
$\psi_{Province}\ \gamma_{Year}\ \varepsilon_{.}\ p_{Effort + Method + Year + Jday}$	−3088.96	16	6,210.65	8.32	0.01
$\psi_{Water\ level}\ \gamma_{Prov}\ \varepsilon_{Year}\ p_{Effort + Method + Year + Jday}$	−3,087.67	18	6,212.25	9.91	0.00

[1] Number of estimated parameters.

TABLE 3. Model-averaged parameter estimates on logit scale from multi-season occupancy models for Least Bittern data from Ontario, Québec, and Manitoba from 2005–2009.

Parameter*	Model-averaged estimate	Unconditional SE	95% unconditional CI
Occupancy in 2005 (ψ_{2005})			
β_{QC}	−1.19	0.37	−1.92, −0.45
$\beta_{Water.level}$	−0.24	0.37	−0.96, 0.48
Colonization (γ)			
β_{QC}	1.81	0.59	0.65, 2.98
β_{ON}	0.25	0.44	−0.61, 1.11
Extinction (ε)			
β_{2006}	0.54	0.78	−0.99, 2.07
β_{2007}	1.25	0.65	−0.03, 2.53
β_{2008}	0.31	0.68	−1.02, 1.64
Detection probability (P)			
β_{Jday}	−0.01	0.002	−0.02, −0.01
β_{2006}	−0.05	0.14	−0.34, 0.23
β_{2007}	0.28	0.14	0.01, 0.55
β_{2008}	0.64	0.14	0.36, 0.92
β_{2009}	0.21	0.13	−0.04, 0.45
$\beta_{Passive1}$	−1.19	0.14	−1.45, −0.92
$\beta_{Playback}$	−0.22	0.13	−0.48, 0.04
β_{Effort}	0.04	0.03	−0.02, 0.10

*Dummy variables (n level − 1) were used for these categorical variables with Manitoba as the reference level for the calculation of γ and ψ_{2005}; 2005 for the calculation of ε and Passive 2 for the calculation of P.

Fig. 3A). Detection probability was greatest early in the season (mid-May; 0.19) and decreased thereafter to mid-July (0.09) (Table 3, Fig. 3B). Average detection probability varied moderately across years (0.32–0.48) (Table 3; Fig. 3C) and sampling effort did not influence detection probability (Table 3).

DISCUSSION

Occupancy Dynamics.—Our results indicated that occupancy dynamics varied both temporally and geographically with different extinction probability across years and greater colonization probability in Québec than either in Ontario or Manitoba. During the first year of the study,

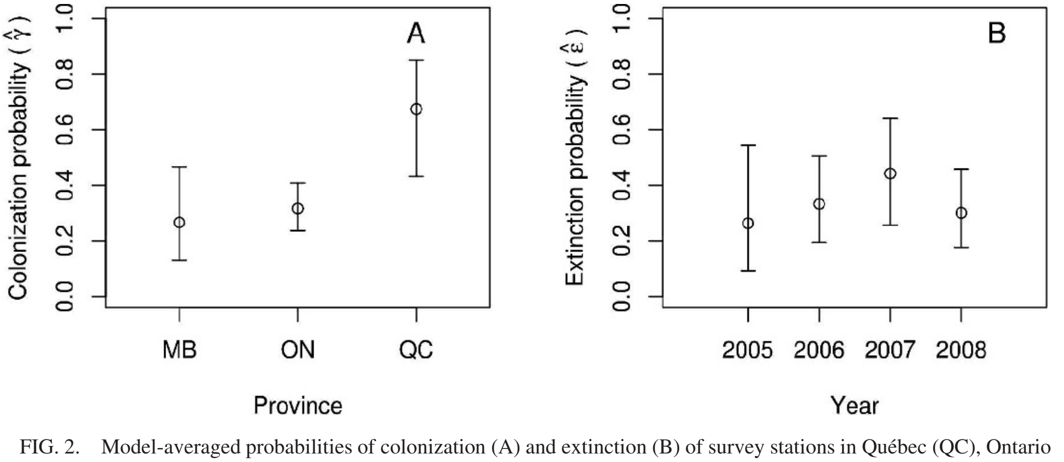

FIG. 2. Model-averaged probabilities of colonization (A) and extinction (B) of survey stations in Québec (QC), Ontario (ON), and Manitoba (MB) surveyed for Least Bitterns from 2005–2009. Error bars denote 95% unconditional confidence intervals back-transformed from the logit scale.

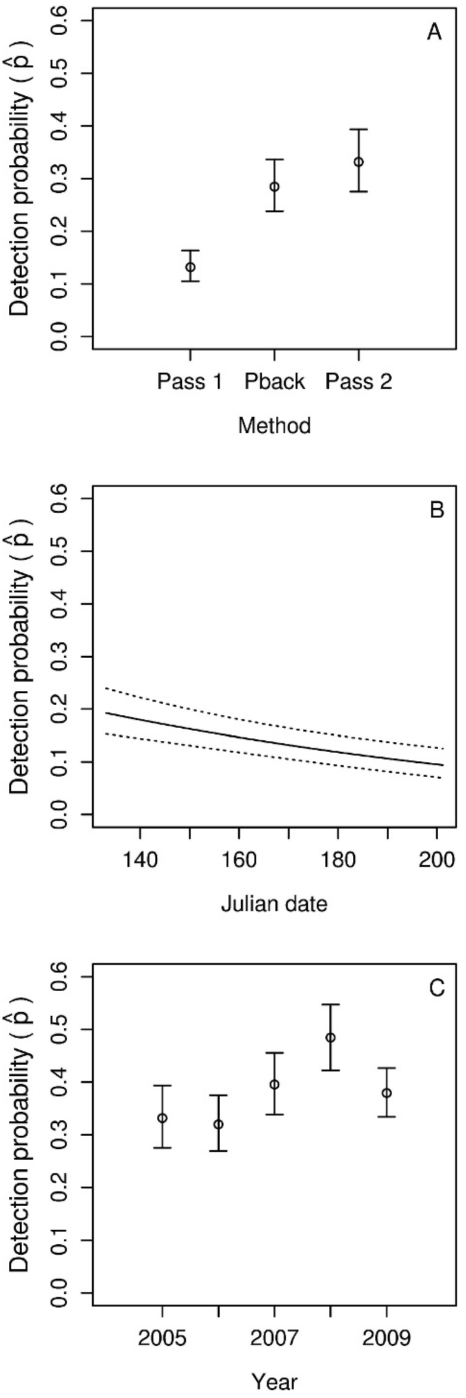

FIG. 3. Least Bittern detection probability during surveys at stations in Ontario, Québec, and Manitoba from 2005–2009 across sampling method (A), Julian date (B), and year (C). Note that predictions were computed with numeric covariates held constant to their mean value and

Québec sites had a substantially lower occupancy than Manitoba sites (0.26 vs 0.53). Many of the unoccupied sites in Québec were colonized by Least Bittern in later years, resulting in occupancy probability between 0.6–0.7 thereafter. These changes may reflect regional and annual water-level fluctuations and weather pattern variations that could in turn affect habitat suitability and associated bird settlement patterns and reproductive success. As such, nearly ¼ of stations visited in 2005 in Québec were in the Nicolet impoundments where water level was abnormally low resulting in low occupancy followed by an increase in site occupancy in 2006 because of higher water level (Jobin et al. 2009). In addition, wetland conditions change through anthropogenic impacts and natural processes (Lougheed et al. 2008, Keddy 2010) which could modify long-term occupancy dynamics. Observed extinction and colonization variability may also be associated with unknown factors occurring along migration routes or in wintering areas (COSEWIC 2009, Poole et al. 2009) which may also cause annual variation in occupancy dynamics. Nonetheless, only continued monitoring of Least Bittern populations across the breeding range will allow for detection of geographic variation and changes in occupancy and for implementation of associated management actions.

Factors Affecting Detection Probability.— Previous studies have shown that call-broadcast either increased or had no effect on Least Bittern detection (Conway and Gibbs 2011). Our observation of greater Least Bittern detection probability during the playback period compared to the passive listening period prior to playback emphasizes the importance of broadcasting the call of the Least Bittern for several minutes to increase detection of this species (Swift et al. 1988, Bogner and Baldassarre 2002, Rehm and Baldassarre 2007). Furthermore, we noted that Least Bittern detection increases during the second passive listening period after the call-broadcast period. Although this additional period is not part of the Standardized North American Marsh Bird Monitoring Protocol (Conway 2009, 2011), additional

←

categorical variables at the reference level. Dotted lines and error bars indicate 95% unconditional confidence limits (back-transformed from the logit scale) around predicted detection probabilities.

Least Bitterns have been detected during this period, stressing the need to add this second passive listening period during Least Bittern surveys (Jobin et al. 2011b).

Past studies did not detect clear evidence on the effect of weather conditions on the detection probability of marsh birds, possibly because of overwhelming effects of time of day or season (Nadeau et al. 2008, Conway and Gibbs 2011). We specifically tested the effect of air temperature (both linear or quadratic effects), wind speed, or cloud cover on Least Bittern detection probability while controlling for covariates such as season, year, province, and survey method, and we did not find any effect of weather conditions on Least Bittern detection probability. Surveys were conducted when air temperature was between 5–34 °C, wind speed was between 0–20 km/hr, and cloud cover was between 0–100%. These values are within recommended survey conditions (Conway 2011, Jobin et al. 2011b) and Least Bittern detection probability was not impaired when surveys were conducted under this wide range of weather conditions.

Seasonal peaks in vocalization probability vary geographically among coexisting species and years (Rehm and Baldassarre 2007, Conway and Gibbs 2011). Geographical discrepancies in vocalization activity are likely associated with the timing of the spring migration and arrival on breeding grounds with later peaks most likely to be observed at higher latitudes. We conducted three surveys from mid-May to mid-July at most survey stations, ensuring that at least one survey was conducted during the peak of the Least Bittern clutch initiation period when birds are most likely to vocalize (Bogner and Baldassarre 2002, Darrah and Krementz 2010). Our data showed that Least Bittern song activity reaches a maximum around mid-May/early June in Canada and decreases thereafter. Point count surveys should therefore start in mid-May at higher latitudes such as southern Canada when Least Bittern vocalization activity is high.

ACKNOWLEDGMENTS

We thank landowners for granting access to their properties and all surveyors and volunteers, for their assistance with field work, most notably G. E. Desy, M. Duong, P. Fradette, I. Fife, C. A. Friis, C. Kovacs, C. Latendresse, L. Latramouille, P. Messier, S. W. Meyer, J. Palframan, M. Pilakowski, S. Richer, A. Richman, L. Robillard, M. Seabert, and G. Tremblay. We also thank L. A. Maynard for her continued support through the years, Canadian Wildlife Service managers for data sharing and continued support, and M. Schummer for his comments on the manuscript. Funding was provided by Environment Canada, Long Point Waterfowl, Ontario Ministry of Natural Resources, Bird Studies Canada, Nature Canada, Canada-Ontario Agreement, the World Wildlife Fund Canada, S. C. Johnson and Son Ltd., and the Bluff's Hunt Club.

LITERATURE CITED

Bogner, H. E. and G. A. Baldassarre. 2002. The effectiveness of call-response surveys for detecting Least Bitterns. Journal of Wildlife Management 66:967–984.

Burnham, K. P. and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Second Edition. Springer-Verlag, New York, USA.

Conway, C. J. 2009. Standardized North American marsh bird monitoring protocols. Wildlife Research Report Number 2009-02. U.S. Geological Survey, Arizona Cooperative Fish and Wildlife Research Unit, Tucson, USA.

Conway, C. J. 2011. Standardized North American marsh bird monitoring protocol. Waterbirds 34:319–346.

Conway, C. J. and J. P. Gibbs. 2011. Summary of intrinsic and extrinsic factors affecting detection probability of marsh birds. Wetlands 31:403–411.

Conway, C. J., C. Sulzman, and B. E. Raulston. 2004. Factors affecting detection probability of California Black Rails. Journal of Wildlife Management 68:360–370.

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, Ontario, Canada. www.sararegistry.gc.ca (accessed 16 Feb 2012).

Dahl, T. E. 2006. Status and trends of wetlands in the conterminous United States 1998 to 2004. USDI; Fish and Wildlife Service, Washington, D.C., USA.

Darrah, A. J. and D. Krementz. 2010. Occupancy and habitat use of the Least Bittern and Pied-billed Grebe in the Illinois and Upper Mississippi River valleys. Waterbirds 33:367–375.

Ducks Unlimited Canada. 2010. Southern Ontario wetland conversion analysis. Final Report. Ducks Unlimited Canada-Ontario Office, Barrie, Ontario, Canada. www.ducks.ca/aboutduc/news/archives/prov2010/pdf/duc_ontariowca.pdf (accessed 16 Feb 2012).

Fiske, I. and R. Chandler. 2011. An R package for fitting hierarchical models of wildlife occurrence and abundance. Journal of Statistical Software 43:1–23.

Gonzalo-Turpin, H., C. Sirami, L. Brotons, L. Gonzalo, and J.-L. Martin. 2008. Teasing out biological effects and sampling artifacts when using occupancy rate in monitoring programs. Journal of Field Ornithology 79:159–169.

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.

JOBIN, B., P. FRADETTE, AND S. LABRECQUE. 2011a. Habitat use by Least Bitterns (*Ixobrychus exilis*) in Québec. Waterbirds 34:143–150.

JOBIN, B., R. BAZIN, L. MAYNARD, A. MCCONNELL, AND J. STEWART. 2011b. Least Bittern (*Ixobrychus exilis*) survey protocol. Waterbirds 34:225–233.

KEDDY, P. A. 2010. Wetland Ecology: Principles and Conservation. Second Edition. Cambridge University Press, Cambridge, UK.

LOR, S. AND R. A. MALECKI. 2006. Breeding ecology and nesting habitat associations of five marsh bird species in western New York. Waterbirds 29:427–436.

LOUGHEED, V. L., M. D. MCINTOSH, C. A. PARKER, AND R. J. STEVENSON. 2008. Wetland degradation leads to homogenization of the biota at local and landscape scales. Freshwater Biology 53:2402–2413.

MACKENZIE, D. I., J. D. NICHOLS, J. E. HINES, M. G. KNUTSON, AND A. B. FRANKLIN. 2003. Estimating site occupancy, colonization, and local extinction when a species is detected imperfectly. Ecology 84:2200–2207.

MACKENZIE, D. I., J. D. NICHOLS, G. B. LACHMAN, S. DROEGE, A. ROYLE, AND C. A. LANGTIMM. 2002. Estimating site occupancy when detection probabilities are less than one. Ecology 83:2248–2255.

MACKENZIE, D. I., J. D. NICHOLS, J. A. ROYLE, K. H. POLLOCK, L. L. BAILEY, AND J. E. HINES. 2006. Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence. Academic Press, New York, USA.

MAZEROLLE, M. J. 2006. Improving data analysis in herpetology: using Akaike's Information Criterion (AIC) to assess the strength of biological hypotheses. Amphibia-Reptilia 27:169–180.

MAZEROLLE, M. J. 2012. AICcmodavg: Model selection and multimodel inference based on (Q)AIC(c). R package Version 1.24, Vienna, Austria. cran.r-project.org/web/packages/AICcmodavg/index.html (accessed 16 Feb 2012).

NADEAU, C. P., C. J. CONWAY, B. S. SMITH, AND T. E. LEWIS. 2008. Maximizing detection probability of wetland-dependant birds during point-count surveys in northwestern Florida. Wilson Journal of Ornithology 120:513–518.

NATURESERVE. 2011. NatureServe Explorer: an online encyclopedia of life. Version 7.1. NatureServe, Arlington, Virginia. www.natureserve.org/explorer (accessed 16 Feb 2012).

POOLE, A. F., P. LOWTHER, J. P. GIBBS, F. A. REID, AND S. M. MELVIN. 2009. Least Bittern (*Ixobrychus exilis*). The birds of North America. Number 17.

R DEVELOPMENT CORE TEAM. 2012. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. www.R-project.org (accessed 16 Feb 2012).

REHM, E. M. AND G. A. BALDASSARRE. 2007. Temporal variation in detection of marsh birds during broadcast of conspecific calls. Journal of Field Ornithology 78:56–63.

SARA (SPECIES AT RISK ACT). 2002. Bill C-5, An act respecting the protection of wildlife species at risk in Canada. Ottawa, Ontario, Canada. www.parl.gc.ca/HousePublications/Publication.aspx?DocId=2330990&Language=E&Mode=1&File=16 (accessed 16 Feb 2012).

SWIFT, B. L, S. R. ORMAN, AND S. W. OZARD. 1988. Response of Least Bitterns to tape-recorded calls. Wilson Bulletin 100:496–499.

THOMPSON, W. L. 2002. Towards reliable bird surveys: accounting for individuals present but not detected. Auk 119:18–25.