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Variation in Clapper Rail and Least Bittern Detection Probability Among Tidal Stages on the Northern Coast of the Gulf of Mexico.

Final Report

Christopher P. Nadeau, Courtney J. Conway, Meaghan A. Conway, and Joe Reinman

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Executive Summary

We surveyed clapper rails (*Rallus longirostris*) and least bitterns (*Ixobrychus exilis*) during high, mid, and low tides at St. Marks and St. Vincent National Wildlife Refuges on the northern coast of the Gulf of Mexico. The objective of our study was to determine the optimal tidal stage for conducting marsh bird surveys. We tested four different questions to address this objective: (1) does the number of marsh birds detected along survey routes differ among tidal stages? (2) does the optimal tidal stage for conducting surveys differ between boat- and land-based survey points? (3) does the optimal tidal stage for conducting surveys differ depending on the tidal range? and (4) does the optimal tidal stage for conducting surveys differ between the two species? The number of birds detected varied markedly among tidal stages during our surveys for both clapper rails and least bitterns, but the effect size was much greater for least bitterns. Moreover, the variation in the number of birds detected among tidal stages differed between boat- and land-based points for both species. We detected the most birds during high-tide surveys at boat-based points and a similar number of birds among the tidal stages at land-based points for both species. Furthermore, the variation in the number of clapper rails detected among tidal stages was greatest when the tidal range (i.e., the difference in water depth between high and low tide) was smallest. Our results suggest that marsh bird surveys on the northern coast of the Gulf of Mexico should be conducted during high tide at both boat- and land-based survey points to maximize the number of clapper rails and least bitterns detected.

Introduction

The amount of emergent wetland vegetation in North America has declined sharply during the past century (Tiner 1984). Populations of many marsh birds that are dependent on emergent wetlands appear to be declining (Tate 1986, Eddleman et al. 1988, Conway et al. 1994, Conway and Sulzman 2007). Despite evidence of population declines and the need to set responsible harvest limits, a monitoring program specifically designed to determine status and estimate population trends of marsh birds is lacking. The Breeding Bird Survey includes survey data on some secretive marsh birds, but does not adequately sample wetlands (Bystrak 1981, Robbins et al. 1986, Gibbs and Melvin 1993, Lawler and O'Connor 2004). Adequately sampling marsh bird populations can be difficult. Marsh birds (i.e., rails and bitterns) are among the most inconspicuous groups of birds in North America. They vocalize infrequently and often occur in isolated wetlands, which complicates efforts to monitor their populations (Bystrak 1981, Gibbs and Melvin1993).

For these reasons, managers and research scientists have put extensive effort into developing a marsh bird monitoring protocol over the last decade, including: (1) three workshops that discussed the design of a continental marsh bird monitoring protocol (Ribic et al. 1999, USFWS 2001, USFWS 2006), and (2) the development and testing of a draft monitoring protocol for North America (Conway 2009, Conway and Nadeau 2006, 2010, Conway et al. 2008). The protocols include methods to maximize the detection probability of these rare and inconspicuous birds. Maximizing detection probability of rare or inconspicuous birds during point-count surveys helps ensure that sufficient individuals are detected to reliably estimate population trends. Surveyors can use call-broadcast to increase marsh bird detection probability during point-count surveys (Conway and Gibbs 2005, Conway and Nadeau 2006, 2010, Nadeau et al. 2008), and recent research has sought to identify the time of day (Nadeau et al. 2008) and the time of year (Rehm and Baldassarre 2007) that is optimal for marsh bird surveys. However, tidal activity may also affect the detection probability of marsh birds in coastal areas, yet few studies have examined the tidal stage which is optimal for marsh bird surveys. The objective of this study was to examine the effects of tidal stage on numbers of marsh birds detected during standardized surveys on the northern coast of the Gulf of Mexico. We addressed four specific questions: (1) does the number of marsh birds detected along survey routes differ among tidal stages? (2) does the optimal tidal stage for conducting surveys differ between boat- and land-based survey points? (3) does the optimal tidal stage for conducting surveys differ depending on the tidal range? and (4) does the optimal tidal stage for conducting surveys differ between the two species?

Tidal stage may affect the number of marsh birds detected during surveys in a variety of ways. For example, birds may be pushed into areas of shallower water closer to the upland during high tide. This could affect detection probability in two opposite ways: (1) detection probability could increase because density in near-upland marshes is increased causing an increase in territorial vocalizations, or (2) detection probability could decrease because birds are more vulnerable to upland predators and hence they are reluctant to vocalize. The effects of tidal stage on number of marsh birds detected may also vary among locations in the marsh. For example, detection probability might decrease during low tide in deep-water sections of the marsh because the habitat is less fragmented causing a decrease in territorial vocalizations and mate-communication (Rush et al. 2009). In contrast, detection probability might increase during low tide in shallower water sections of the marsh if individuals forage over a wider area causing an increase in territorial vocalizations and mate-communication. We need more empirical data on the relationship between tide stage and the number of marsh birds detected during surveys in order to provide better guidance on survey timing for future marsh bird survey efforts.

We focused this study on two species: clapper rail (*Rallus longirostirs*) and least bittern (*Ixobrychus exilis*). These two species are ideal for examining the effect of tidal stage because they use opposite strategies for locomotion and nest placement within marsh vegetation. Hence, clapper rail and least bittern detection probability may be affected differently by tidal stage. Clapper rails move through the marsh primarily by swimming or walking on the substrate and they build their nests close to the ground (Eddleman and Conway 1998). This type of locomotion and nest placement is common among North American rails. Hence, clapper rail (and other rail) behavior likely changes in response to tides as rails are forced to move about the marsh due to varying water levels. In contrast, least bitterns typically move through the marsh vegetation well above the substrate and they build elevated nests (Gibbs et al. 1992). This strategy is similar to many marsh-obligate passerines. Hence, numbers of least bitterns detected during surveys (and that of marsh obligate passerines) may not differ among tidal stages as much as clapper rails unless most of the marsh vegetation is inundated with water. By comparing differences in numbers of clapper rails and least bitterns detected during surveys at different tide stages, we should better understand how detection probability varies among tidal stages for a larger group of marsh bird species.

Methods

We counted secretive marsh birds on St. Vincent and St. Marks National Wildlife Refuges following the point-count survey methods described by Conway (2009). We conducted 469 point-count surveys at 96 points on 8 survey routes (1 at St. Vincent NWR and 7 at St. Marks NWR) between 22 March and 1 June 2008. The survey period consisted of a five-minute initial passive period followed a five-minute call-broadcast period. The five-minute call-broadcast period consisted of 30 seconds of silence and 30 seconds of call-broadcast for each of the following five species in the following order: black rail (*Laterallus jamaicensis*), least bittern, clapper rail, common moorhen (*Gallinula chloropus*), and purple gallinule (*Porphyrio martinica*). Surveys were conducted either: 1) on foot from dike roads adjacent to tidal marshes (241 point-count surveys at 49 points), 2) from a kayak in a narrow, tidally influenced river (201 point-count surveys at 37 points), or 3) from a kayak in a tidal bay (27 point-count surveys at 10 points). We recorded whether each individual bird was located in a tidal marsh or a non-tidal marsh (at those points where birds could be detected in either). We removed all birds detected in non-tidal marshes prior to analysis. We conducted all surveys in the morning between first light and 9:50 AM or in the evening between 5:30 PM and dark.

We visited survey points 3 times (at high, mid, and low tides) within a 6-10 day period (hereafter we refer to these three paired visits as a survey block) so that we could examine the effects of tidal stage while controlling for variation among points and days. This design minimized the number of days between surveys at different tidal stages, which allowed us to control for any week-to-week variation in detection probability or abundance. This design also allowed us to control for inherent spatial variation in bird density among points. We conducted 1-3 replicate survey blocks at each of 96 survey points, which yielded a sample 172 survey blocks. We separated the survey blocks by at least 8 days at points where we surveyed more than one survey block. We surveyed during the same time of day for each of the three surveys within a survey block to control for differences in detection probability between morning and evening surveys. We also varied the chronological order in which we surveyed tidal stages within a survey block to control for any possible effects of using call-broadcast repeatedly at a survey point within a 6-10 day period.

We used daily high- and low-tide predictions from the University of South Carolina (Pentcheff 2008) to schedule high-, mid-, and low-tide surveys. We scheduled a high- or low-tide survey on days when the respective tidal stage occurred within 1 hour of sunrise for morning surveys or within 1 hour of sunset for evening surveys. We scheduled mid-tide surveys on days when neither high nor low tide occurred within 1 hour of sunrise for morning surveys or within 1 hour of sunset for evening surveys. The timing of tidal stages is strongly affected by weather patterns on the northern coast of the Gulf of Mexico and can therefore be difficult to predict from standard tide tables. Hence, we installed staff gauges on each of our survey routes and recorded water depth on those gauges during each survey on a route. We also developed an index (1-6) that we used to rank the amount of marsh inundated with water at each survey point (1 = marsh completely inundated; 6 = extensive mudflats present at the interface between open water and emergent vegetation). We used the staff gauge records and the inundation index from each survey to verify that the tide was highest on the high-tide survey and lowest on the low-tide survey within each survey block. We changed the tidal stage of the survey to the observed tidal stage if the scheduled and observed tidal stages differed. The scheduled and observed tidal stages matched on 71% of the survey blocks. We also used the difference between the minimum and maximum inundation index within a survey block to represent the tidal range within the survey block at each point (i.e., larger differences reflect a larger tidal range).

We used Poisson mixed models to evaluate whether the number of birds detected differed among tidal stages for both clapper rail and least bittern. We used Akaike's Information Criterion adjusted for small sample size (AICc) to compare a suite of candidate models. We defined top models as those models that had an AICc weight ≥0.10 and we assumed that all the explanatory variables included in the suite of top models influenced the number of birds detected. We included the random effect of survey block (nested within point, within route) in each of our models to account for the nested structure of our data. We compared 5 fixed-effects models to test the following hypotheses for each species: (1) the number of birds detected varied among tidal stages (TIDE_STAGE) and the effect differed between boat- and land-based points (UPLAND_PROXIMITY) and depended on the tidal range within the survey block (TIDAL_RANGE); (2) the number of birds detected varied among tidal stages, but the effect differed only between boat- and land-based points; (3) the number of birds detected varied among tidal stages, but the effect depended on the tidal range within the survey block; (4) the number of birds detected varied among tidal stages, and did not vary between boat- and land-based points or with tidal range; and (5) the number of birds detected did not vary among tidal stages. We defined tidal stage and the proximity to upland (boat- vs land-based points) as factors and tidal range as a covariate in each model. We centered the tidal-range covariate by subtracting the grand mean of the tidal range from the tidal-range measurement at each point. Grand-mean centering helps reduce estimation problems in hierarchical mixed models (Hoffman and Gavin 1998).

Results

We detected ≥1 clapper rail at each of the 96 survey points and we detected an average of 8.4 clapper rails per survey. We detected least bitterns at 44 of the 96 survey points and we detected an average of 0.20 least bitterns per survey across all surveys. We detected an average of 0.62 least bitterns per survey at the 44 points where we detected least bitterns.

Table 1. Candidate models to explain the number of clapper rails detected during three tidal stages (high, mid, and low). TIIDAL_STAGE was a repeated measure indicating the tidal stage during which the point-count survey was completed, UPLAND_PROXIMITY distinguishes boat- and land-based survey points, and TIDAL_RANGE is a covariate representing the tidal range within a survey block (i.e., the difference in the tidal height between the high- and low-tide survey).

Fixed Effects Model*	Deviance	K	AICc	ΔAICc	Weight
[TIDAL_STAGE] + [TIDAL_STAGE*UPLAND_PROXIMITY]	1343	7	1357.26	0.00	0.52
[TIDAL_STAGE] + [TIDAL_STAGE*UPLAND_PROXIMITY] + [TIDAL_STAGE*TIDAL_RANGE]	1339	9	1357.42	0.16	0.48
[TIDAL_STAGE] + [TIDAL_STAGE*TIDAL_RANGE]	1367	7	1381.26	24.00	<0.001
[TIDAL_STAGE]	1377	5	1387.14	29.88	<0.001
[.]	1391	4	1399.09	41.83	<0.001

**each model also contained a nested random effect of [ROUTE(POINT(SURVEY_BLOCK))]*

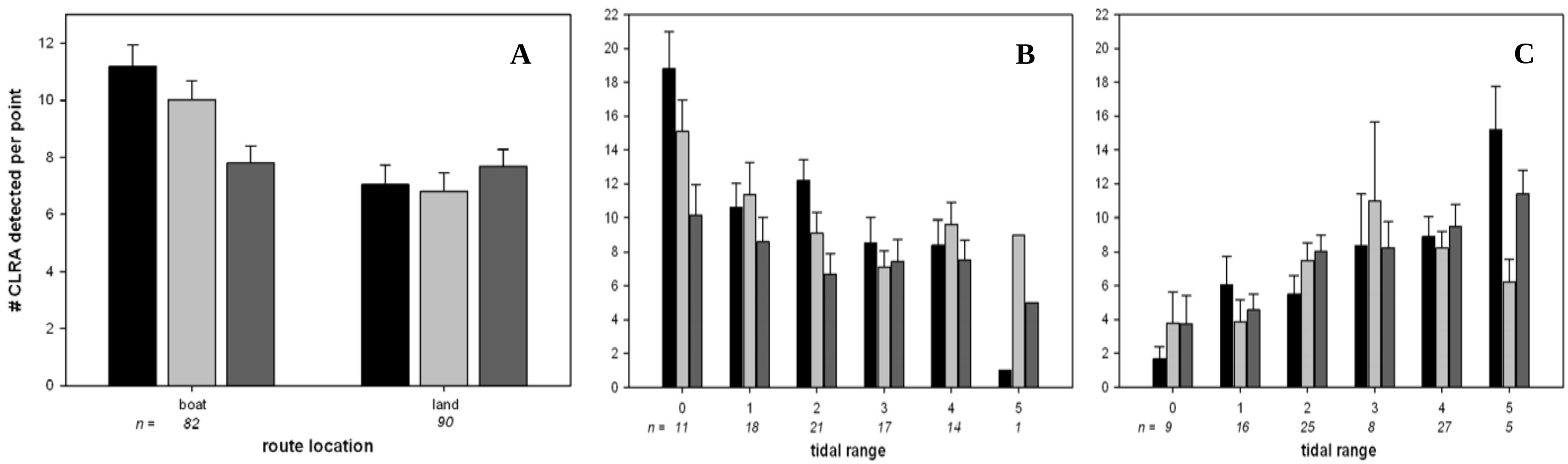

Figure 1. Number of clapper rails detected per point-count survey during high (black), mid (light grey), and low tide (dark grey) on: (A) survey points accessed by boat versus survey points accessed by land, (B) survey points accessed by boat at varying tidal ranges, and (C) survey points accessed by land at varying tidal ranges. Tidal range is the difference in the tidal height between high- and low-tide surveys in a survey block. The sample size listed under each group is the number of survey blocks in each group.

Table 1. Candidate models to explain the number of least bitterns detected during three tidal stages (high, mid, and low). TIIDAL_STAGE was a repeated measure indicating the tidal stage during which the point-count survey was completed, UPLAND_PROXIMITY distinguishes boat- and land-based survey points, and TIDAL_RANGE is a covariate representing the tidal range within a survey block (i.e., the difference in the tidal height between the high- and low-tide survey).

Fixed Effects Model*	Deviance	K	AICc	∆AICc	Weight
[TIDAL_STAGE] + [TIDAL_STAGE*UPLAND_PROXIMITY]	305.9	7	320.16	0.00	0.81
[TIDAL_STAGE] + [TIDAL_STAGE*UPLAND_PROXIMITY] + [TIDAL_STAGE*TIDAL_RANGE]	305.5	9	323.92	3.76	0.12
[TIDAL_STAGE]	316.2	5	326.34	6.18	0.04
[.]	319.9	4	327.99	7.83	0.02
[TIDAL_STAGE] + [TIDAL_STAGE*TIDAL_RANGE]	315.2	7	329.46	9.30	0.01

**each model also contained a nested random effect of [ROUTE/POINT/SURVEY_BLOCK]*

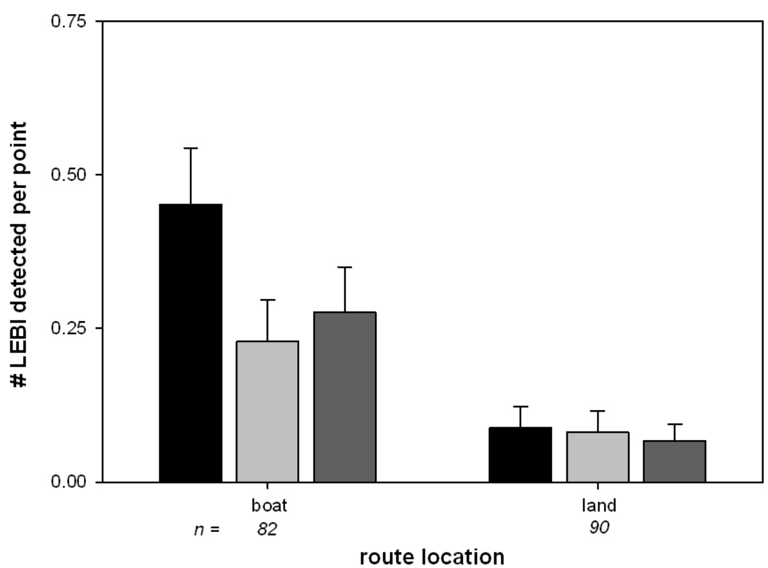

Figure 2. Number of least bitterns detected per point-count survey during high (black), mid (light grey), and low tide (dark grey) at survey points accessed by boat versus survey points accessed by land. The sample size listed under each group is the number of survey blocks in each group.

We found support for two of our candidate models for clapper rails: (1) the number of clapper rails detected varied among tidal stages, but the effect differed only between boat- and land-based points; and (2) the number of clapper rails detected varied among tidal stages and the effect differed between boat- and land-based points and depended on the tidal range within the survey block (Table 1). These two models received similar AICc weights suggesting they are both equally likely models to explain the data (Table 1). We detected the most clapper rails during high-tide surveys at boat-based survey points (Fig. 1A). We detected an average of 1.2 (12%) more clapper rails on high-tide surveys when compared to mid-tide surveys, and an average 3.4 (44%) more clapper rails on high-tide surveys when compared to low-tide surveys at boat-based survey points. In contrast, we detected a similar number of clapper rails among the tidal stages at land-based survey points (Fig. 1A). We observed the greatest effect of tidal stage on boat-based survey blocks with the smallest tidal range (Fig. 1B). We detected more clapper rails on boat-based high-tide surveys when the tidal range was small and similar numbers of clapper rails when the tidal range was large. We detected similar numbers of clapper rails among the tidal ranges on land-based surveys (Fig. 1C).

We also found support for two of our candidate models for least bitterns: (1) the number of least bitterns detected varied among tidal stages, but the effect differed only between boat- and land-based points; and (2) the number of least bitterns detected varied among tidal stages and the effect differed between boat- and land-based points and depended on the tidal range within the survey block (Table 2). The first model received most support (81% model weight) and tidal range appeared to be a pretending variable (Anderson 2008) suggesting that tidal stage and the interaction between tidal stage and upland proximity are the strongest explanatory variables (Table 2). Hence, we assumed that tidal range did not affect the number of least bitterns we detected. We detected the most least bitterns during high-tide surveys at boat-based survey points (Fig. 2). We detected an average of 0.22 (96%) more least bitterns on high-tide surveys when compared to mid-tide surveys, and an average 0.18 (64%) more least bitterns on high-tide surveys when compared to low-tide surveys at boat-based survey points. Similar to clapper rails, we failed to detect any differences in number of least bitterns among the tidal stages at land-based survey points (Fig. 2).

Discussion

The number of birds detected varied among tidal stages during our surveys for both clapper rails and least bitterns, but the effect size was greater for least bitterns. Moreover, the variation in the number of birds detected among tidal stages was most pronounced at boat-based points (compared to land-based points) for both species. Other studies have also found that clapper rail detection probability is highest during high-tide surveys on boat-based surveys on the northern coast of the Gulf of Mexico (Rush et al. 2009), but no prior study had evaluated whether detection probability varies among tidal stages for least bitterns or if the variation in detection probability among tidal stages differs between boat- and land-based survey points. The National Marsh Bird Monitoring Protocol (Conway 2009) encourages surveyors to establish survey routes that are accessed from a boat and other routes that are accessed from land. Hence, quantifying any differences in data collected from boat- and land-based surveys is important. Furthermore, the variation in the number of clapper rails detected among tidal stages on boat-based surveys was greatest when the tidal range within a survey block was smallest. This result is perplexing, but suggests that conducting surveys during the optimal tidal stage is important, even when the tidal range is small.

Numbers of clapper rails and least bitterns detected were both greatest during high tides at boat-based points, despite interspecific differences in locomotive strategy and nesting behavior. However, the few previous studies that have evaluated the effects of tide on detection probability of marsh birds suggest that there may be interspecific variation within regions. Clapper rail and seaside sparrow detection probability during call-broadcast point-count surveys was positively correlated with tidal height (i.e., the height of the water relative to mean sea level) on the coast of the Gulf of Mexico in Mississippi and Alabama, but marsh wren detection probability was negatively correlated with tidal height (Rush et al. 2009). More research is needed in other regions to determine the optimal tidal stage for surveying each focal species of the National Marsh Bird Monitoring Program. Understanding if the optimal tidal stage during which to conduct surveys differs among species is necessary to inform a national marsh bird survey effort. Consequently, if the optimal tidal stage during which to survey differs among species, survey protocols may need to make species-specific recommendations on the optimal tidal stage during which to conduct surveys.

Based on our results, we suggest that surveyors on the northern coast of the Gulf of Mexico conduct surveys during high tide regardless of whether their survey routes are boat- or land-based survey routes. Moreover, surveyors should record the tidal stage at the start of each survey (i.e., the time of the most recent high tide in the marsh(es) surveyed). Previous studies suggest regional differences in the optimal tidal stage at which to conduct marsh bird surveys. Contrary to our results, the frequency of spontaneous clapper rail vocalizations (Zembal and Massey 1987) and the detection probability of black rails during call-broadcast surveys (Spear 1999) were both negatively correlated with tidal height on the Pacific Coast of California. However, neither of these studies compared the detection probability of birds among tidal stages within a tidal-cycle. Regional differences in the effects of tidal-stage on detection probability of marsh birds (if indeed there are any) could be due to differences in a variety of factors: variation in tidal height, marsh structure (Rush et al. 2009), slope of the inter-tidal zone, or amount of vegetation in the upland adjacent to the tidal marsh. High tides on the Pacific Coast can completely submerge the marsh vegetation, forcing rails into the upland where they are less likely to vocalize (Zembal and Massey 1987). High tides on the northern coast of the Gulf of Mexico do not force rails out of the emergent marsh vegetation. We urge further research on the optimal tidal stage during which to conduct marsh bird surveys throughout North America at both land- and boat-based survey points.

Our results, and those of other studies, suggest that tidal stage can have a substantial effect on marsh bird detection probability. Hence, at the very least, surveyors need to standardize (and record) the tidal stage during which they conduct surveys both within a year and among years (Conway 2009, Rush et al. 2009). Doing so will reduce unnecessary variation in counts across surveys (or allow analysts to account for such variation), effectively improving the ability to estimate population trends and determine differences in abundance among management treatments.

Literature Cited

Anderson, D. R. 2008. Model based inference in the Life Sciences: a primer on evidence. Springer Science and Business Media, LLC, New York, New York.

Bystrak, D. 1981. The North American breeding bird survey. *Studies in Avian Biology* 6:34-41.

Conway, C. J., and J. P. Gibbs. 2005. Effectiveness of call-broadcast surveys for monitoring marsh birds. *The Auk* 122:26-35.

Conway, C. J., and C. Nadeau. 2006. Development and field-testing of survey methods for a continental marsh bird monitoring program in North America. Wildlife Research Report # 2005-11. USGS Arizona Cooperative Fish and Wildlife Research Unit, Tucson, Arizona.

Conway, C. J., and C. Sulzman. 2007. Status and habitat use of the California black rail in the southwestern U.S.A. *Wetlands* 27:987-998.

Conway, C. J., C. P. Nadeau, R. J. Steidl, and A. Litt. 2008. Relative Abundance, Detection Probability, and Power to Detect Population Trends of Marsh Birds in North America. Wildlife Research Report #2008-02. U.S. Geological Survey, Arizona Cooperative Fish and Wildlife Research Unit, Tucson, AZ.

Conway, C. J. 2009. Standardized North American Marsh Bird Monitoring Protocols, version 2009-2. Wildlife Research Report #2009-02. U.S. Geological Survey, Arizona Cooperative Fish and Wildlife Research Unit, Tucson, AZ.

Conway, C. J., and C. P. Nadeau. 2010. Effects of broadcasting conspecific and heterospecific calls on detection of marsh birds in North America. *Wetlands* 30: 358-368.

Eddleman, W. R., F. L. Knopf, B. Meanley, F.A. Reid, and R. Zembal. 1988. Conservation of North American rallids. *Wilson Bulletin* 100:458-475.

Eddleman, W. R. and C. J. Conway. 1998. Clapper Rail (*Rallus longiirostris*). *In* The Birds of North America, No. 340 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

Gibbs, J. P., and S. M . Melvin. 1993. Call-response surveys for monitoring breeding waterbirds. *Journal of Wildlife Management* 57:27-34.

Gibbs, J. P., F. A. Reid, and S. M. Melvin. 1992. Least Bittern (*Ixobrychus exillis*). *In* The Birds of North America, No. 17 (A. Poole and Gill, eds). The Birds of North America, Inc., Philadelphia, PA.

Hofmann, D. A. and M. B. Gavin. 1998. Centering decisions in hierarchical linear models: implications for research in organizations. *Journal of Management* 24: 623-641.

Lawler, J. J., and R. J. O'Connor. 2004. How well do consistently monitored breeding bird survey routes represent the environments of the conterminous United States? *Condor* 106:801-814.

Nadeau, C. P., C. J. Conway, B. S. Smith, and T. E. Lewis. 2008. Maximizing detection probability of wetland-dependent birds during point-count surveys in northwestern Florida. *Wilson Journal of Ornithology* 120:*513-518.*

Pentcheff, D. 2008. WWW Tide and Current Predictor. University of South Carolina, Columbia, SC. Accessed online: http://tbone.biol.sc.edu/tide

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.

Ribic, C.A., S. Lewis, S. Melvin, J. Bart, and B. Peterjohn. 1999. Proceedings of the Marsh bird monitoring workshop. USFWS Region 3 Administrative Report, Fort Snelling, MN.

Robbins, C. S., D. Bystrak, and P. H. Geissler. 1986. The breeding bird survey: its first fifteen years, 1965-1979. U.S. Dept. of the Interior, Fish and Wildlife Service Resource Publication 157. Washington, D.C.

Rush, S. A., E. C. Soehren, K. W. Stodola, M. S. Woodrey, and R. J. Cooper. 2009. Influence of tidal height on detection of breeding marsh birds along the northern Gulf of Mexico. *The Wilson Journal of Ornithology* 121: 399-405.

Spear, L. B., S. B. Terrill, C. Lenihan, and P. Delevoryas. 1999. Effects of temporal and environmental factors on the probability of detecting California black rails. *Journal of Field Ornithology* 70:465-480.

Tiner, R. W., Jr. 1984. Wetlands of the United States: current status and recent trends. U.S. Fish and Wildlife Service, National Wetlands Inventory, Washington, DC.

Tate, J. 1986. The blue-list for 1986. *American Birds* 40:227-236.

U.S. Fish and Wildlife Service. 2001. Proceedings of the Marsh Bird Conservation Workshop, August 21-22, 2001. Denver, Colorado.

U.S. Fish and Wildlife Service. 2006. Proceedings of the 2006 Marsh Bird Monitoring Technical Workshop, March 6-8, 2006. Patuxent Wildlife Research Center, Laurel, Maryland. Accessed online: www.fws.gov/birds/waterbirds/monitoring/marshmonitoring.html.

Zembal, R., and B. W. Massey. 1987. Seasonality of vocalizations by light-footed clapper rails. *Journal of Field Ornithology* 58:41-48.