Factors influencing detection probability and the benefits of call broadcast surveys for monitoring marsh birds

by

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EXECUTIVE SUMMARY

Populations of many species of marsh birds are thought to be declining in North America. Despite the perceived population declines, we currently lack an effective monitoring program to estimate population trends of marsh birds. The most commonly-used method to determine presence and abundance of marsh birds in local areas is the broadcast of recorded calls. Understanding the magnitude of benefits and drawbacks associated with call broadcast surveys is essential prior to implementing a continent-wide monitoring program. We summarized existing information and analyzed data from previous and on-going marsh bird surveys in North America to help evaluate the benefits and drawbacks of call broadcast surveys for monitoring marsh birds. We also summarized intrinsic and extrinsic factors influencing total counts and detection probability of marsh birds.

Summary of 36 previous studies provide strong evidence for increased detection probability associated with call broadcast surveys for only 4 species of marsh birds (soras, Virginia rails, king rails, and limpkins). Evening surveys have proven better in some local studies, whereas morning surveys were better in others, and the effectiveness of morning vs evening surveys may vary seasonally. Peak in vocalization probability can vary among co-existing species within a particular survey period. Optimal weather conditions for conducting surveys are better in the morning in some regions, but better in the evening in others. Vocalization probability varies daily, annually, and among species. Marsh bird surveys should be timed to coincide with peak in clutch initiation in local areas.

Results from previous studies suggest that 3 annual replicate surveys are needed for a standardized monitoring program. Conducting 3 replicate surveys can 1) ensure that survey timing is optimal for all co-existing species in each local area, 2) help ameliorate the problems associated with daily variation in vocalization probability, and 3) help ameliorate biases created by annual variation in seasonal peak vocalization probability. Weather variables often explain only a small portion of the temporal variation in vocalization probability in local studies. Vocalization probability appears to be positively correlated with local density in Virginia rails, soras, and clapper rails, and this presents problems for monitoring. Most studies report a rather rapid decline in new detections over the course of the survey period, and that each species vocalizes most frequently in response to conspecific broadcasts. Movement of birds toward the broadcast source is common and precludes using survey data to estimate local density. More studies are needed to estimate observer detection probabilities associated with passive and call broadcast survey methods.

We also pooled data from 16,406 survey points from 15 cooperators who provided their data for a pooled analysis to evaluate the usefulness of incorporating call broadcast surveys into continental monitoring protocols for marsh birds. Analyses of these pooled data suggest that call broadcast surveys are most effective at increasing detection probability for rails. The proportional increase in mean number of birds detected per survey point on call broadcast surveys compared to passive surveys averaged 43% for pied-billed grebe, 260% for sora, 540% for Virginia rail, 925% for king rail, 650% for clapper rail, 185% for black rail, 103% for green-backed heron, 6% for American bittern, 137% for least bittern, 160% for common moorhen, and 179% for marsh wren. However, duration of call broadcast was longer than duration of the passive period in all but 3 studies. Hence, the average proportional increase in numbers detected

on call broadcast surveys is misleading due to unequal survey duration. However, call broadcast does appear to increase detection probability even after controlling for differences in survey duration; the results from our overall Repeated Measures ANCOVA model were significant even after controlling for the difference in minutes surveyed between passive and broadcast periods.

Proportion of points at which zero birds were detected was lower for call broadcast surveys compared to passive surveys, but zero counts were relatively common for all species for both types of surveys. Call broadcast appears to reduce the number of zero counts most significantly in Virginia rails. Temporal variation in numbers counted was higher for call broadcast surveys compared to passive surveys. The differences were most pronounced for rails, and the results from the overall Repeated Measures ANCOVA model were significant even after controlling for the difference in minutes surveyed between passive and broadcast periods. Spatial variation in number of birds detected was higher for call broadcast surveys compared to passive surveys for soras, Virginia rails, and king rails. Because zero birds are detected at most points, call broadcast may increase spatial variance in birds detected simply by turning some otherwise zero counts into points with $\geq$1 bird detected. Proportion of zero counts was high for both passive and call broadcast surveys, and was only slightly lower for call broadcast surveys. Our field trials demonstrated that detection probability of both American and least bitterns was low, but was higher on call broadcast surveys (30.8% and 12.5 %, respectively) compared to passive surveys (7.7% and 0%, respectively). Detection probability varied dramatically among individual birds.

Call broadcast increases detection probability of most species of marsh birds, but also increases temporal and spatial variation in counts. Differences in relative length of passive vs call broadcast periods presented problems for our pooled analyses across studies and limited our ability to draw strong inferences from this data. Based on our review of past and on-going survey efforts, and on the results and analytical constraints associated with our analysis of pooled cooperator survey data, we developed a standardized continental marsh bird monitoring protocol. We recommend a monitoring protocol that includes an initial passive period followed by a period of call broadcast. This design allows us to take advantage of the benefits while avoiding the drawbacks of both survey methods. Our protocol is a first attempt at standardization of marsh bird survey efforts in North America. Such an effort will be extremely useful by allowing us to pool data across studies and across regions to estimate population trends of marsh birds.

INTRODUCTION

Populations of many species of marsh birds are thought to be declining in North America (Eddleman et al. 1988, Conway et al. 1994, Ribic et al. 1999). Breeding Bird Survey (BBS) data suggests significant population declines for American bittern (*Botaurus lentiginosus*) and king rail (*Rallus elegans*; Sauer et al. 2000). Estimated BBS population trends for other marsh birds are not significant, but sample sizes are extremely low because the BBS does not adequately sample emergent wetlands (Bystrak 1981, Robbins et al. 1986, Gibbs and Melvin 1993). Other information suggests that continental marsh bird populations have declined. Black rails (*Laterallus jamaicensis*) are on the National Audubon Society's "*WatchList*", are state threatened in California (California Department of Fish and Game 1989), Arizona (Arizona Game and Fish Department 1988), and New Jersey (Kerlinger and Wiedner 1991), are a species of national management concern (U.S. Fish and Wildlife Service 1987), and the California subspecies (*L. j. coturniculus*) was previously a Category 1 "candidate" species for federal listing under the Endangered Species Act (U. S. Dept. of Interior 1989). Yellow rails (*Coturnicops noveboracensis*) are on the National Audubon Society's "*WatchList*" and are a species of national management concern (U.S. Fish and Wildlife Service 1987). Three western races of clapper rails (*Rallus longirostris obsoletus*, *R. l. levipes*, and *R. l. yumanensis*) are federally endangered (U. S. Fish and Wildlife Service 1973). Both American and least bitterns (*Lxyobrychus exilis*) are on the National Audubon Society's Blue List (Tate and Tate 1982) and are species of national management concern (U.S. Fish and Wildlife Service 1987). Pied-billed grebes (*Podilymbus podiceps*) are on the National Audubon Society's Blue List (Tate 1986). Moreover, several species of marsh birds (Virginia rail, *Rallus limicola*; sora, *Porzana carolina*; clapper rail; king rail) are game species in many states and managers need estimates of population trends to set responsible harvest limits. Despite the perceived population declines, we currently lack effective monitoring programs to adequately estimate population trends of marsh birds. Hence, we need a new standardized monitoring program to document population trends of marsh birds in North America.

Effective population monitoring is critical to effective conservation and management because monitoring allows us to identify declining populations long before these populations are threatened with extinction (Goldsmith 1991, Hagan 1992). Identifying population declines early results in more effective and less costly recovery efforts (Green and Hirons 1991). Continent-wide avian monitoring programs currently in place (e.g., Breeding Bird Survey) target terrestrial habitats and do not adequately sample emergent wetlands in North America (Butcher 1989, U.S. Fish and Wildlife Service 1990). Emergent marshes are often inaccessible with minimal road access. Hence, we need a separate survey targeting wetland birds (Gibbs and Melvin 1993, Eddleman et al. 1994, Tacha and Braun 1994). Recently, a new marsh bird monitoring program has been proposed for North America (Ribic et al. 1999). The primary goal of such a monitoring program would be to estimate population change in marsh birds, with particular emphasis on rails and bitterns. However, the sampling methods and survey protocols for such a large-scale monitoring program remain topics of debate (Ribic et al. 1999). Developing an effective monitoring protocol at the outset is essential for collection of long-term data designed to provide rigorous estimates of population change.

When designing a monitoring program, the goal is not necessarily to maximize the total number of individuals counted (Barker et al. 1993). The most effective monitoring protocol for any organism is one that is standardized, repeatable, and incorporates a survey methodology in which detection probability is high, temporal and spatial variation in detection probability are low, observer variability is low, and extraneous factors that influence detection are eliminated or are accounted for statistically. Detection probability, *p*, is the probability that an individual bird that is present in the surveyed area during the time of the survey is detected by the observer. If the goal is to reliably estimate population trends, a survey design that maximizes statistical power to detect change over time or one that minimizes temporal variance in detection probability will be better than one that solely maximizes total count. Hence, choice of appropriate field protocols for a new monitoring program is extremely important because an effective monitoring program should not change sampling methods over time.

Most avian monitoring protocols combine aural and visual detections. Marsh bird surveys are predominantly aural surveys because many species of marsh birds stay hidden within emergent vegetation making visual surveys ineffective. The most commonly-used method to determine presence and abundance of marsh birds in local areas is the broadcast of recorded calls (Glahn 1974, Johnson et al. 1981, Marion et al. 1981, Manci and Rusch 1988, Swift et al. 1988). Marsh birds vocalize infrequently and call broadcast surveys (often called tape playback surveys or acoustic-lure surveys) can increase total number of individual birds counted in local surveys of selected marsh birds (Glahn 1974, Johnson and Dinsmore 1986b, Manci and Rusch 1988, Gibbs and Melvin 1993). Moreover, proper identification of marsh bird calls may be enhanced when observers repeatedly hear species calls broadcast at each survey point.

However, we know nothing about how call broadcast surveys influence temporal variation in detection probability. Moreover, call broadcast surveys have potential drawbacks for monitoring: broadcasting calls of one species may decrease vocalizations (and hence detection probability) of coexisting species, birds can habituate to broadcast calls after repeated exposure (Smith 1974, Irish 1974), tape/equipment quality may change over the course of the monitoring program, sound quality may decline with prolonged use of broadcast equipment, broadcast volume may vary among observers, type/origin of broadcast calls may vary among observers, call broadcast surveys increase costs required of survey participants, and broadcast calls may unnecessarily disturb breeding birds (Glinski 1976 in Marion et al. 1981, Kerlinger and Wiedner 1991). These issues reduce our ability to standardize survey methods spatially and temporally. Broadcasting calls also may prompt birds to fly toward the source, biasing estimates of local population density and estimates of detection probability via distance sampling. In contrast, passive surveys can provide trend estimates for all co-existing marsh birds simultaneously. Understanding the magnitude of benefits and drawbacks associated with call broadcast surveys is essential prior to implementing a continent-wide monitoring program.

All surveys provide only an *index* to population size (rather than true population size), and this index is then used to estimate population trend under the assumption that the trend in the index is equivalent to the trend in population size. This key assumption depends on the precision of the index. The population size (N) is equal to the number of birds counted (C) divided by the detection probability (p). Hence, $N = C/p$ as long as p is constant over space and time, and is not density-dependent (i.e., p is independent of population size) (Sauer 1994). Any analysis of count data relies on implicit assumptions about the temporal and spatial variation in p (Sauer 1994). Yet little research has examined factors affecting variation in detection probability and few monitoring programs have explicitly considered the factors influencing variation in p prior to designing field methods for broad-scale monitoring programs. An index to population size should be accurate (approximate the true population size), but more importantly, the index should be precise (Johnson 1995). The accuracy of the index is measured by detection probability (accuracy is high as p approaches 1.0) and the precision of the index (i.e., the correlation between C and N) is measured by variation in detection probability. The validity of using the trend in the index as a measure of the trend in population size depends on the variation associated with detection probability and whether or not p is independent of N (i.e., whether or not detection probability is correlated with population density).

In this study, we summarize existing information and analyze data from previous and on-going marsh bird surveys in North America to help evaluate the benefits and drawbacks of call broadcast surveys for monitoring marsh birds. We summarize survey methods from 36 previous studies involving marsh bird monitoring efforts. From these studies, we summarize the intrinsic and extrinsic factors that influence total counts and detection probability of marsh birds in local studies. We also asked colleagues working on local marsh bird survey efforts to contribute their data to a pooled overview analysis examining the usefulness of call broadcast surveys. We obtained data from 12 studies that included a passive survey period prior to their call broadcast survey at each survey point. This design (passive survey followed immediately by call broadcast survey) allows an opportunity to examine the influence of call broadcast on detection probability and temporal variation in detection probability. Hence, we pooled data from these 12 cooperators conducting monitoring efforts on marsh birds throughout North America to evaluate the usefulness of incorporating call broadcast surveys into continental monitoring protocols for marsh birds. Direct estimates of detection probability associated with marsh bird surveys are rare (but see Conway et al. 1993, Legare et al. 1999), so we also conducted field trials to estimate vocalization probability of radio-marked least and American bitterns during both passive and call broadcast surveys in central New York.

METHODS

Summary of previous and on-going marsh bird survey efforts

We conducted an extensive literature review searching for published manuscripts and unpublished reports on North American marsh birds. We also sent letters to approximately 200 authors that have published papers on marsh birds over the past 30 years requesting unpublished reports on local or regional marsh bird survey efforts. We summarized survey methodology, equipment used, and issues related to detection probability for each study. We also summarized intrinsic and extrinsic factors that influence vocalization probability to aid in development of a common standardized survey protocol.

Pooled cooperator data

The strength of any study result relies on replication of results. To demonstrate the ubiquity of any result, replication within a study is important, but replication of studies in space and time is far more important (Hawkins 1986). Hence, we sent letters to approximately 200 authors that have published papers on marsh birds over the past 30 years requesting raw data on local or regional marsh bird survey efforts. We also contacted the 40 participants of the marsh bird monitoring workshop (Ribic et al. 1999) and requested raw data on their local or regional marsh bird survey efforts. We received usable data from 15 cooperators (Tables 4 and 9). We converted each cooperator's data into a standardized format and entered data from original data forms from several cooperators. We conducted extensive data quality checks on each contributed data set and worked with cooperators to correct errors and inconsistencies. We used the pooled data set to evaluate the extent to which call broadcast surveys increase detection probability and reduce temporal and spatial variation in detection probability compared to passive surveys. We used Repeated Measures Analysis of Covariance (ANCOVA) models to test whether mean number of birds detected per point, temporal variation in number of birds detected, and spatial variation in number of birds detected differed between passive and broadcast surveys. In the Repeated Measures ANCOVA models, survey type (passive vs call broadcast) was a main factor and the difference in minutes surveyed between passive and call broadcast surveys was the covariate.

Field trials to estimate vocalization probability on radio-marked bitterns

Despite the widespread realization of the importance of detection probability in monitoring programs, efforts to estimate detection probability and to determine the factors affecting variation in detection probability are rare. One reason efforts to estimate detection probability are rare is the suggestion that detection probability be estimated by comparing total count in an area to a population estimate using another technique (e.g., capture-recapture) (Sauer 1994, Thomas 1996). This approach requires using populations of organisms as the primary sampling units. However, one can estimate detection probability by estimating two component parameters directly; vocalization probability and observer detection probability.

Detection probability, p, is the probability that an individual that is within the area of interest during the survey is detected by the observer. For vocal surveys, detection probability is the product of vocalization probability (the probability that an individual bird that is within the sampled area vocalizes during the survey period; p_v), and observer detection probability (the probability that the observer hears and records an individual bird that vocalizes during the survey period; p_o). Some methods purported to estimate detection probability actually estimate one of these two component parameters. For example, Nichols et al.'s (2000) double-sampling method estimates observer detection probability, while Farnsworth et al.'s (2000) method of segmenting the sampling period estimates vocalization probability. The bias associated with using one of the component parameters as a surrogate for detection probability depends on which of the two component parameters is more variable. For marsh birds p_v is probably more variable than p_o; marsh birds vocalize sporadically (high variation in p_v) but calls are relatively loud and fairly distinct among species (resulting in low variation in p_o).

Separating detection probability into vocalization probability and observer detection probability is useful because we can more easily estimate each component parameter since an individual bird (or observer) is the sampling unit. We can also examine how different environmental factors influence each component parameter. For example, call broadcast surveys are often assumed to increase p_v, but may either increase p_o (if the repeated calls broadcast during a survey makes observers more likely to recognize a soft or rare call) or decrease p_o (if the noise associated with call broadcast prevents the observer from hearing some vocalizations). Moreover, these two component parameters may respond to environmental covariates in opposite ways. For example, p_v typically declines as the morning progresses in most species, but p_o may increase later in the morning due to a reduction in the total number of calls that may mask calls from the focal species. In other words, high p_v and p_o may be negatively correlated; increasing numbers of vocalizations may increase the probability that an observer will miss any one call. Nichols et al. (2000) mention that the double-sampling approach to estimating detection probability will not be useful for species or classes of individuals with low detection probabilities (e.g., <0.40), and recommend use of an alternative survey method that does not rely on observation. However, vocal surveys may still be the most efficient way to estimate population change for species with low detection probability. A more important consideration is whether detection probability varies temporally and spatially. The best approach is to estimate both p_v and p_o directly (and the environmental factors influencing variation in each parameter).

Estimates of vocalization probability associated with call broadcast surveys have been published for several species of rails (Brackney and Bookhout 1982, Conway et al. 1993, Legare et al. 1999), but similar estimates are not available for bitterns. Hence, we conducted vocalization probability trials on radio-marked bitterns at Iroquois National Wildlife Refuge in western New York from 18-23 June 1999. We conducted trials in the morning (from dawn until 1100) and in the evening (from 1630 until dusk). We conducted 26 vocalization probability trials on 7 male American bitterns (*Botaurus lentiginosus*), 8 trials on 2 male least bitterns (*Lxyobrychus exilis*), and 3 trials on 3 female least bitterns. We found nests of 2 of our radio-marked birds; one was incubating during the time the trials were conducted and the other trial was just prior to incubation.

RESULTS

Summary of previous and on-going marsh bird survey efforts

Many local marsh bird survey efforts have been designed and carried out independently over the past 30 years with little standardization among surveys. Survey efforts differed in the type of broadcast equipment used (Table 1). Most used small handheld tape cassette players with a powerhorn attached. However, many studies used the same or similar tape players without a powerhorn. Most studies failed to report the broadcast volume used during surveys and whether or not any attempt was made to standardize broadcast volume. Broadcast volume varied from 81-96 dB at 1m in front of the speaker for the 9 studies that did report broadcast volume (Table 1). Maximum distance at which broadcast calls could be heard by observers was only reported by 4 authors and varied from 60-100m. Cost of broadcast equipment used in local studies varied from \$40 to \$300 (Table 1).

Thirty-one local survey efforts differed tremendously in length of survey period (1-22 min), distance between adjacent survey points (40-1330 m), number of replicate surveys per year (1-30), survey radius (18m to unlimited), and time of day and season surveys were conducted (Table 2). The average number of birds detected per point was typically low but varied among species (0.00-2.0 birds/point). Survey efforts also reported large variation in the maximum distance at which birds were detected (80 to >1000 m). Rarely are marsh birds observed during surveys; most birds detected on marsh bird surveys (73-100%) were aural detections only (Table 3; also see Glahn 1974, Marion et al. 1981, Swift et al. 1988, Gibbs and Melvin 1993). The seasonal peak in number of birds detected varies among marsh bird species and even among locations within species (as early as mid-March and as late as the end of July; Table 3). Interspecific and inter-regional variation in peak seasonal response of marsh birds must be considered in designing a standardized continental monitoring program. Despite large differences in equipment and survey methodology, some patterns and results are common across local survey efforts. Below we summarize the consistency with which certain factors do or do not influence numbers counted and/or detection probability across studies.

Increase in vocalization probability associated with call broadcast surveys

Call broadcast surveys increased vocalization probability of soras (Rabe and Rabe 1985, Glahn 1974, Marion et al. 1981, but see Manci and Rusch 1988) and Virginia rails (Rabe and Rabe 1985, Baird 1974, Glahn 1974, Marion et al. 1981, Johnson and Dinsmore 1986b, Manci and Rusch 1988, Gibbs and Melvin 1993) compared to passive surveys. Call broadcast surveys increased vocalization probability of king rails (Manci and Rusch 1988), Yuma clapper rails in Arizona (R. L. Todd in Mangold 1974), and limpkins (*Aramus guarauna*; Marion et al. 1981). In contrast, call broadcast surveys were ineffective at increasing vocalization probability of American or least bitterns in Pennsylvania (Manci and Rusch 1988, Cashen 1998) and did not stimulate additional calling of clapper rails in New Jersey (Mangold 1974). Usefulness of call broadcast surveys was equivocal for black rails in Arizona; mean birds per survey point was greater with tapes than without (0.30 vs 0.16) in 1987, was not greater (0.11 vs 0.08) on the same study site in 1988, and birds/survey point was lower with tapes (0.13 vs 0.21) on another study area in 1988 (Flores and Eddleman 1991). However, black rails may have been habituated to broadcast calls in the Arizona study (Flores and Eddleman 1991). Hence, previous studies provide unequivocal evidence for increased detection probability associated with call broadcast surveys for only 4 species of marsh birds (soras, Virginia rails, king rails, and limpkins).

Estimates of detection probability

Direct estimates of detection probability are lacking for any species of marsh birds in North America. Numerous authors have published educated guesses for detection probability based on assumed number of breeding pairs on their study area. Detection probability was assumed to be 70-95% for Yuma clapper rails in Arizona (Smith 1975, Bennett and Ohmart 1978) and <50% for other clapper rail subspecies (Mangold 1974, Meanley 1985). The percentage of territorial pairs responding to call broadcast surveys varied from 20-100% for soras and 22-72% for Virginia rails (Glahn 1974). However, these authors failed to describe the method by which they estimated the number of territorial pairs on their study areas.

Another approach involves measuring vocalization probability by observing a focal bird during call broadcast survey trials and recording whether focal individuals call during the survey period. If observers seldom fail to record a vocalizing bird during surveys (low observer bias) then vocalization probability approaches detection probability. Vocalization probability of male common moorhen (*Gallinula chloropus*) from pairs with known locations was 93% (n = 28 males), but female vocalization probability was only 21% (n = 28 females; Brackney and Bookhout 1982).

Authors have also estimated vocalization probability by monitoring radio-marked birds during call broadcast survey trials and recording whether calls were elicited from the location of the radio-marked bird. This approach can overestimate vocalization probability because a radio-marked bird may inappropriately be recorded as calling when another individual very close to the radio-marked bird called. Mean vocalization probability of radio-marked black rails in Florida during the breeding season was 50% for males and 20% for females (Legare et al. 1999).

Vocalization probability of radio-marked Yuma clapper rails (19% across seasons) varied seasonally, and was highest (40%) during the early breeding season (Conway et al. 1993).

Detection probability has also been estimated by recording the number of replicate surveys of areas known to contain birds during which at least one bird was detected (Gibbs and Melvin 1993). This approach overestimates true detection probability by some unknown factor because only one individual bird within a sampled area needs to vocalize during each survey in order to obtain 100% detection probability (yet some unknown number of individuals are still not detected). Clearly, more robust estimates of detection probability associated with both passive and call broadcast surveys are needed for marsh birds.

Correlation between call broadcast survey counts and other indices of population size

Another approach used to provide insight into detection probability associated with marsh bird surveys is to compare numbers recorded on vocal surveys to other indices of population size (e.g., number of nests located, estimated number of breeding territories via spot-mapping, number of individuals captured). For example, counts from vocal surveys are correlated with number of nests located in some studies. Number of light-footed clapper rail pairs recorded on passive surveys was highly correlated ® = 0.966, n = 9 marshes) with the number of nests found in those same marshes (range 3-35 pairs per marsh, marshes with 0 rails detected on both surveys not included; Zembal and Massey 1981). Number of calling clapper rails during passive surveys in New Jersey was reported to be highly correlated with known nest sites (Mangold 1974), although sample sizes and raw data were not reported. Mangold (1974) estimated detection probability of clapper rails as 0.44 (range 0.31-0.75, S.D. = 0.115) by comparing number of birds surveyed to number of known active nests. Number of male common moorhens detected on call broadcast surveys was correlated ® = 0.92, P = 0.009, n = 6 Lake Erie wetlands) with the number of nests located during standardized nest-search transects (Brackney and Bookhout 1982). However, counts from surveys were not correlated with number of nests found in other studies. Number of breeding pairs detected on passive surveys of light-footed clapper rails (*Rallus longirostris obsoletus*) did not appear to correlate with the number of nests located during extensive systematic rope drag transects within 3 study areas in California (Harvey 1988).

Other authors have presented correlations between counts from vocal surveys and number of territories estimated via spot-mapping. The mean number of Virginia rails and soras detected during call broadcast surveys was positively correlated ® = 0.97 and 0.93, respectively, n = 4 sites) with the number of breeding territories estimated from spot-mapping (Griese et al. 1980). However, the number of breeding territories estimated via spot-mapping is based on birds detected during vocal surveys and hence does not represent an independent comparison.

Others have reported correlations between counts from vocal surveys and number of individuals captured. Weekly variation in total number of soras detected during fall surveys showed the same pattern as weekly variation in sora captures (Kwartin 1995). In contrast, the number of soras, king rails, and Virginia rails estimated from trapping and banding was not closely correlated with the number estimated from call broadcast surveys in Kansas (Tacha 1975). Correlations between counts from vocal surveys and other population indices are difficult to interpret because comparing one index to another does not necessarily validate either index.

Variation in detection probability

Temporal variation in number of individuals detected in a local area affects the statistical power to detect population trends (Gibbs and Melvin 1997). The best survey methodology is one that produces low temporal and spatial variation in detection probability, yet we lack estimates of variation in detection probability for passive or call broadcast surveys of any marsh bird. Previous authors have made anecdotal statements suggesting that variation in detection probability is high for both passive and call broadcast surveys. Glahn (1974) implied that the use of call broadcast surveys reduces temporal variation in detection probability compared to passive surveys, but did not present data to support his assertion. Baird (1974) suggested that temporal variation in vocalization probability of soras was higher than that of Virginia rails on call broadcast surveys and suggested that this high temporal variation precludes the effective use of call broadcast surveys for soras. Temporal variation (C.V.) in number of birds detected per survey point was lower during call broadcast surveys compared to passive surveys in 2 of 3 study areas/years for black rails in Arizona (Flores and Eddleman 1991). Coefficients of variation in number of birds detected was >80% in 4 species studied in Maine (Gibbs and Melvin 1997). Temporal variation (across replicate surveys) in the number of Virginia rails and soras responding to call broadcast surveys was extremely variable across study sites in Colorado; coefficient of variation in the number of individuals detected ranged from 9-150% (average 50%) across 4 study sites (Griese et al. 1980). Even fewer estimates of spatial variation in detection probability associated with marsh bird surveys are available. Number of soras detected was highly variable across survey stations during fall surveys in Maryland (Kwartin 1995).

High spatial and temporal variation in detection probability may be caused by differences in breeding status and/or variation in age or sex ratios. For example, detection probability may differ between males and females within a local population; detection probability of male black rails (81%) was higher than females (21%) during call broadcast survey trials (Legare et al. 1999). Breeding status may influence detection probability and temporal and spatial variation in detection probability may be partially explained by temporal and spatial variation in proportion of breeding birds in the population. Smith (1973) suggested that call broadcasts are much more effective in eliciting vocalizations from unpaired clapper rails compared to paired clapper rails. Clearly, we need more rigorous estimates of temporal and spatial variation in detection probability associated with both passive and call broadcast surveys for marsh birds.

Time of day

Quantifying variation in detection probability throughout the day is important for adopting an optimal survey window when designing a standardized continental monitoring program because vocalization probability of most marsh birds varies with time of day (e.g., Legare et al. 1999). Previous marsh bird surveys have been conducted in the morning, in the evening, at night, throughout the day, or some combination of these times. Morning or evening surveys are considered best for most marsh birds (except yellow rails and eastern black rails which may call more at night), and numerous studies have compared morning vs evening surveys. Evening surveys have proven better in some local studies (Rabe and Rabe 1985, Tacha 1975, Johnson and Dinsmore 1986b), whereas morning surveys were better in others (Repking 1975, Cashen 1998). Other studies reported no difference between morning and evening counts (Tacha 1975, Marion et al. 1981, Kwartin 1995, Spear et al. 1999, Tecklin 1999). Studies on black rails have shown equivocal results. Number of black rails detected per survey point during call broadcast surveys in Florida was only slightly higher during evening compared to morning surveys, but radio-marked black rails vocalized more readily during morning surveys ($p_v = 0.63$) compared to evening surveys ($p_v = 0.37$; Legare et al. 1999). Similarly, passive calling of black rails was more common during evening surveys in Arizona, but call broadcast was more effective at increasing vocalization probability during morning surveys compared to evening surveys (Flores and Eddleman 1991). The relative effectiveness of morning vs evening surveys may vary seasonally; morning surveys were most effective at eliciting responses from soras and Virginia rails in late April and May in Missouri, but morning surveys elicited few responses in early June (late incubation and brood-rearing) even though evening surveys were still effective (Johnson and Dinsmore 1986b).

Peak in vocalization frequency can vary among co-existing species within a particular survey period; peak was highest 0400-0600 for American bitterns and Virginia rails, 0600-0800 for pied-billed grebes, and 0800-1000 for least bitterns and soras in Maine (Gibbs and Melvin 1993). Optimal weather conditions for conducting surveys are better in the morning in some regions (Baird 1974, Todd 1980, Conway and Sulzman 2001), but better in the evening in others (Mangold 1974). Sound interference from other birds is typically greater in the morning (Mangold 1974, Johnson and Dinsmore 1986b) and more volunteers may be available for evening surveys (R. Weeber, pers. comm.), but the peak in vocalization probability may be shorter in evenings compared to mornings (Spear et al. 1999, but see Zembal and Massey 1987). Loud choruses of anurans can severely reduce detection probability of marsh birds during evening and night surveys in some regions of North America (Runde et al. 1990).

Daily, seasonal, and breeding cycle variation in vocalization probability

Understanding regional and interspecific differences in seasonal vocalization probability is important in designing a standardized continental monitoring program to ensure optimal survey timing in all survey locations. Vocalization probability during call broadcast surveys typically varies throughout the breeding season at local sites (Glahn 1974, Gill 1979, Johnson and Dinsmore 1986b, Kerlinger and Wiedner 1991, Legare 1996, but see Brackney and Bookhout 1982). For example, vocalization probability during call broadcast surveys differed among seasons for Yuma clapper rails in Arizona (Conway et al. 1993). Number of black rails responding to call broadcast surveys was higher and less variable during the breeding season (late April - early June) compared to other seasons (Spear et al. 1999). In contrast, the number of black rails detected did not differ among early spring, late spring, and winter surveys in northern California (Tecklin 1999, also see Tomlinson and Todd 1973). Vocalization probability probably varies seasonally due to hormonal changes associated with the breeding cycle. Indeed, stage of the nesting cycle influenced vocalization probability of soras, Virginia rails (Glahn 1974), and radio-marked black rails (Legare et al. 1999). Vocalization probability often peaks with the start of egg laying through hatching (Kaufmann 1971). For example, vocalization probability during call broadcast surveys was extremely high during early breeding in spotless crakes (*Porzana tabuensis*), but was near zero once incubation began (Kaufmann 1988). Hence, marsh bird surveys should be timed to coincide with peak in clutch initiation in local areas.

Peak in vocalization probability can differ among co-existing species in the same marsh (Gibbs and Melvin 1993). For example, seasonal peak in numbers of birds responding to call broadcast surveys was not consistent across study areas or between Virginia rails and soras within the same study area in Colorado (Griese et al. 1980). Seasonal peak in number of clapper rail calls recorded on passive surveys varied among study sites and differed among calls within study sites (peak in *clatters* was earlier than peak in *keks*; Zembal and Massey 1987). Peak in black rail calling frequency seemed to vary among locations even within a year (Kerlinger and Wiedner 1991). Peak in number of rails detected during call broadcast surveys differed between two adjacent study areas in Arizona (Eddleman 1989, Flores and Eddleman 1991). Many studies have reported 2 seasonal peaks in number of birds detected, the second peak probably coincides with the time when juvenile birds begin calling. Number of black rails detected during call broadcast surveys varied among months within the breeding season; number of responses during late July was significantly higher than other spring/summer months (Legare et al. 1999). Hence, replicate surveys are needed in a standardized monitoring program to ensure that survey timing is optimal for all co-existing species in each local area.

Vocalization probability also varies among individuals and among days within a season (Mangold 1974, Meanley 1985, Zembal et al. 1985, Spear et al. 1999). Day-to-day variation in detection probability appears to be very high for many species of marsh birds. For example, the number of rails vocalizing on a local study site on different days under seemingly identical weather conditions is often extremely variable (Zembal and Massey 1987, pers. observ.). Controlling for daily and among-individual variation in vocalization probability is more difficult, yet this variation influences effectiveness of count data to index population change. Bart et al. (1984) detected no obvious variation among 5 nights in the proportion of yellow rails detected, although individual birds tended to be silent on some nights and vocal on others. Rate of passive calling in black rails varied greatly among individuals (23-1380 calls/min) within one location (Kerlinger and Wiedner 1991). Breeding status is one factor that can cause individual variation in vocalization probability; non-nesting radio-marked black rails had higher vocalization probability (60%) compared to nesting birds (46%) on call broadcast surveys (Legare 1996). Increased detection probability during years when breeding success is low (large numbers of non-nesting males) may bias estimates of population trends. Replicate surveys can help ameliorate the problems associated with daily variation in vocalization probability.

Variation among years in optimal survey timing

Peak in vocalization probability varies among years and this variation can influence power to detect population trends if not considered in design of survey methodology. Seasonal peak in soras and Virginia rails detected during call broadcast surveys differed by 1-2 weeks across 2 years (Johnson and Dinsmore 1986b, Manci and Rusch 1988). Seasonal peak in black rails detected during call broadcast surveys differed by 1 month across 2 years (Flores and Eddleman 1991). Peak in soras detected during weekly fall surveys was 2-3 weeks apart in two consecutive years (Kwartin 1995). Replicate surveys can also help ameliorate biases created by annual variation in seasonal peak vocalization probability.

Effects of weather and environmental factors on vocalization probability

Variation in detection probability reduces power to detect population trends. Identifying factors that explain some of the temporal and spatial variation in detection probability is useful because these parameters can be incorporated into trend analyses. Weather conditions are often assumed to influence vocalization probability and have been the most frequent covariates measured during local marsh bird surveys. However, weather variables often explain only a small portion of the temporal variation in vocalization probability in local studies. For example, temporal and environmental variables explained 15-20% of the variation in number of black rails responding to call broadcast surveys during the breeding season (Spear et al. 1999). In contrast, temperature explained a significant amount of variation in number of black rails detected on weekly call broadcast surveys, but wind velocity and cloud cover did not explain significant variation (Legare et al. 1999). Moreover, the effects of weather on vocalization probability may vary among coexisting species. Of 5 species studied, rainfall reduced calling of soras only (Gibbs and Melvin 1993). Vocalization probability was negatively correlated with wind velocity in American bitterns only (Gibbs and Melvin 1993). Vocalization probability was negatively correlated with cloud cover in American bitterns, but positively correlated with cloud cover in Virginia rails (Gibbs and Melvin 1993). Light-footed clapper rails were slightly less vocal on cold, windy evenings (Zembal and Massey 1981). Rain, exceptionally cold weather, and wind over 5 mph all reduced vocalization probability of clapper rails in New Jersey (Mangold 1974). Clapper rail vocalizations decreased markedly when wind velocity exceeded 16 kph (Smith 1974). Morning temperatures appeared to influence the probability that clapper rails respond to call broadcast surveys; birds in spring seldom vocalized during call broadcast prior to sunrise but frequently did so during the summer (Smith 1974). Number of black rails detected on call broadcast surveys was positively correlated with air temperature and negatively correlated with cloud cover (Spear et al. 1999). Wind velocity and cloud cover did, but temperature did not, appear to affect vocalization probability in soras, Virginia rails, and king rails (Tacha 1975). Weather does not appear to influence vocalization probability in some studies. Weather conditions did not help explain variation in the number of soras detected during fall surveys (Kwartin 1995).

Environmental factors other than weather can also influence vocalization probability of marsh birds. High tides reduced calling activity of clapper rails in California (Zembal and Massey 1987). Number of black rails detected on call broadcast surveys was positively related to moon light the preceding night and negatively related to tide height (Spear et al. 1999). In contrast, environmental factors had negligible effects on calling frequency in black rails in Arizona (Flores and Eddleman 1991).

Effects of density on vocalization probability

Vocalization probability also varies among marshes within a local area. For example, vocalization probability of radio-marked black rails in response to call broadcast survey trials varied among two study sites (29% vs. 62%) in Florida (Legare 1996). Local breeding density may explain some of the spatial variation in vocalization probability. Vocalization probability appears to be positively correlated with local density in Virginia rails (Glahn 1974), soras (Kaufmann 1971), and clapper rails (Zembal and Massey 1981, 1987; Zembal et al. 1985). In contrast, isolated pairs of common moorhens vocalized during call broadcast as readily as pairs in high density areas (Brackney and Bookhout 1982). A positive correlation between detection probability and breeding density is problematic for monitoring because population change (declines and increases) will be overestimated. More studies are needed to determine whether passive surveys or call broadcast surveys produce count data in which vocalization probability is less correlated with breeding density.

Duration of survey period

Duration of survey period has varied greatly among local marsh bird survey efforts. A longer survey period results in more birds detected (higher detection probability). However, the rate of new detections declines with survey duration, and a longer survey duration results in fewer points surveyed within the optimal survey period. Choosing an optimal survey duration suitable for all marsh bird species and all regions is important for a standardized continental monitoring program. Most studies report a rather rapid decline in new detections over the course of the survey period. For example, most rails in Pennsylvania were detected within the first minute of the call broadcast period (Cashen 1998). Of the birds detected in Colorado, thirty-five percent were detected during the first call sequence (first 30 seconds) and 79% were detected within the first five call sequences (first 2.5 minutes; Glahn 1974). Fifty percent of radio-marked male black rails and 20% of females vocalized either during the first minute of call broadcast or the 2 minutes immediately following call broadcast (Legare et al. 1999). Only another 14% of males and 20% of females vocalized during the final 8 minutes of the 11 minute (1min tape, 10 min passive) survey period (Legare et al. 1999). Optimal survey duration may differ seasonally. Most soras in Missouri vocalized during the first tape sequence on surveys within the laying season, but number of responses did not differ among tape sequences on surveys after the laying season (Johnson 1984).

Conspecific calls vs calls of coexisting species

The goal of a continental marsh bird monitoring program is to estimate population trends of multiple marsh bird species simultaneously. Call broadcast surveys may be less desirable in multi-species monitoring efforts because the use of broadcast calls of one species may influence vocalization probability of coexisting species. Hence, examining the effect of broadcasting calls of other marsh birds on vocalization probability of target species is important prior to making decisions on whether to adopt a passive or a call broadcast survey methodology. Local studies addressing this issue report conflicting results, and many individual studies report differences among species. Most studies report that each species vocalizes most frequently in response to conspecific broadcasts compared to interspecific tape sequences (soras, Johnson and Dinsmore 1986b, Gibbs and Melvin 1993; Virginia rails, Gibbs and Melvin 1993). Seventy-eight percent of Virginia rail vocalizations and all king rail vocalizations during call broadcast surveys in Kansas were in response to conspecific taped calls (Tacha 1975). Other studies report that some species vocalize equally in response to conspecific and other species broadcast calls. Soras and Virginia rails respond as readily to each other's broadcast calls as they do to their own (Glahn 1974, Kaufmann 1983, Johnson and Dinsmore 1986b, Contreras 1992). Virginia rails were stimulated to vocalize by sora and king rail broadcast calls in addition to conspecific calls (Irish 1974). Virginia rails (but not soras) commonly responded to broadcast black rail calls in northern California (Tecklin 1999). Finally, still other studies report that species vocalize **more** readily in response to other species broadcast calls compared to their own. Soras often respond more to Virginia rail calls than to conspecific (or yellow rail) calls (Rabe and Rabe 1985, Tacha 1975). Sometimes soras appeared to respond more readily to Virginia rail calls compared to conspecific calls and vice-versa (Cashen 1998). Some species show seasonal variation in whether they respond more to conspecific or other species broadcast calls. Soras responded to conspecific taped calls significantly more often than to Virginia rail taped calls throughout the breeding season, but Virginia rails responded more readily to conspecific calls only during the post-laying period (Johnson and Dinsmore 1986b). Conspecific calls may elicit more responses than interspecific broadcasts, but the real question of interest is whether or not broadcasting calls of other species decreases detection probability compared to a survey which includes only conspecific call broadcast. This question has rarely been addressed. In a rare exception, broadcasting clapper rail calls in addition to black rail calls in Arizona increased the number of black rails detected (Todd 1980). Clearly, this issue deserves more rigorous study.

Tape sequence

Whether or not detection probability of a particular species is affected by including call broadcast of a coexisting species may depend on the broadcast sequence during the survey. This issue has received little study. Order in which species calls were broadcast did not influence vocalization probability of soras or Virginia rails (Johnson and Dinsmore 1986b). More study of this issue is needed.

Type of calls

When designing a standardized call broadcast survey, we need to decide which calls to include for each target species. Few studies report which calls were included on their broadcast sequence, but most local surveys have probably used the most common call of each species. Others have used multiple calls for each species. Choice of calls on broadcast sequence may affect detection probability in some species. For example, *grrr* calls given by California black rails typically can not be heard beyond 30m but *kicky-doo* calls can be heard over 100m away (Tecklin 1999). In contrast, call selection may not affect detection probability. Although *keep* was the most common call given by fall migrant soras in response to call broadcast surveys (58% of responses, compared to 23% *per-weep* and 18% *whinny* responses), birds vocalized equally in response to *keep*, *per-weep*, and *whinny* tape sequences; 36%, 35%, and 29% of responses (Kwartin 1995).

Many rails give paired duets. One question that has not been largely ignored is whether or not using paired duets in the broadcast sequence increases detection probability of rails. In a rare exception, broadcasting duets appeared to be more effective than broadcasting calls of single birds in eliciting responses from Virginia rails and soras during the breeding season (Glahn 1974). Choice of calls to include in standardized broadcast sequences needs more study.

Do broadcast calls cause birds to move toward source

Data from call broadcast surveys has been used to estimate local population density using distance sampling techniques. This approach requires that observers accurately estimate the distance to each bird detected. Movement of birds toward the broadcast source would violate a critical assumption of distance sampling and result in overestimates of local density (Buckland et al. 1993). Birds moving toward the broadcast source has been reported in pied-billed grebes (Gibbs and Melvin 1993), limpkins (Marion et al. 1981), Virginia rails (Baird 1974, Tacha 1975), soras (Baird 1974), king rails (Tacha 1975), clapper rails (Smith 1974), black rails (Weske 1969, Evens et al. 1986, Legare et al. 1999, Spear et al. 1999, Tecklin 1999), and spotless crakes (Kaufmann 1988). Movement toward the source is problematic only if birds move prior to vocalizing. Black rails moved toward the tape player prior to vocalizing in Florida (Legare et al. 1999) and northern California (Tecklin 1999). Propensity of birds to approach the source of call broadcast can vary among individuals. Black rails in Maryland moved toward the tape player during 58% of trials, moved away from the tape during 4% of trials, and remained stationary during 38% of trials (Weske 1969). Variation among individuals may be the result of variation in breeding status. Unpaired clapper rails approached the tape player much more readily than did paired birds (Smith 1974). Propensity of birds to approach the broadcast source can also vary among males and females. Male black rails moved toward the tape player during 57% of trials (mean distance 9.5m, range 2-60m, n = 92 trials), moved away from the tape during 6% of trials, and remained stationary during 37% of trials (Legare et al. 1999). In contrast, female black rails moved toward the tape player during 44% of trials (mean distance 4.9m, range 2-35m, n = 42 trials), moved away from the tape during 3% of trials, and remained stationary during 53% of trials (Legare et al. 1999).

The average distance individuals birds move toward the broadcast source also may vary among locations, but distances birds move has rarely been addressed. Black rails in California moved an average of 6.2m toward the broadcast source prior to vocalizing (Evens et al. 1986). Movement of birds toward the broadcast source prior to vocalizing precludes using survey data to estimate local density and is another drawback of call broadcast surveys (see Discussion).

Distance between adjacent survey points

Distance between adjacent survey points has varied greatly among local marsh bird survey efforts (Table 2). Optimal point spacing may differ among target species. Choosing a standardized distance between adjacent points for a continental marsh bird monitoring program must take into account the maximum or average distance at which each species of interest typically responds to call broadcasts. We have little data to address this issue. On calm nights in Florida, observers could hear broadcast calls up to 150m away (Runde et al. 1990). However, just because observers can hear broadcast calls at some distance does not mean that birds will respond to broadcast calls at that distance. In northern California, 30-35% of black rails responding to call broadcast were within 5m of the tape (Tecklin 1999). Distance from the broadcast source influenced vocalization probability of black rails in Florida (Legare et al. 1999). Vocalization probability was higher for clapper rails closer to the broadcast source (Zembal et al. 1985). Although detection probability decreases with distance from the broadcast source, widely spaced survey points prevent observers from double counting individual birds and allow observers to survey a larger area per unit time.

Observer detection probability (observer bias)

Detection probability is the product of vocalization probability and observer detection probability. Several studies have estimated vocalization probability of marsh birds associated with both passive and call broadcast surveys (see *Estimates of detection probability* section above), but no study has estimated observer detection probability associated with marsh bird surveys. We believe that observer detection probability is higher and less variable (temporally and spatially) compared to vocalization probability, but observers obviously differ in their ability to detect calling marsh birds. Indeed, observers differed in their ability to hear clapper rail calls in New Jersey (Mangold 1974). Some factors may increase inter-observer variation in detection probability. Mockingbirds mimicked black rail calls in northern California (Tecklin 1999), and observers may vary in their ability to distinguish real calls from mimics. Mangold (1974) used a professional quality Uher tape recorder, microphone, and parabola to record all vocalizations during surveys to eliminate observer bias in the field. This approach may be useful for eliminating observer bias in local studies, but is probably cost prohibitive for an extensive continental monitoring program. However, more studies are needed to estimate observer detection probabilities associated with passive and call broadcast survey methods.

Aberrant noises

Aberrant noises (e.g., traffic, airplane noise, other bird vocalizations) can influence observer detection probability and perhaps even vocalization probability of resident birds. Increases is aberrant noise over the course of a monitoring program could result in a reduction in numbers detected. Such a reduction in numbers counted would be considered local population declines, but may simply be due to decreases in observer detection probability. When selecting the permanent location of survey points as part of a long-term monitoring program, observers should attempt to place points were aberrant noise is low and unlikely to increase over time. A standardized survey should also require observers to record the level of aberrant noise during each survey point so we can control for noise level as a covariate in future trend analyses.

Other factors influencing vocalization probability

Several studies have reported that loud, abrupt noises elicit as many, or more, vocalizations than call broadcast. Kwartin (1995) used a canoe paddle to slap the water surface three times following each call broadcast survey. Twenty-six percent of all soras detected were in response to the broadcast calls whereas 74% were in response to the 3-5 brief paddle slaps, despite the fact that broadcast calls always preceded the paddle slaps and new detections should drop in frequency as the survey progresses. Maximum sound pressure of paddle slaps (120 db 1m from the paddle) was greater than maximum sound pressure of the broadcast calls (90 db 1m from the speaker). Hence, the difference in volume may explain the increased detection probability associated with paddle slaps. However, breeding soras in Minnesota vocalized more often in response to 3 sharp raps against an aluminum canoe than to call broadcast (Fannucchi et al. 1986).

Not every disturbance/loud noise will elicit more birds to vocalize than broadcast calls; call broadcast elicited more soras and Virginia rail vocalizations compared to throwing rocks in the water (Glahn 1974). A squeezable dog toy, a starter pistol, and hand claps were not as effective in eliciting sora responses as were call broadcast and paddle slaps (Kwartin 1995).

Firing a shotgun did not effectively induce calling of clapper rails in Georgia (Oney 1954). And the sound of an outboard motor starting up following a call broadcast survey induced previously silent clapper rails to vocalize only occasionally (Smith 1974). Abrupt noises are difficult to standardize and hence can not be incorporated into a standardized marsh bird survey protocol.

Habitat structure may also influence vocalization probability. For example, rails may possibly vocalize more frequently in dense marshes since their primary calls are often thought to function as a means of communicating location among members of a mated pair (Conway 1995, Eddleman and Conway 1998). A standardized survey should require observers to quantify basic habitat information at each survey point so that we have the ability to treat habitat configuration as a potential covariate in future trend analyses. Future analyses would also be able to examine correlations between local/regional habitat changes and local/regional population declines.

Pooled cooperator data

We received usable marsh bird survey data from 15 cooperators of which 12 included both an initial passive survey period and a subsequent call broadcast survey period (Table 4). We pooled data from 16,406 survey points from these 15 cooperators (Table 4). The pooled data includes 12 *primary* marsh-bird species for which conspecific call broadcast was part of the survey protocol plus 11 additional *secondary* species for which responses were recorded but conspecific tapes for these species were not broadcast. Most cooperators used an unlimited survey radius, except Penttila (80m) and Shieldcastle (100m). Studies varied in the number of years of survey data (1-20 years), number of observers (1-58), distance between adjacent points (100-800 m), number of replicate surveys per year (1-36), and the time of day and season surveys were conducted (Table 4). All but 3 of the 15 cooperators recorded some weather information at each survey point. Cooperator data sets also varied in total length of the survey period (5-46 min), the length of the initial passive period relative to the call broadcast period, and the number of species included in the broadcast call sequence (1-11 species; Table 4). These differences in relative length of passive vs call broadcast periods presented problems for pooled analyses across studies.

The relative benefit of using call broadcast surveys to increase numbers of birds detected varied among species and among studies. Call broadcast surveys appear most effective at increasing detection probability for rails. The proportional increase in mean number of birds detected per survey point on call broadcast surveys compared to passive surveys averaged 43% for pied-billed grebe, 260% for sora, 540% for Virginia rail, 925% for king rail, 650% for clapper rail, 185% for black rail, 103% for green-backed heron, 6% for American bittern, 137% for least bittern, 160% for common moorhen, and 179% for marsh wren (Table 6). However, duration of call broadcast was longer than duration of the passive period in all but 3 studies. Hence, the average proportional increase in numbers detected on call broadcast surveys is misleading due to unequal survey duration. The results from the overall Repeated Measures ANCOVA model were significant even after controlling for the difference in minutes surveyed between passive and broadcast periods (Table 6). Proportion of points at which zero birds were detected was lower for call broadcast surveys compared to passive surveys, but zero counts were relatively common for all species for both types of surveys (Table 5). Call broadcast appears to reduce the number of zero counts most significantly in Virginia rails (Table 5).

Although the mean number of birds detected per survey point was higher for call broadcast surveys for most species, temporal variation in detection probability is also an important parameter to consider when testing among alternative survey methods. We tested whether temporal variation in number of birds counted across replicate surveys differed between call broadcast surveys and passive surveys. If local population size at each study site is constant during each annual survey period (1-5 months; Table 2), then the temporal variance in number of birds counted across replicate surveys is equal to the temporal variance in detection probability. Temporal variation in numbers counted was higher for call broadcast surveys compared to passive surveys (Table 7). The differences were most pronounced for rails, and the results from the overall Repeated Measures ANCOVA model were significant even after controlling for the difference in minutes surveyed between passive and broadcast periods (Table 7).

Another important parameter to consider when making decisions regarding which survey method to use for a continental marsh bird monitoring program is spatial variation in number of birds detected. A survey method that has low spatial variation in number of birds detected is superior to one that has high spatial variation, all else being equal. Spatial variation in number of birds detected was higher for call broadcast surveys compared to passive surveys for soras, Virginia rails, and king rails (Table 8). Because zero birds are detected at most points, call broadcast may increase spatial variance in birds detected simply by turning some otherwise zero counts into points with $\geq$1 bird detected. We examined this possibility by comparing the proportion of zero counts associated with call broadcast and passive surveys. Proportion of zero counts was high for both passive and call broadcast surveys, and was only slightly lower for call broadcast surveys (Table 5).

Field trials to estimate detection probability on radio-marked bitterns

We detected the focal American bittern during the 5 minute passive period on 2 of 26 trials (7.7% detection probability, passive surveys), and detected the focal bird during the 5-minute call broadcast period on 8 of 26 trials (30.8% detection probability, call broadcast surveys). We did not detect the focal male least bittern during the 5-minute passive survey on any of the 8 trials (0% detection probability, passive surveys), and detected the focal male least bittern during the 5-minute call broadcast period on 1 of 8 trials (12.5% detection probability, call broadcast surveys). We did not detect the focal female least bittern during either survey period on any of the 3 trials. Detection probability differed among individual birds; one American bittern responded to call broadcast on all 4 trials (100% detection probability) whereas another bittern failed to respond on all 5 trials (0% detection probability).

DISCUSSION

Survey methods, call broadcast volume, and equipment used on past and on-going marsh bird survey efforts has varied greatly. Standardization is needed to maximize interpretation of data, allow comparison across studies, and create the ability to pool data for regional and continental analyses. One of the first decisions we need to make regarding survey methodology is whether to use passive surveys, call broadcast surveys, or both. Our summary of previous studies suggests that call broadcast does increase total number of birds counted for soras, Virginia rails, king rails, and limpkins, does not increase total numbers counted for American and least bitterns, and the results are equivocal for black rails and clapper rails. Our pooled analyses of 12 cooperator data sets produced similar results; call broadcast increases detection probability for rails, but is less effective at increasing numbers detected for bitterns, pied-billed grebes, coots and moorhens. However, our detection trials on radio-marked bitterns demonstrated that call broadcast surveys do increase detection probability of bitterns. Vocalization probability during the call broadcast portion of our survey trials was substantially higher compared to the passive portion for American bitterns (31% vs 8%, respectively). Call broadcast also increased vocalization probability for least bitterns (12.5% vs 0%). The discrepancy between our pooled analysis of cooperator data and our field trials could be due to the rarity and low local densities of bitterns. A very high proportion of survey points yield zero counts for bitterns at local study sites throughout their range. The relative benefit of using call broadcast surveys to increase numbers of birds detected varied among species and among studies. The proportional increase in mean number of birds detected per survey point on call broadcast surveys compared to passive surveys varied between 6% for American bitterns and 925% for king rails. Published estimates of detection probability associated with marsh bird surveys range from 19-100%, but most used biased measures of detection probability. Few reliable estimates of detection probability are available for any species of marsh bird. More studies are needed to estimate observer detection probabilities associated with passive and call broadcast survey methods.

However, comparing passive and call broadcast segments of our cooperator data is problematic because the length of the passive segment was not equal to the length of the call broadcast segment on most of the surveys. Hence, we would expect higher counts during the call broadcast period even if call broadcast does not increase detection probability simply because this period was typically longer. In only 2 studies was the duration of the passive segment equal to the duration of the call broadcast segment (Kirsch and Paine; Table 4). Call broadcast increased numbers of birds detected for sora (Paine), Virginia rail (Kirsch and Paine), and common moorhen (Paine), but not for pied-billed grebe, least bittern, or green-backed heron in these two studies (Table 6).

Using the number of birds detected per minute rather than total number detected would be one approach to correct for different duration of passive and call broadcast segments. However, birds detected per minute would be higher for whichever period was shorter (typically the passive period) because detection of new individuals declines with time at a survey point. Moreover, even though the length of the call broadcast period was longer than the length of the passive period in most cooperator's data, only a portion of the call broadcast period involved conspecific calls; most cooperators included multiple marsh bird species in their broadcast sequence. The relative lengths of the passive and call broadcast segments and the number of species included in the broadcast sequence varied among studies and these differences limited our analytical options. Our Repeated Measures ANCOVA analysis allowed us to include the difference in minutes between passive and call broadcast segments at each survey point as a covariate in our pooled analysis. This approach allowed us to test whether number of birds detected was higher on call broadcast segments after controlling for relative differences in survey duration. The results from the overall Repeated Measures ANCOVA model were significant even after controlling for the difference in minutes surveyed between passive and broadcast periods. Future studies can alleviate this analytical problem by keeping the initial passive segment and the call broadcast segment the same duration.

Although high detection probability is helpful, a more important consideration for monitoring is which method results in the lowest spatial and temporal variation in detection probability. Published analyses of survey data commonly ignore variation in detection probability and, hence, make the implicit assumption that detection probability is constant across time and space. This assumption is never tested and is undoubtedly unrealistic (Barker et al. 1993). Indeed, detection probability of marsh birds often differs between males and females (Brackney and Bookhout 1982, Legare et al. 1999). Our results suggest that call broadcast surveys increase temporal and spatial variation in number of birds detected for all species we considered. Higher temporal variation in numbers counted on call broadcast surveys compared to passive surveys is opposite of what many previous authors had assumed. High temporal variation in detection probability reduces our ability to detect population trends. Proportion of zero counts was high for both passive and call broadcast surveys, and was only slightly lower for call broadcast surveys.

Although local, regional, and continental surveys and monitoring efforts are relatively common and widespread, attempts to validate the relationship between counts obtained on surveys and actual numbers of individuals are rare. The few validation efforts that exist have focused on six approaches for evaluating the ability of count data to index local population size:

1) examining the correlation between count data and some other index (e.g., nest density) of population size that is thought to be more accurate (Robbins 1970, Zembal and Massey 1981, Brackney and Bookhout 1982, Dunn 1986, Rappole and Waggerman 1986, Holmes and Sherry 1988, Butcher et al. 1990, Hagan et al. 1992, Hussell et al. 1992, Witham and Hunter 1992),
2) examining the correlation between count data and local population estimates based on capture-recapture methodology,
3) examining the cumulative proportion of new individuals detected during repeated surveys of local areas (Bart et al. 1984, Spear et al. 1999),
4) the number of replicate surveys of areas known to contain birds during which at least one bird was detected (Gibbs and Melvin 1993),
5) response of "known pairs" (based on location of responses on previous surveys) on a survey (Glahn 1974, Smith 1975), and
6) estimating vocalization probability by examining the probability that a focal individual responds during a survey trial (Brackney and Bookhout 1982, Conway et al. 1993, Legare et al. 1999).

The first approach is unappealing because lack of a correlation between two indices does not necessarily indicate that counts do not index local population size and, conversely, existence of a correlation does not necessarily mean that either index tracks local population size (Sauer 1994). The second approach requires an accurate population estimate using capture-recapture of marsh birds. Yet, accurate population estimates from capture-recapture require large numbers of individuals marked (e.g., >100) and high recapture probability; requirements that are extremely difficult (if not impossible) and expensive for most marsh birds. The third approach assumes that all birds vocalize during at least one replicate survey, that observers can definitively determine the number of individual birds in an area after numerous replicate surveys, and that birds do not habituate to repeated call broadcast surveys. The fourth approach overestimates true detection probability by some unknown factor because only one individual bird within a sampled area needs to vocalize during each survey in order to obtain 100% detection probability (yet some unknown number of individuals are still not detected). The sixth approach assumes that the large majority of detections are aural and that observer bias is low (although we can estimate observer bias and incorporate into our estimate of detection probability).

Number of individual birds detected per survey point will be low for marsh birds relative to other continental avian monitoring programs. Estimates of the number of detections per point from previous empirical studies (i.e., those listed in Table 3) is undoubtedly an overestimate since previous studies are initiated in areas in which the species of interest was known to be abundant. A standardized continental marsh bird monitoring program would have to survey all emergent wetlands within the area or habitat chosen by the sampling frame. Many of these marshes would have lower densities of marsh birds compared to areas selected subjectively for previous local studies.

Although detection probabilities are relatively low for marsh birds and daily variation in vocalization probability is apparently high, surveys of marsh birds may have relatively low among-observer variation in detection probability because detections are predominantly aural (Table 3; Glahn 1974, Marion et al. 1981, Swift et al. 1988, Gibbs and Melvin 1993). Point count surveys often used to monitor other avian taxa typically require observers to record all birds heard and/or seen during the survey period. A drawback to combining aural and visual detections is that detection probability becomes density-dependent because visual detection probability is reduced when bird densities are high since surveyors recording singing birds on data forms are not observing birds. Ways to minimize this potential bias include using a tape recorder or a second observer to record birds detected. Temporal and spatial variation in detection probability cause many scientists to question conclusions produced from analyses of survey data. Hence, any method that eliminates one or more factors that create additional variation in detection probability will probably result in a better index.

Vocalization probability (p_v) is not independent of population size (N). Numerous authors have suggested that calling rate of marsh birds is density-dependent. Indeed, the assumption that detection probability is positively correlated with population size is implicit in the use of call broadcast (if one individual's call did not increase the detection probability of other nearby birds then call broadcast would not increase number of birds detected). The use of call broadcast may help reduce density-dependent count data or may compound the problem. Studies are needed to address this important issue.

Our pooled analysis of cooperator data was based on studies that conducted passive surveys immediately prior to broadcast surveys at the same points. This approach is useful because we can use paired analytical methods, but this approach also has a potential bias. Observers who detect a bird during the initial passive segment may pay greater attention to that particular species, call, or location during the subsequent call broadcast segment. This would increase observer detection probability in the later segment and result in overestimating the usefulness of call broadcast at increasing detection probability. To avoid such a time-effect, future studies may consider repeating entire surveys on different days alternating between passive and call broadcast survey methods.

Another critical issue in designing a continental or regional marsh bird monitoring program is the sampling frame and how permanent survey points are selected. The most basic requirement for effective survey methodology is standardization of survey effort (i.e., the survey should be conducted in exactly the same way in all locations and across all years of the survey). Most, if not all, extensive monitoring programs suffer from an incomplete sampling frame (i.e., the survey points sampled were not drawn from the population of interest using a valid sampling design). This problem limits our ability to extrapolate any trend estimate produced to the population at large regardless of whether call broadcast is used for sampling or not. To draw conclusions about continental and regional population trends (the primary goal of most monitoring efforts) we need a monitoring program that chooses specific locations (e.g., marshes or survey routes) to include in annual surveys in an unbiased manner. Both area-based and habitat-based sampling frames have been proposed for use in a continental marsh bird survey (Ribic et al. 1999).

Area-based sampling frames would choose areas randomly within which to conduct surveys and observers would survey all emergent wetlands within that area each year. Habitat-based sampling frames would choose a subset of emergent wetlands randomly among existing emergent wetlands. One habitat-based sampling approach used in local surveys (Tecklin 1999, C. Paine, unpubl. data) and suggested for possible use in a continental monitoring program (Ribic et al. 1999) is choosing a random sample of palustrine emergent wetlands from the National Wetland Inventory (NWI) maps (Cowardin 1979). Habitat-based sampling frames have a large bias for long-term monitoring that is especially problematic for wetland habitats. Many emergent wetlands are not perennial; succession and water level changes result in changes in location of ideal marsh bird habitat. Hence, habitat-based sampling frames may be biased toward negative population trends simply because of changes or shifts in location and quality of wetland habitat. For example, only 31 of the 71 wetlands that contained black rails in northern California were labeled as emergent wetlands on NWI maps and many of the emergent wetlands identified on NWI maps no longer existed (Tecklin 1999). However, NWI maps may be useful in a more general sense as part of an area-based sampling frame; NWI maps did put observers in northern California into wetland concentration areas where observers could then search the surrounding area visually and ask locals the location of additional wetland areas (Tecklin 1999).

Many local marsh bird survey efforts ask observers to record the distance to each bird detected. One use of this data is to estimate local density using distance sampling. However, using distance sampling of marsh bird survey data to estimate local population density has several potential problems. Response to call broadcasts could be reduced near the tape recorder (e.g., pied-billed grebes rarely vocalized within 25m of an observer; Gibbs and Melvin 1993). Moreover, observers often broadcast calls from just outside suitable habitat (e.g., at edge of adjacent upland or from a boat in open water). When observers do broadcast calls from survey points within the emergent vegetation, observer movement between points may affect propensity to vocalize for birds in the immediate vicinity. Birds moving toward the broadcast source has been reported in pied-billed grebes, limpkins, Virginia rails, soras, king rails, clapper rails, black rails, and spotless crakes. Movement of birds toward the broadcast source prior to vocalizing violates a critical assumption of distance sampling (Buckland et al. 1993) and is another drawback of call broadcast surveys. Observer error in distance estimation can be substantial at distances >50m (Scott et al. 1981). Some marsh birds often turn slowly while calling causing apparent changes in the volume of calls, and others call from both below and on top of the emergent substrate, causing great differences in apparent distance to calling birds (Bart et al. 1984). Black rails sometimes changed directions while calling, which greatly affected observer detection probability and caused observers to under- or over-estimate distance to the calling bird (Kerlinger and Wiedner 1991). For these reasons, we question our ability to accurately estimate local marsh bird density using distance sampling on aural surveys.

Our summary of 36 previous studies provided additional insight into the intrinsic and extrinsic factors that influence detection probability on marsh bird surveys. Evening surveys have proven better in some local studies, whereas morning surveys were better in others, and the relative effectiveness of morning vs evening surveys may vary seasonally. Daily peak in vocalization probability can vary among co-existing species within a particular survey period. Optimal weather conditions for conducting surveys are better in the morning in some regions, but better in the evening in others. The peak in vocalization probability may be shorter in evenings compared to mornings. Vocalization probability probably varies seasonally due to hormonal changes associated with the breeding cycle. Hence, future marsh bird surveys should be timed to coincide with peak in clutch initiation in local areas. Weather variables often explain only a small portion of the temporal variation in vocalization probability in local studies. Peak in vocalization probability also varies among co-existing species. Conducting 3 replicate surveys can 1) ensure that survey timing is optimal for all co-existing species in each local area, 2) help ameliorate the problems associated with daily variation in vocalization probability, and 3) help ameliorate biases created by annual variation in seasonal peak vocalization probability.

Duration of survey period has varied greatly among local marsh bird survey efforts. Choosing an optimal survey duration suitable for all marsh bird species and all regions is important for a standardized continental monitoring program. Most studies report a rather rapid decline in new detections over the course of the survey period. Most studies report that each species vocalizes most frequently in response to conspecific broadcasts compared to interspecific tape sequences, but results vary among studies. This issue deserves more rigorous study.

Standardized marsh bird survey protocols

Based on our review of past and on-going survey efforts, and on the results and analytical constraints associated with our analysis of pooled cooperator survey data, we developed a standardized continental marsh bird monitoring protocol (Appendix 1). This protocol takes into account the results of our analyses of the pooled dataset reported in this paper (Tables 2-8), the recommendations of the marsh bird monitoring workshop (Ribic et al. 1999), and the need to generate additional data to better test some of the monitoring protocol issues still unresolved due to the lack of standardization among previous studies (Table 2).

We recommend a survey protocol that includes an initial passive period followed by an equivalent-length call broadcast period. This approach will allow us to compare numbers detected during passive vs call broadcast segments in the near future without the problems associated with different survey durations. We also recommend separating both the passive segment and the call broadcast segment into $\geq$3 1-min time intervals. For example, if the passive segment is 3-minutes then observers record whether each individual bird was detected within the first minute, second minute, and/or the third minute. This design will allow us to estimate vocalization probability by treating the data produced at each point as a removal experiment (Farnsworth et al. 2001). A design such as this which has the capability within the sampling program to estimate detection probability is extremely useful (Burnham 1981, Skalski and Robson 1992).

Detection probability and the effectiveness of call broadcast changes seasonally and optimal timing differs regionally and even locally. Call broadcast may be effective during one narrow portion of the breeding season but much less effective 2 weeks later. The seasonal window when detection probability is highest may vary among co-existing marsh bird species. Hence, a continental monitoring program should include 3 replicate surveys each year at each survey point. The level of background noise varies spatially and temporally and influences detection probability. A standardized survey should also require observers to record the level of aberrant noise during each survey point so we can control for noise level as a covariate in future trend analyses. We also recommend observers quantify basic habitat information at each survey point so that we have the ability to treat habitat configuration as a potential covariate in future trend analyses.

This protocol is a first attempt at standardization of marsh bird survey efforts in North America. Such an effort will be extremely useful by allowing us to pool data across studies and across regions to estimate population trends of marsh birds. The sampling design avoids the analytical problems associated with our effort to pool data from previous survey efforts and will also allow us to better determine the usefulness of call broadcast surveys in the near future. Finally, the survey design will also allow us to better estimate detection probability and spatial and temporal variation in detection probability associated with marsh bird surveys. These parameters will allow us to more accurately determine the number of survey points needed to estimate population change for marsh birds in North America.

The best survey methodology is one that produces low temporal and spatial variation in detection probability. This study is the first to report estimates of variation in detection probability for passive and call broadcast surveys of marsh birds. Our results suggest that call broadcast increases detection probability but also increases temporal and spatial variation in numbers counted. However, we need more rigorous estimates of temporal and spatial variation in detection probability on surveys in which passive and call broadcast segments are of equal duration; our new survey protocol will provide us with this data.

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Table 1. Equipment used to broadcast recorded calls of marsh birds during standardized surveys, maximum sound pressure used (dB at 1m in front of the speaker), maximum distance broadcast calls were audible by observers, and cost of equipment used in previous and on-going local marsh bird survey efforts.

	Powerhorn	decibels @ 1m	distance audible (m)	cost (U.S.$)	reference
Boombox-type tape players					
SONY Sports Series CFD-980	no			200	Soch Lor
SONY boombox CFS-903	no		80	100	Crowley 1994
SONY boombox CFS-903	no		80	100	Gibbs and Melvin 1993
Handheld walkman-type cassette players					
Panasonic Slimline RQ 2101	no	90		40	Evens et al. 1991
handheld tape player	no			<100	Joy Albertson, pers. comm.
Radio Shack CTR-76	yes	90		50	Legare et al. 1999
Sanyo MGR59	yes				Weiss 1995
handheld tape player	no	90	100		Kwartin 1995
Realistic 14-1053 or 14-1151	no			<100	Weeber - MBMP
Lloyd's model # V630	no				Weeber - MBMP
Norelco cassette recorder	no	96			Griese et al. 1980
cassette recorder		90			Johnson and Dinsmore 1986b
9-volt cassette tape player	yes				Brackney and Bookhout 1982
small tape player	yes				Piest and Campoy 1998
Realistic model CTR-48	yes		60		Todd 1980
Sony A-B cassette-corder					Repking 1975
Sony model TCS-580V	yes	81-85			Tecklin 1999
Realistic model SCP-29	yes				Spear et al. 1999
Sony model 110-A					Tacha 1975
Sony model 110-A					Baird 1974
cassette tape recorder	yes				Manolis 1978
Others					
Johnny Stewart game caller	yes			300	Diane Penttila
Johnny Stewart game caller	yes	90		300	Conway et al. 1993; Eddleman 1989
Johnny Stewart game caller	yes	90		300	Flores and Eddleman 1991
Uher model 4000	no	94.5			Glahn 1974
Uher model 4400					Zimmerman 1984
Realistic 505A reel-to-reel	yes				Smith 1974
Amplified speakers to attach to cassette players					
Radio Shack 277-1008 ampl speaker				12	C. Conway, unpubl. data
Radio Shack powerhorn megaphone					Linden Piest
Radio Shack metal loudspeaker/powerhorn					Legare et al. 1999
Perma Power Elect. half-mile hailer					Weiss 1995
portable outdoor speaker					Brackney and Bookhout 1982
Realistic model 40-1237 remote power horn					Smith 1974
Radio Shack Powerhorn megaphone					Piest and Campoy 1998
Fanon model MVS-10 megaphone					Todd 1980
Radio Shack mini amplifier-speaker, Cat. #277-1008C					Tecklin 1999
Realistic No. 4-1303 stereo-amplified speaker system					Spear et al. 1999
15 watt power horn					Manolis 1978

Table 2. Variation in survey methods and protocols for published marsh bird survey efforts in North America.

species	min/ point[1]	survey radius (m)	# points	point spacing (m)	# surv.	# repl/ yr	time of day [5]	dates of survey	reference
all marsh birds				≥250		2	1800-ss	25 May-5 Jul	MBMP-Weeber
pbgr, lebi, ambi, sora, vira, grbh, amco, como			347	~250	835		0430-1000	May-mid Jul	Gibbs and Melvin 1993
sora, vira, lebi, ambi	4-2-0	18	186			3	sr-1000	May-Jun	Brown and Dinsmore 1986
sora, vira, kira, lebi, ambi	2-3-2	80					0700-1100	1 Apr-30 Jun	Manci and Rusch 1988
sora, vira, kira, yera, blra	0-6-0		107			1	all	mid Apr-mid Jun	Weiss 1995
sora, vira, kira-1974	3			100		12	early morning	27 Mar-end Jul	Tacha 1975
sora, vira, kira-1975	10			80		12	sr/ss	27 Mar-10 Jun	Tacha 1975
sora, vira, kira	3-3-0			100		21	0.75h bef-2.75h aft sr	27 Apr-27 Jul	Baird 1974
sora, vira	20		~23	>100	85	1-7	sr-3h aft sr/2h bef ss-ss	mid Mar-end Jun	Zimmerman 1984
sora, vira	5			60		10	sr-3h aft/3h prior-ss	26 Apr-28 May	Glahn 1974
sora, vira			114	80-130		3-7	sr/ss	Apr-Oct	Griese et al. 1980
sora, vira	4		108	30-150		6-7	1h bef-3h aft sr/1-4h aft ss	15 Apr-16 Jun	Johnson and Dinsmore 1986b
blra, vira	10[4]		229			1-6	0.5h bef ss-?		Kerlinger & Sutton 1989; Kerlinger & Wiedner 1991
clra, blra	7-15-0		157	40-250	157	1	dawn-1000	6-17 May	Todd 1980
como	1	40					0630-1030	mid Jun-ear Aug	Brackney and Bookhout 1982
sora	1.1	100	149	>100		7	all	Aug-Oct	Kwartin 1995[2]
sora	3.7			60			0800-1200	26 Aug-15 Sep	Fannucchi et al. 1986
clra	18			1330			0.5h aft ss-dark	ear Apr-mid Jun	Mangold 1974
clra							2h prior to ss-dark	24 Mar-17 May	Zembal and Massey 1981[3]
clra							0.5h bef sr-0900	24 Mar-28 May	Smith 1974

Table 2. (continued).

clra	2-2-2		140	100-200	140	1	sr-1000	12-14 May	Piest and Campoy 1998
clra	~2.5		30		380	12	dawn-1h aft dawn/1h bef ss-ss	10 May-22 Nov	Zembal et al. 1985
clra	4		64	~115			dawn-1000	Mar-Aug	Conway et al. 1993; Eddleman 1989
yera						7	2300-0430	26 Jun-3 Jul	Bart et al. 1984
blra	2-1-0		~620	60-100			2100-0430	Mar-Jul	Runde et al. 1990
blra	0-4-2			40		1-3	0.5h bef sr-1000	Dec-Aug	Repking 1975, Repking and Ohmart 1977
blra	1-4-2	30	225/158	80-100		1-3	sr-0930/1h bef-1h aft ss	1 Apr-30 Jun/1 Dec-15 Jan	Tecklin 1999
blra	10		40	50	1200	30	1.5h bef-2.5h aft sr/15h bef-2h aft ss	30 Apr-9 Jul	Spear et al. 1999
blra	2-2-2			100			sr-3h aft ss/2h bef-1h aft ss	Mar-Aug	Legare et al. 1999
blra	0-4-0		11	100		>20	am/pm		Flores 1991; Flores and Eddleman 1991
blra								25 Mar-14 Jul	Manolis 1978
blra-Colorado River	1-1.5-3.5	30	929	100	929	1	0600-1000/1700-2100	23 Mar-23 Apr	Evens et al. 1991; Laymon et al. 1990
blra-San Fran Bay	1-1.5-3.5	30	1168	100	1168	1	dawn-0930	3 Mar-28 Jun	Evens et al. 1991

[1]surveys that included an initial passive and a subsequent call broadcast period are represented as: initial passive-call broadcast-final passive
[2]includes responses in response to tapes and canoe paddle slaps
[3]passive surveys only
[4]variable (10-40min) survey length; only broadcast black rail calls, no Virginia rail calls
[5]ss=sunset, sr=sunrise

Table 3. Detection distance, percent aural detections, peak seasonal response, mean birds detected per point, and detection probabilities from previous studies of marsh birds in North America.

species	mean detect dist (m)	max detect dist (m)	% detect aural only	peak in seasonal response	# pts indiv detect	# indiv detect	indiv detect per point	# calls/ point	detect prob (%)	range in detect prob	reference
pied-billed grebe	192	500	73	lat May-ear Jul			0.15		86[6]	73-94[6]	Gibbs and Melvin 1993
least bittern	63	99	74	lat May-lat Jun			0.04		56[6]	38-73[6]	Gibbs and Melvin 1993
least bittern				mid May							Manci and Rusch 1988
American bittern	172	500	80	ear May			0.23		65[6]	54-74[6]	Gibbs and Melvin 1993
American bittern				mid May							Manci and Rusch 1988
sora	98	200	91	lat May-lat Jun			0.19		73[6]	59-84[6]	Gibbs and Melvin 1993
sora										20-100[7]	Glahn 1974
sora							1.7 - 2.0				Kwartin 1995[1]
sora	68										Johnson and Dinsmore 1986b
sora				1st wk May							Manci and Rusch 1988
sora						149	1.4				Weiss 1995
sora				24 Apr-7 May		44	0.52[10]				Zimmerman 1984
Virginia rail				8-21 May		32	0.38[10]				Zimmerman 1984
Virginia rail						116	1.1				Weiss 1995
Virginia rail				3rd wk May							Manci and Rusch 1988
Virginia rail	77	200	96	lat May-ear Jul			0.26		74[6]	64-82[6]	Gibbs and Melvin 1993
Virginia rail										22-72[7]	Glahn 1974
Virginia rail						39	0.17				Kerlinger & Sutton 1989
Virginia rail-am	51						0.4				Johnson and Dinsmore 1986b

Virginia rail-pm	118						0.9			Johnson and Dinsmore 1986b

Table 3. (continued).

sora/vira combined		80[4]						2.68[3]		Glahn 1974
sora/vira combined								0.62[2]		Glahn 1974
king rail				ear - mid Jun						Manci and Rusch 1988
king rail						2	0.02			Weiss 1995
kira, sora, vira-1974	<40	60		ear May-mid Jun						Tacha 1975
kira, sora, vira-1975				mid-lat Apr						Tacha 1975
kira, sora, vira				11 May-14 Jun						Baird 1974
clapper rail		300								Smith 1974
clapper rail		100				240	1.7			Piest and Campoy 1998
clapper rail						123				Todd 1980
clapper rail				1 Apr-3 Jun					19[15]	Conway et al. 1993; Eddleman 1989
clapper rail				mid Apr-ear May						Todd 1986
clapper rail				May						Bennett and Ohmart 1978
clapper rail				ear May-ear Jun						Montgomery 1987
clapper rail									75[7]	Smith 1975
clapper rail									95[8]	Smith 1975
clapper rail-am				ear May-end Jun[9]	51	57	0.15	0.15		Zembal et al. 1985
clapper rail-pm				ear May-end Jun[9]	40	48	0.12	0.12		Zembal et al. 1985
yellow rail		>1000	100						72[5]	Bart et al. 1984
yellow rail						0	0.0			Weiss 1995
black rail			97			30	~0.05			Runde et al. 1990
black rail						0	0.0			Weiss 1995

black rail			95		45	80	0.51		Todd 1980
black rail		120				960	0.80		Spear et al. 1999

Table 3. (continued).

black rail[2]				lat Mar- May			0.11-0.30		Flores 1991; Flores and Eddleman 1991
black rail[3]				lat Mar- May			0.08-0.21		Flores 1991; Flores and Eddleman 1991
black rail							0.04-1.58		Nur et al. 1997
black rail			97	Mar-May		33			Manolis 1978
black rail		>400		lat Apr-ear May		23	0.10		Kerlinger & Sutton 1989; Kerlinger & Wiedner 1991
black rail-m	60	80		lat Jul			0.23-0.51	81[11]	Legare et al. 1999
black rail-f	20	80					0.23-0.51	19[12]	Legare et al. 1999
black rail-am								63[13]	Legare et al. 1999
black rail-pm								37[14]	Legare et al. 1999
black rail-CoRiver					9	116	0.12		Evens et al. 1991; Laymon et al. 1990
black rail-SFBay					25	497	0.43		Evens et al. 1991
black rail, Mar-Aug '73						106			Repking 1975, Repking and Ohmart 1977
black rail, Dec-Feb '73				lat May-lat Jun		34			Repking 1975, Repking & Ohmart 1977
black rail, Mar-Aug '74						96			Repking 1975; Repking & Ohmart 1977
black rail, Apr-Jun '97		>100				184	0.89		Tecklin 1999
black rail, Dec-Jan						91	0.58		Tecklin 1999
black rail, Apr-Jun '98						125	0.87		Tecklin 1999
American coot							0.004		Gibbs and Melvin 1993
common moorhen							0.01		Gibbs and Melvin 1993
common moorhen-m								93[16]	Brackney and Bookhout 1982
common moorhen-f								21[16]	Brackney and Bookhout 1982

green-backed heron	0.01	Gibbs and Melvin 1993

[1]includes responses in response to tapes and canoe paddle slaps
[2]passive surveys
[3]call broadcast surveys
[4]90% were within 60m
[5]estimate based on the cumulative proportion of individual birds detected on the first of $\geq$4 replicate surveys on each of 5 nights at one study site.
[6]estimates of detection probability based on the number of replicate surveys of areas known to contain birds during which at least one bird was detected. This approach overestimates true detection probability by some unknown factor because only one individual bird within a sampled area needs to vocalize during each survey in order to obtain 100% detection probability (yet some unknown number of individuals are still not detected).
[7]response of “known pairs” based on location of responses on previous surveys
[8] response of “known unpaired males” based on location of responses on previous surveys
[9]earlier dates not surveyed.
[10]only includes stations and dates where at least one Virginia rail or sora was detected, so this is biased high
[11]non-nesting males
[12]nesting females
[13]based on radio-marked birds in the morning
[14]based on radio-marked birds in the evening
[15]percentage of radio-marked birds vocalizing in response to call broadcast survey; varied seasonally; 0.40 Mar-Apr, 0.20 May-Jul, 0.07 Aug-Oct, and 0.10 Nov-Feb.
[16]percentage of focal birds vocalizing in response to call broadcast survey

Table 4. Summary of cooperator data contributed for pooled analysis.

Cooperator	state	# of species on tape	# yrs	years	# yrs same pts surv.	# obs	min per point[1]	# pts	pt spacing (m)	# surveys	# repl per yr	time of day[2]	season	includes weather data
Brininger[6]	Mn	6	3	97-99	1-3	1	3/12/0[3]	25	320	90	1-2	m	May-Jun	yes
Brinker	Md	9	2	90-91	**1**-2	3	5/36/5	265	805	721	1-20	m,e,n	Apr-Sep	yes
Cantu	Mo	9	1	98	1	2	2/8/2	15	350	62	4-5	m	Jun-Jul	no
Crowley	Ma/Me	5-9	2	91-92	1	3	3/5-9/0	449	100	1304	1-3	m	May-Jul	yes
Gibbs	Me	8	1	92	1	1	3/8/0	370	225	522	1-3	m,e	May-Jul	yes
Kirsch	Ia/Wi	7	2	94-95	1-2	7	10/10/0	108	200	181	1	m	May-Jul	yes
Lapp	Co	5	1	98	1	1	0/16/0	44	520	44	1	m,e	Jun	yes
Legare	Fl	1	2	93-94	2	1	2/1/2	22	100	992	2-36	m,e	Mar-Aug	yes
Lor	Ny	5	2	97-98	1-**2**		3/5/2	123	100	1932	1-14	m	Apr-Jul	yes
Melvin	Ma	8	1	92	1	3	3/8/0	43	100	110	1-**3**	m	May-Jul	yes
Paine	Il	4-11	3	96-98	1-**3**		8/8/3[4]	142	175	1094	1-8	m	Apr-Aug	yes
Penttila	Wi	7	13	83-98[7]	1-13	5	2/3-6/2	58	800	1632	1-10	m	Apr-Jun	no
Piest	Az	1	20	79-98	**1**-17	36	0/5-6/0	1066	180	3222	**1**-3	m,e	Apr-Jun	yes
Ribic	Wi	5-7	4	95-98	1-3	7	5/6/1[5]	218	200	826	1-13	m,e	May-Sep	yes
Shieldcastle	Oh	5	8	91-98	1-8	58	0/5/0	700		3660	1	m	May-Jun	no

[1]minutes initial passive period/minutes during call broadcast/minutes final passive period.
[2]m=morning, e=evening, n=nighttime.
[3]some points were surveyed 0/18/0
[4]some points were surveyed 0/8/8
[5]some points were surveyed 5/7/2, some 0/15/0
[6]call broadcast period includes only individual birds that were not detected during prior passive period.
[7]1987-89 not surveyed.

Table 5. Proportion of survey points at which ≥1 bird was detected for both call broadcast and passive surveys from marsh bird survey efforts in North America. Numbers are based on individual survey points across all years (replicate surveys not pooled within years).

	sora		Virginia rail		black rail		king rail		clapper rail		common moorhen		American coot		pied-billed grebe		American bittern		least bittern		green-backed heron		marsh wren	
	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape
Brinker	1	8	13	48	1	4	2	16	1	8	4	10			0.2	0.7	0	0.4	1	4				
Cantu	3	5	0	2			2	10			0	0			19	18	0	0	8	8			2	10
Crowley	3	1	4	23			0.1	0.1			0.2	1					1	1	0.3	1	3	5		
Gibbs	9	4	5	30							1	3	0	0	5	9	11	15	0.4	1				
Kirsch	3	3	3	9							14	16			9	10			4	5				
Legare					12	9																		
Melvin	3	8	8	30			0	0			0	0			0	0	0	0	1	3	4	3		
Paine	10	18	9	25	0	0	0	0			15	21	9	9	0	0	0	0	5	5	0.4	2	36	33
Penttila	12	26	4	23			0.1	2									2	2	1	1			32	35
Piest										40														
Ribic	15	24	11	51			0	2									4	3	5	12				
Lor	2	5	3	23											21	25	12	12	2	2				

Table 6. Mean number of individual birds detected per point during initial passive and subsequent call broadcast portions of marsh bird surveys, and statistical results of repeated measures analysis of covariance examining differences between passive and tape portions of the surveys controlling for the difference in minutes during each of the survey periods. Replicate surveys at each point within a year were averaged prior to analysis. Numbers in bold-face are those significantly higher (P < 0.05) than their counterpart (tape survey recorded more birds/point than passive survey, or vice-versa).

	sora		Virginia rail		black rail		king rail		clapper rail		common moorhen		American coot		pied-billed grebe		American bittern		least bittern		green-backed heron		marsh wren	
	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape
Brinker	0.007	**0.056**	0.199	**1.720**	0.004	**0.065**	0.011	**0.133**	0.041	**0.275**	0.024	**0.112**			0.001	0.008	0.00	0.002	0.002	**0.014**				
Cantu	0.033	0.050	0.00	0.016			0.017	**0.120**			0.00	0.00			0.203	0.320	0.00	0.00	0.097	0.113			0.017	0.133
Crowley	0.013	**0.044**	0.054	**0.357**			0.001	0.001			0.002	0.005					0.008	0.010	0.003	0.007	0.025	0.038		
Gibbs	0.062	**0.186**	0.072	**0.457**							0.005	**0.025**	0.00	0.00	0.066	**0.139**	0.137	**0.182**	0.004	0.012				
Kirsch	0.054	0.141	0.033	**0.272**							0.587	0.533			0.380	0.348			0.109	0.109				
Legare					**0.134**	0.087																		
Melvin	0.027	0.093	0.081	**0.392**			0.00	0.00			0.00	0.00			0.00	0.00	0.00	0.00	0.008	0.031	0.039	0.023		
Paine	0.222	**0.483**	0.097	**0.826**	0.00	0.00	0.00	0.00			0.330	**0.612**	0.117	0.127	0.00	0.00	0.00	0.00	0.076	0.085	0.001	0.035	**1.45**	0.797
Penttila	0.126	**0.346**	0.041	**0.288**			0.001	**0.024**									0.023	0.022	0.009	0.005			0.775	**0.870**
Ribic	0.232	**0.426**	0.167	**1.102**			0.00	0.028									0.028	0.021	0.049	0.185				
Lor	0.020	**0.080**	0.044	**0.306**											0.319	0.356	0.168	0.162	0.034	0.031				
ANCOVA	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
tape vs passive	149.1	**<0.001**	58.3	**<0.001**	0.6	0.453	0.1	0.805			8.6	**0.003**	1.0	0.320	10.6	**0.001**	5.6	**0.018**	1.2	0.281	1.9	0.169	41.1	**<0.001**
minutes surveyed	10.9	**0.001**	156.9	**<0.001**	12.3	**0.001**	62.1	**<0.001**			0.0	0.944	0.6	0.428	0.5	0.473	0.1	0.729	0.1	0.740	0.4	0.512	36.6	**<0.001**

Table 7. Temporal variance in number of individual birds detected (average standard deviation of number of birds detected on replicate surveys at a point within a year) during initial passive and subsequent call broadcast portions of marsh bird surveys, and statistical results of repeated measures analysis of covariance examining differences between passive and tape portions of the surveys controlling for the difference in survey minutes between the periods. Numbers in bold-face are those significantly higher (P < 0.05) than their counterpart (standard deviation in birds counted at a point on replicate surveys higher on tape survey compared to passive survey, or vice-versa).

	sora		Virginia rail		black rail		king rail		clapper rail		common moorhen		American coot		pied-billed grebe		American bittern		least bittern		green-backed heron		marsh wren	
	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape
Brinker	0.026	**0.075**	0.280	**1.192**	0.014	**0.052**	0.026	**0.223**	0.019	**0.132**	0.049	**0.198**			0.003	0.018	0.00	0.007	0.012	**0.054**				
Cantu	0.067	0.072	0.00	0.033			0.033	**0.253**							0.373	0.538			0.160	0.230			0.033	0.228
Crowley	0.017	**0.067**	0.079	**0.370**			0.001	0.001			0.004	0.009					0.014	0.018	0.005	0.012	0.089	0.123		
Gibbs	0.014	0.028	0.047	**0.379**							0.025	**0.066**			0.042	0.050	0.077	**0.140**	0.006	0.006				
Kirsch																								
Legare					**0.350**	0.232																		
Melvin	0.050	0.159	0.128	**0.391**															0.016	0.062	0.062	0.047		
Paine	0.421	**0.865**	0.124	**0.906**							0.308	**0.523**	0.234	0.228					0.137	0.117	0.004	0.060	**1.276**	0.827
Penttila	0.233	**0.489**	0.097	**0.368**			0.001	**0.046**									0.055	0.055	0.026	0.014			0.832	0.866
Ribic	0.370	0.520	0.266	**0.958**			0.00	0.057									0.067	0.050	0.099	0.176				
Lor	0.056	**0.164**	0.106	**0.472**											0.533	0.557	0.342	0.332	0.078	0.056				
ANCOVA	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
tape vs passive	173.8	**<0.001**	150.3	**<0.001**	9.4	**0.002**	0.1	0.938			10.5	**0.001**	0.1	0.805	1.9	0.172	0.5	0.498	0.8	0.357	2.0	0.154	26.2	**<0.001**
minutes surveyed	20.0	**<0.001**	30.7	**<0.001**	19.2	**<0.001**	76.5	**<0.001**			1.8	0.186	0.1	0.883	0.0	0.911	0.4	0.532	5.3	**0.022**	0.2	0.672	22.1	**<0.001**

Table 8. Spatial variance in number of individual birds detected (average standard deviation of number of birds detected among points within a year at each study site) during initial passive and subsequent call broadcast portions of marsh bird surveys, and statistical results of repeated measures analysis of covariance examining differences between passive and tape portions of the surveys controlling for the difference in survey minutes between the periods. Numbers in bold-face are those significantly higher ($P < 0.05$) than their counterpart (standard deviation of birds/point on tape survey higher than passive survey, or vice-versa).

	sora		Virginia rail		black rail		king rail		clapper rail		common moorhen		American coot		pied-billed grebe		American bittern		least bittern		green-backed heron		marsh wren	
	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape	pass	tape
Brinker	0.054	0.233	0.690	3.321	0.036	0.180	0.076	0.501	0.213	0.629	0.170	0.606			0.005	0.083	0.00	0.017	0.020	0.095				
Cantu	0.088	0.140	0.00	0.065			0.065	0.176							0.166	0.400			0.205	0.184			0.065	0.265
Crowley	0.090	0.159	0.199	0.552			0.009	0.009			0.028	0.041					0.053	0.061	0.031	0.044	0.159	0.182		
Gibbs	0.260	0.570	0.293	0.758							0.055	0.164			0.263	0.413	0.342	0.419	0.055	0.105				
Kirsch	0.174	0.530	0.150	0.576							1.604	1.312			1.128	1.014			0.398	0.425				
Legare					0.095	0.092																		
Melvin	0.102	0.219	0.197	0.510															0.051	0.122	0.130	0.086		
Paine	0.565	0.847	0.220	1.267							0.894	1.140	0.306	0.372					0.240	0.303	0.009	0.214	2.065	1.275
Penttila	0.156	**0.344**	0.089	**0.278**			0.002	**0.064**									0.056	0.055	0.031	0.019			0.737	**0.788**
Ribic	0.472	0.686	0.333	1.308			0.00	0.116									0.080	0.070	0.156	0.473				
Lor	0.055	0.190	0.106	0.312											0.325	0.349	0.193	0.194	0.099	0.116				
ANCOVA	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
tape vs passive	32.5	**<0.001**	41.9	**<0.001**	1.3	0.343	9.9	**0.008**	1.7	0.420	0.6	0.462	0.8	0.470	5.8	**0.047**	0.7	0.432	1.1	0.304	0.3	0.660	1.1	0.326
minutes surveyed	1.2	0.379	8.6	**<0.001**	1.3	0.385	3.8	**0.015**			0.5	0.779			2.3	0.158	0.5	0.869	0.5	0.863	0.5	0.738	5.7	**0.010**

Table 9. Cooperators that provided usable data for our pooled analysis of marsh bird survey methodology.

Cooperator	Institution	Current Address	location of survey
Wayne Brininger	U.S. Fish and Wildlife Service	Rice Lake NWR, 36289 State Hwy 65, McGregor, MN 55760	Rice Lake NWR, MN
David Brinker	Maryland Dept of Natural Resources	Maryland DNR, 580 Taylor Ave. E-1, Annapolis, MD 21401	throughout Maryland
Rick Cantu	U.S. Fish and Wildlife Service	Mark Twain NWR, P.O. Box 88, Annada, Missouri 63330	Clarence Cannon NWR, MO
Shawn Crowley	University of Massachusetts	N/A	throughout Massachusetts
James Gibbs	State University of New York - ESF	SUNY-ESF, 1 Forestry Drive, Syracuse, NY 13210	throughout Maine
Eileen Kirsch	U.S. Geological Survey - BRD	USGS-BRD, Upper Mississippi Science Center, P.O. Box 818, La Crosse, WI 54602	Upper Mississippi NWR, WI/IO
Chris Lapp	U.S. Fish and Wildlife Service	Browns Park NWR, 1318 Hwy 318, Maybell, CO 81640	Browns Park NWR, CO
Michael Legare	University of Rhode Island	Dynamac Corporation, Mail Code DYN-2, Kennedy Space Center, FL 32899	St. Johns NWR, FL
Scott Melvin	Massachusetts Div. of Fish and Wildlife	Massachusetts Div. of Fish and Wildlife, Rt. 135, Westboro, MA 01581	throughout Massachusetts
Charles Paine	Max McGraw Wildlife Foundation	Max McGraw Wildlife Foundation, P.O. Box 9, Dundee, IL 60118	throughout northern Illinois
Diane Penttila	U.S. Fish and Wildlife Service	Horicon NWR, W4279 Headquarters Rd., Mayville, WI 53050	Horicon NWR, WI
Linden Piest	Arizona Game and Fish Department	9140 E. County 10½ St., Yuma, AZ 85365	SW Arizona
Christine Ribic	U.S. Geological Survey -BRD	Wisconsin Coop. Wildlife Research Unit, 1630 Linden Dr., Madison, WI 53706-1598	Horicon, Necedah, and Trempealeau NWRs, WI
Mark Shieldcastle	Ohio Division of Wildlife	Crane Creek Wildlife Research Station, 13229 West St. Rt. 2, Oak Harbor, OH 43449	throughout Ohio
Socheata Lor	Cornell University	303 T Anheuser-Busch Bldg., Univ. Missouri-Columbia, Columbia, MO 65211	Iroquois NWR, NY

Appendix 1. Proposed standardized survey protocols for North American marsh bird monitoring program.

STANDARDIZED NORTH AMERICAN MARSH BIRD MONITORING PROTOCOLS

Introduction

The amount of emergent wetland habitat 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), but we currently lack adequate monitoring programs to determine status and estimate population trends. Marsh birds include all species that primarily inhabit marshes (i.e., marsh-dependent species). Primary species of concern in North America include King Rails (*Rallus elegans*), Clapper Rails (*Rallus longirostris*), Virginia Rails (*Rallus limicola*), Soras (*Porzana carolina*), Black Rails (*Laterallus jamaicensis*), Yellow Rails (*Coturnicops noveboracensis*), American Bitterns (*Botaurus lentiginosus*), Least Bitterns (*Ixobrychus exilis*), Pied-billed Grebes (*Podilymbus podiceps*), American Coots (*Fulica americana*), Purple Gallinules (*Porphyrula martinica*), and Common Moorhens (*Gallinula chloropus*). The U.S. Fish and Wildlife Service has identified Black Rails, Least Bitterns, and American Bitterns as species of special concern because they are relatively rare and we lack basic information on status and trends in most areas (U. S. Fish and Wildlife Service 1987). Many states consider these species threatened or of special concern for similar reasons. Because rails and bitterns consume a wide variety of aquatic invertebrates, populations may be affected by accumulation of environmental contaminants in wetland substrates (Odom 1975, Klaas et al. 1980, Eddleman et al. 1988, Gibbs et al. 1992, Conway 1995). Marsh birds are also vulnerable to invasion of wetlands by purple loosestrife (*Lythrum salicaria*) (Gibbs et al. 1992, Meanley 1992). Hence, marsh birds represent "indicator species" for assessing wetland ecosystem quality, and their presence can be used as one measure of the success of wetland restoration efforts. Marsh birds also have high recreational value; many species are highly sought-after by recreational birders. Finally, several rails are game species in many states yet we lack responsible population surveys on which to base harvest limits.

For these reasons, numerous federal agencies are cooperating to monitor marsh bird populations in North America to estimate population trends. Continued monitoring will also allow resource managers to evaluate whether management actions or activities adversely impact wetland ecosystems. Any management action that alters water levels, reduces mudflat/open-water areas, alters invertebrate communities, or reduces the amount of emergent plant cover within marsh habitats could potentially affect habitat quality for marsh birds (Conway 1995).

During surveys for primary marsh birds, observers will also record species of secondary concern that are also under-sampled by other monitoring programs, e.g., grebes, herons, egrets, waterfowl, Forster's and Black Terns (*Sterna forsteri* and *Chlidonias niger*), Common Snipe (*Gallinago gallinago*), Sandhill Cranes (*Grus canadensis*), Northern Harriers (*Circus cyaneus*), Belted Kingfishers (*Ceryle alcyon*), Alder and Willow Flycatchers (*Empidonax alnorum* and *E. traillii*), Sedge and Marsh Wrens (*Cistothorus platensis* and *C. palustris*), Red-winged and Yellow-headed Blackbirds (*Agelaius phoeniceus* and *Xanthocephalus xanthocephalus*), Sharp-tailed and LeConte's Sparrows (*Ammodramus caudacutus* and *A. leconteii*), Common Yellowthroats (*Geothlypis trichas*).

PARAMETERS TO BE ESTIMATED

Density/abundance indices

Abundance is the total number of birds within a defined area of interest. Density is abundance divided by area, or the number of birds/ha of emergent habitat within a wetland during one season. Surveys rarely count all individuals present in the sampling area because detection probability is typically less than 100%. However, number of birds responding during standardized surveys will provide an index to abundance that will allow comparisons among wetland basins and habitat types. Abundance indices will also allow examination of the effects of management actions (e.g., wetland restoration) on marsh birds by comparing changes in abundance indices between managed and un-managed sites both before and after activities have occurred. Indices also allow comparison among other areas in the region to determine the relative importance/quality of local habitats to regional marsh bird populations. The value of an abundance index relies on a **consistent** positive correlation between number of individuals detected during a survey and number of individuals actually present in the area sampled (i.e., low spatial and temporal variation in detection probability). Few reliable estimates of detection probability during marsh bird surveys are currently available (but see Conway et al. 1993, Legare et al. 1999). Validation of indices based on call broadcast surveys for primary marsh bird species will be obtained by incorporating methods for estimating detection probability into survey protocols. In the meantime, we will assume number of birds responding during standardized surveys provide a useful index to abundance. We will calculate abundance indices for the primary marsh bird species during the breeding season.

Population trend

Population trend is the percent annual change in population size for each species. Population trend estimates allow managers to determine whether local or regional marsh bird populations are declining. Managers can establish a priori population trend thresholds or trigger points below which immediate management action will be taken. Such actions can prevent local extinctions by identifying population problems before they become severe. We will estimate population trends of marsh birds by using weighted linear regression to analyze annual changes in the number of individuals detected per survey point. Few estimates of marsh bird population trends currently exist, and reliable estimates of population trends will probably require >5 years of survey data. We will estimate population trends for the primary marsh bird species during the breeding season. After 2 years of data collection at a variety of sites across the country we will be able to conduct a meaningful power analysis to determine the percent annual change detectable with a specific number of survey points. Currently, a power analysis is premature since we don’t have reliable estimates of temporal and spatial variation in numbers counted using this protocol.

Trends in habitat availability

We will also estimate trends in emergent habitat availability. Trends in habitat availability are the percent annual change in the amount of each major wetland habitat type. Information on emergent habitat availability will allow us to: 1) extrapolate density indices to estimate total numbers of marsh birds regionally, 2) correlate changes in marsh bird numbers with changes in habitat availability to identify potential causes of observed population changes (Gibbs and Melvin 1993), 3) identify emergent habitats that need protection, and 4) design management actions in ways that either improve or minimize adverse effects to preferred habitat of marsh birds.

FIELD PROCEDURES, METHODS, PROTOCOLS

Wetland basins included in surveys

Surveys will be conducted in all freshwater emergent marshes within the management area that are >0.5 ha in total area. The "management area" can be an entire refuge (for very small refuges) or a portion of larger refuges. Observers should not place survey points or survey routes only in areas/marshes where they know marsh birds exist (or exist in high density). Such an approach is a biased sampling design that will always lead to perceived population declines (if you place samples in areas where density is highest then only declines can occur). Hence, we need an "area-based" sampling frame rather than a "marsh-based" sampling frame. Emergent habitat is not perennial and changes spatially over time - we want a sampling design that allows for that. By sampling "all emergent marshes within a defined area" observers will have to add or remove survey points as emergent habitat increases, decreases, or shifts within their defined management area. Survey routes should include as many survey points as needed to cover the area of interest (management area). Cooperators initiating a survey should attempt to include a minimum of 15 survey points in their management area.

Location of survey points

Fixed, permanent survey points will be chosen and marked with inconspicuous markers in the field. If possible, locations of all survey points should also be plotted on maps of each wetland using a GPS. Point spacing in previous studies has varied from 40m to 800m. The more survey points included in an area, the more precise the resulting estimates of local population change. For the standardized continental monitoring program, distance between adjacent survey points is 400 m (200 m intervals can be used in smaller management areas in order to obtain a sufficient number of survey points, but a 200-m interval increases the risk of double-counting individual birds and reduces the total area covered by monitoring efforts). Survey points in ponds should be located either on the upland-emergent interface or on the open water-emergent interface, whichever will allow easier access and travel between survey points. Some marshes may be more effectively surveyed by boat (with survey points on the open water-emergent interface) and others more effectively surveyed on foot (with survey points on the upland-emergent interface). Survey points within freshwater marshes associated with rivers should be located along mid-river channels where possible. Many local marsh bird survey efforts place survey points at the interface between emergent marsh and upland. This approach minimizes travel time between adjacent points, reduces trampling vegetation within the marsh, and may increase the distance at which observers can hear vocalizing birds due to increased elevation relative to the marsh vegetation. Each survey point receives a unique identification number. The number of survey points per marsh will be correlated with marsh size. Points should be in a 400m grid system in larger marshes (hence, 1 point per 16 ha of marsh). In many locations, emergent habitat occurs in small patchy marshes less than 16 ha in size. Include at least one survey point in all marshes >0.5 ha within the management area. Additional survey points can be added in small marshes as long as they are 400m apart.

Timing of surveys

All surveys begin 30 minutes before sunrise and must be completed by 11:00 am. Conduct 3 surveys annually during the presumed peak breeding season for all primary marsh birds in your area. Each of the 3 replicate surveys will be conducted during a 10-day window, and each of the 10-day windows will be separated by 7 days. Seasonal timing of these 3 replicate survey windows will vary regionally depending on migration and breeding chronology. The first survey should be conducted when migratory passage is over, but prior to breeding. For example, in south-central Washington the first survey should be between 1-10 May, the second survey 17-27 May, and the third survey 3-13 June. Marsh birds are typically most vocal during courtship and egg-laying periods. Try to maintain 2 weeks between each replicate survey. Three surveys are needed to confirm seasonal presence/absence of marsh birds in a wetland with 90% certainty (Gibbs and Melvin 1993). Three replicate surveys per year is warranted, **especially** in areas where personnel organizing survey times may not initially know local timing of breeding cycle. And, timing of breeding cycle differs among co-existing species of interest (e.g., American bitterns often breed much earlier than least bitterns and rails in some areas; clapper rails and king rails breed earlier than Virginia rails and soras in some areas). Finally, including 3 replicates per season will provide us with data on temporal and spatial variation in numbers counted (parameters needed to conduct reliable power analyses once enough preliminary data are available). The 3 survey windows increase our probability of conducting at least one survey during the peak seasonal response period of all primary marsh bird species in a local management area. One observer should expect to survey approximately 10-20 survey points each morning, depending on travel times between survey points.

Survey methods

Standardized survey methods for marsh birds have recently been developed to aid agencies developing marsh bird monitoring programs (Ribic et al. 1999). We will follow the general guidelines suggested in these continental protocols and the survey methods and protocols described here expand upon suggestions made at the Patuxent marsh bird monitoring workshop (Ribic et al. 1999). The methods outlined here are currently being used on 8 USFWS Region 5 National Wildlife Refuges, 2 refuges in eastern Washington, and Cape Cod National Seashore. Because many marsh birds are secretive, seldom observed, and vocalize infrequently, we will use broadcast calls to elicit vocalizations during vocal surveys (Gibbs and Melvin 1993). But because we want to estimate detectability, evaluate the usefulness of call broadcast for future survey efforts, and survey secondary species, we will also record birds during a passive period prior to playing tapes.

At each survey point, observers will record all species detected (both primary and secondary species) during both a 5-minute passive period prior to broadcasting recorded calls, and during a period in which a cassette tape of pre-recorded vocalizations is broadcast into the marsh. The cassette tape includes calls of the primary marsh bird species and is broadcast using a portable cassette player (e.g., SONY Sports Series CFD-980, or Johnny Stewart Game Caller). The tape should be obtained from the Cornell Laboratory of Ornithology's Library of Natural Sounds (contact Andrea Priori at 607-254-2404). Order tapes well in advance; the Cornell Lab may require 2-3 months to fill your order. The tape should include exactly 30 seconds of calls of each of the primary marsh bird species interspersed with 30 seconds of silence between each species. The 30 seconds of calls should consist of a series of typical calls interspersed with 5 seconds of silence. For example, an entire survey tape might look like this:

5 minutes of silence
30 seconds of calls of first primary species configured like this:
    a Least Bittern call
    5 seconds of silence
    a Least Bittern call
    5 seconds of silence
    a Least Bittern call
    5 seconds of silence
    .
    .
30 seconds of silence
30 seconds of calls of second primary species configured like this:
    a Sora call
    5 seconds of silence
    a Sora call
    5 seconds of silence
    a Sora call
    5 seconds of silence
    .
30 seconds of silence
30 seconds of calls of third primary species
    etc.

The chronological order of calls on the tape will vary with each management area, but will always be consistent within an area. Species to include in the call broadcast is up to the individual organizing the local survey effort, but we suggest you include all species believed to be local breeders. Order of calls should start with the least intrusive species first, and follow this chronological order: Black Rail, Least Bittern, Yellow Rail, Sora, Virginia Rail, King Rail, Clapper Rail, American Bittern, Common Moorhen, Purple Gallinule, American Coot, Pied-billed Grebe. The call used for broadcast should be the primary advertising call of each species (e.g., '*whinny*' for Sora, '*grunt*' for Virginia Rail, '*clatter*' for Clapper Rail and King Rail, '*kicky-doo*' for Black Rail, *'click-click-click-click-click*' for Yellow Rail, '*coo-coo-coo*' for Least Bittern, '*pump-er-lunk*' for American Bittern). Each individual bird detected (both primary and secondary species) during the survey period will be entered on a separate line on the field data form (Figure 1). Observers should record when each individual is detected: during the initial 5-min passive period, and/or during any of the 1-min tape broadcast periods. Recording all the segments during which an individual bird is detected is extremely important so that we can determine whether tapes are effective at eliciting additional responses for each of the primary species. These data will help us determine whether or not to use tapes of all primary species during surveys in future years. Hence, observers must make a decision as to whether each vocalization heard at a survey point is a new individual for that point or is an individual that vocalized previously from that survey point. Observers should also estimate whether each response is within or beyond 50 m of the survey point. Recording those individuals that are detected within 50 m of each survey point will provide minimum density indices for each species in each habitat type. Density indices by habitat type are useful because they allow managers to extrapolate survey data to estimate a minimum number of each marsh bird species on their entire management area. The cassette recorder should be placed upright on the ground (or on the bow of the boat), and sound pressure should be 90 dB at 1 m in front of the speaker. Use a sound-level meter to adjust volume of the cassette player at the beginning of each survey. Observers should stand 2 m to one side of the speaker while listening for vocal responses. Observers should point the speaker toward the center of the marsh and should **not** rotate the speaker during the call broadcast survey. An additional 1 minute passive period may be added to the end of the tape survey if observers believe that such a protocol will significantly increase total detections. If a final passive period is included in a local survey, observers should record any birds detected during this additional segment in a separate column (e.g., the "*Comments*" column). Surveys should only be conducted when wind speed is <20 km/hr, and not during periods of sustained rain or fog.

Filling out the data sheet

The number of species columns on the data sheet will differ regionally; include only those species for which call broadcast is used in your survey (Figure 1). Prior to the beginning of the survey, write down the day, month, and year at the top of the data sheet. Also write the full name of all observers present during the survey. If more than one observer, write down who recorded the data and who identified calling birds. Write down the name of the marsh, the name of the management area, and other location information (distance and direction to nearest town, county, state). Make notes of weather conditions, and whether (and when) weather changes during the course of the morning.

When you arrive at the first survey point, write down the unique identification number of the survey point and the time. Start the survey. When a bird is detected, write the name of the species in the third column. You can use the 4-letter acronym for the species or write the full species name. A list of 4-letter AOU species acronyms is attached to this protocol. Put a tick in each column in which that individual is detected based on vocalizations and put a "**v**" in each column in which the individual is detected visually. For example, if an individual Virginia Rail calls during the first 5 minutes of passive listening, put a tick in that column. Regardless of whether that individual calls once or many times during the first 5 minutes, you only put one tick in the first column. If that same individual bird also calls during EITHER the 30 seconds of Sora tape or the 30 seconds of silence immediately following the Sora tape, you also put a tick in the column "SORA tape". If that same individual bird calls again during the Virginia Rail tape, you also put a tick in the column "VIRA tape", and so on. Hence, if an individual bird is calling constantly throughout the survey period, you will have a tick in every column for that individual. If the individual is heard **and** seen, put both a tick and a "**v**" in the appropriate column. If you hear a call of the same species but from a different individual (or from an individual of another species), you start a new line on the data sheet and follow the same protocol for this individual bird. The difficulty is determining whether a call is coming from a new individual or a individual detected earlier at that survey point. Observers must make this decision without seeing the bird by using their best judgement. Follow the same procedure at subsequent survey points. If an individual detected at one survey point is thought to be an individual that was recorded at a previous survey point, write “repeat indiv from point *x*” in the comment column. The number of lines filled out on the data sheet will differ among survey points and will correspond to the total number of individual marsh birds detected at each point. If no birds are detected at a survey point, record the point number and starting time, and write “no birds” in the comment column. A sample data sheet is included as an example of what survey data might look like. Also record the level of background noise during the survey at each survey point. This information will be used as a covariate in future trend analyses because level of background noise varies spatially and temporally and influences detection probability. Categorize background noise at each point on a scale from 0 to 4 (0= no background noise, 1=faint background noise, 2=moderate background noise (probably can’t hear birds beyond 100m), 3=loud background noise (probably can’t hear birds beyond 50m), 4=intense background noise (probably can’t hear birds beyond 25m).

Habitat measurements

Natural changes in water level and management activities (e.g., dredging, wetland restoration efforts, prescribed burning, etc.) can lead to dramatic changes in marsh vegetation. Patterns of distribution and local population trends of marsh birds can often be best explained by local changes in wetland habitat. Consequently, quantifying the proportion of major habitat types (e.g., % cattail, bulrush, Phragmites, Spartina, Salicornia, grasses, open water, mudflat, shrub, upland) surrounding each survey point each year can help identify the cause of observed changes in marsh bird populations. Habitat will be quantified at 2 scales: observers should visually estimate the proportion of each major habitat type within a 50m-radius circle around each survey point, and aerial photographs will be used to periodically determine the amount of each major habitat type on the management area. To control for the seasonal progression of annual growth in emergent plants, observers should quantify habitat within the 50-m radius circles during the first two weeks of July each year. As an example, visual estimates of proportions of each habitat at a survey point might look like this: 15% water, 10% California bulrush, 20% three-square bulrush, 5% cattail, 20% shrubs, 10% mudflat, 20% upland.

Personnel and Training

All observers should have the ability to identify all common calls of primary and secondary marsh bird species in their local area. Regularly listening to the recorded calls used for surveys can help learn calls, but observers should also practice call identification at marshes (outside the management area if necessary) where the primary species are frequently heard calling. All observers must pass a vocalization identification exam each year prior to conducting surveys. This exam should be a cassette tape requested from Cornell Laboratory of Ornithology’s Lab of Natural Sounds. The tape should be new each year and observers should not have heard the exam tape prior to taking the exam. All observers should also be trained to accurately determine whether marsh bird calls are within 50 m, and to identify all species of emergent plants on the management area.

Equipment/materials

Where possible, fixed survey points will be permanently marked with inconspicuous markers and numbered. Portable GPS units should be used to mark survey points onto aerial maps. GPS coordinates of each permanent survey point should be recorded and saved for reference in future years. Cassette tapes will be obtained from Cornell Lab of Ornithology, and new tapes should be ordered if tape quality declines. Cassette recorders should be high quality and batteries should be changed frequently (before sound quality declines). Observers should always carry replacement batteries on all surveys. A sound level meter with ±5 dB precision (e.g., EXTECH sound level meter, $99 from Forestry Suppliers, Inc.) should be used to standardize broadcast volume. Binoculars will help observers identify distant birds. A small boat/canoe may be useful for surveying larger wetland habitats adjacent to open water, reducing travel time between survey points. A spare tape player should be kept close-by in case the primary unit fails to operate. A prototype field data form for use on vocal surveys is included (Figure 1). The number of columns on the data sheet will vary among management areas depending on the number of primary marsh bird species that breed in your area.

DATA COLLECTION, ANALYSIS, SUMMARY AND ROUTINE REPORTING

A. Field data. Field data will be manually entered in the field on a data form (Figure 1) and transferred weekly to an electronic form. At each survey point, observers should record: name of observer, name of data recorder (if different from observer), name of wetland, date, survey point #, start time, species of each individual detected, the tape periods during which the individual was detected, and whether the individual was within 50 m of the survey point. Each individual bird detected should be recorded on a new line on the data form. An overview map of the management area with all survey points numbered on the map should be developed for field personnel conducting surveys. All data forms should be reviewed by the supervisor within 24 hours of each survey so that mistakes can be identified and corrected promptly. Copies of original data forms should be stored in two separate locations.

B. Data entry/Database management. Data will be entered into a common spreadsheet program (EXCEL, Lotus, QuattroPro, dBase, etc) as soon after collection as possible, preferably within 1 week of data collection. Timely data entry limits mistakes, reduces probability of loss of data, and helps identify potential sampling biases and logistical problems that might be corrected in future surveys. Completed surveys will be printed out after entry into the spreadsheet and compared to original data forms to assure data quality. Electronic spreadsheets containing field data will be backed up weekly.

C. Data reporting. An annual report should be completed each year. After each season, survey data should be summarized and summaries should include the mean number of individuals detected per survey point during both passive and tape broadcast periods for each marsh bird species. Summaries should identify locations on the management area with seasonal concentrations of marsh birds. After several years, survey data can be used to estimate population trends of marsh birds on the management area using regression analyses. Survey data will also allow comparison of birds detected during initial passive periods and during call broadcast to evaluate the usefulness of using call broadcast surveys to monitor marsh birds. These comparisons will allow improvement of field methods in future years. On a regional basis, estimates of population trend from areas undergoing management activities can be compared to population trends from areas that have not been subject to management activities to evaluate the long-term effectiveness of management efforts.

REGIONAL CONTEXT AND INTEGRATION WITH OTHER MONITORING PROTOCOLS

Estimates of population change in marsh bird populations on the management area will be compared to local population changes in other parts of the region. Comparisons among other local areas in the region will allow managers to determine the importance of local wetlands to regional population health by identifying whether marsh bird populations on the management area are doing better or worse relative to other areas. The U.S. Fish and Wildlife Service Region 5 National Wildlife Refuges began using these marsh bird survey methods in 1999 and Region 6 will begin using these methods in 2001. Cape Code National Seashore began using these survey methods in 2000. We hope to expand use of these protocols to other regions and other management agencies in the coming years. Hence, estimates of marsh bird population trends on the management area can be compared to those from other regions.

Survey data collected using the protocol described above will help our efforts to develop the most rigorous continental monitoring program possible for marsh birds. Please send any survey data to the address below. For assistance obtaining appropriate tapes, additional information, or questions regarding standardized marsh bird survey methods, please contact:

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Date:
Marsh:
Observer:

survey station #	time start	Species	Responded During						<50 m	comments
			passive 5 min	SORA tape	VIRA tape	AMBI tape	AMCO tape	PBGR tape		

Marsh: marsh unit 2, New NWR, Washington
Observer: Robert Thomas

survey station #	time start	Species	Responded During						<50 m	comments
			passive 5 min	SORA tape	VIRA tape	AMBI tape	AMCO tape	PBGR tape		
1	0650	VIRA	1		1	1		1	yes	
		VIRA			1				yes	
		VIRA	1				1		no	
		PBGR	1	1	1	1	1	1	no	
		PBGR	1	1	1	1	1	1	no	
2	0710									no birds
3	0728	SORA	1	1	1			1	yes	
		AMBI	1						no	
		SORA			1				no	
		NOHA	v	v	v				no	
4	0743	AMBI	1			1		1	yes	
		AMCO				1	1		no	
		AMBI	v						yes	

List of AOU 4-letter species acronyms for primary marsh birds in North America.

Primary species

SORA	sora
VIRA	Virginia rail
CLRA	clapper rail
KIRA	king rail
BLRA	black rail
YERA	yellow rail
AMCO	American coot
COMO	common moorhen
PUGA	purple gallinule
LIMP	limpkin
PBGR	pied-billed grebe
AMBI	American bittern
LEBI	least bittern
GNBH	green-backed heron

Examples of Secondary Species of interest

GTBH	great blue heron
FOTE	Forster's tern
BLTE	black tern
COSN	common snipe
SACR	sandhill crane
NOHA	northern harrier
BEKI	belted kingfisher
ALFL	alder flycatcher
WIFL	willow flycatcher
SEWR	sedge wren
MAWR	marsh wren
RWBL	red-winged blackbird
YHBL	yellow-headed blackbird
STSP	sharp-tailed sparrow
LCSP	LeConte's sparrow
COYE	common yellowthroat