FACTORS AFFECTING DETECTION PROBABILITY OF CALIFORNIA BLACK RAILS

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***Abstract*:** Optimal survey methods for estimating population trends are those that result in high detection probability and low temporal variance in detection probability. We compared detection probability of California black rails (*Laterallus jamaicensis coturniculus*) between passive and call-broadcast surveys, and we examined factors that influenced detection probability. The number of black rails detected was 13% higher on call-broadcast surveys compared to passive surveys, but the number of other marsh birds (bitterns and other species of rails) detected was 21% lower. We detected more black rails on evening surveys compared to morning surveys, but we had to cancel 42% of evening surveys due to high wind (>25 km/hr). Detection probability increased from 0500 to 0700 hr and then declined as the morning progressed, but detection probabilities did not vary among hourly time intervals during evening surveys. We failed to detect an effect of broadcast volume on number of black rails detected during paired surveys. Observer detection probability of black rails ($\bar{x}$ = 75.5%) varied among observers but did not differ between passive and call-broadcast surveys. We failed to find a consistent time of year when detection probability was highest at all of our survey locations. We heard the 3 most common black rail calls in consistent proportion from March through June. As many as 15 replicate surveys may be needed to attain >90% detection probability of black rails within potential wetland habitat. We recommend that standardized black rail surveys be repeated annually to provide more precise estimates of population trend and to better determine the distribution and status of this rare species.

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California black rails apparently were much more common in the early 1900s than they are today (Allen 1900). California black rail populations have declined due to loss or degradation of habitat (Evens et al. 1991, Eddleman et al. 1994, Conway et al. 2002). For example, California has lost 91% of the original wetlands in the state (Mitsch and Gosselink 2000). California black rails are considered endangered in Arizona (Arizona Game and Fish Department 1988), threatened in California (California Department of Fish and Game 2003), federally endangered in Mexico (Diario Oficial de la Federacion 2002), and are 1 of the 10 highest priorities for avian conservation action in Arizona (Latta et al. 1999). Black rail populations also have declined in the eastern United States (Kerlinger and Wiedner 1991). Consequently, black rails were listed as a species of national conservation concern (U.S. Fish and Wildlife Service 2002).

Existing avian monitoring programs (e.g., the Breeding Bird Survey of the U.S. Geological Survey) are ineffective at monitoring population trends of black rails (Eddleman et al. 1994). Hence, information on current distribution and abundance is not available and is considered a priority conservation need (Gustafson 1987, Evens et al. 1991, Flores and Eddleman 1991, Kerlinger and Wiedner 1991). The most commonly used method to determine presence and abundance of marsh birds in local areas involves the broadcast of recorded calls (Conway and Gibbs 2001). Indeed, call-broadcast surveys (also referred to as tape-playback surveys) have been used to monitor local and regional black rail populations (Repking and Ohmart 1977, Evens et al. 1991, Legare et al. 1999, Spear et al. 1999). However, this method is not effective for all marsh birds (Conway and Gibbs 2001), and call-broadcast surveys did not increase the number of California black rails detected relative to passive surveys (surveys on which calls are not broadcast) at 1 study area on the lower Colorado River (Flores and Eddleman 1991). Moreover, call-broadcast surveys have many drawbacks not associated with passive surveys (Conway and Gibbs 2001). For example, call broadcast attracts birds toward the

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surveyor (Legare et al. 1999, Spear et al. 1999) and thus prevents density estimation from survey data. Additionally, temporal and spatial variation in broadcast volume and equipment quality may increase observer variation in detection probability.

Understanding the benefits and drawbacks associated with call-broadcast surveys is essential prior to implementing a region-wide black rail monitoring effort. Indeed, development of standardized population surveys and refinement of survey methods are considered high priorities for black rail conservation (Eddleman et al. 1994). In our study, we (1) compared numbers of black rails detected and (2) examined temporal variation in numbers detected between passive and call-broadcast surveys. We conducted replicate surveys in areas with black rails to determine whether broadcast volume, time of day (morning vs. evening), or season influenced detection probability to identify the most effective black rail survey methods.

STUDY AREA AND METHODS

We surveyed potential black rail habitat along the lower Colorado River (Grand Canyon south to the Gila River confluence, Arizona and California, USA), at Morro Bay (San Luis Obispo County, California, USA), Big Morongo Canyon (San Bernardino County, California), wetlands throughout the Imperial Valley of California (including areas along the All-American and Coachella Canals, the New River west of Seeley, Fig Lagoon, and around the Salton Sea), and portions of the Gila River and Bill Williams River in Arizona. All surveys were conducted from 1 March to 28 July (Todd 1970, Repking and Ohmart 1977, Eddleman et al. 1994). We surveyed Morro Bay, Fig Lagoon, the New River, and marshes near Blythe, California, in 2001 and all other areas in 2000. We chose survey sites by searching for suitable wetlands (1) at locations surveyed during previous black rail survey efforts (Repking and Ohmart 1977, Evens et al. 1991), (2) based on our examination of aerial photographs of the Colorado River taken in 1997, and (3) in locations recommended by local biologists and recreational birders.

Most surveys were conducted in the morning from 0.5 hr before sunrise until 1000 hr to coincide with the daily survey period used in previous black rail surveys in the region (Todd 1980, Evens et al. 1991, Flores and Eddleman 1991). Some surveys were conducted in the evening (4 hr before sunset until 0.5 hr after sunset) so that we could compare detection probability between morning and evening surveys.

We established survey points along upland and open water edges of emergent vegetation. The distance between adjacent survey points was approximately 50 m at wetlands with records of black rails and 100–150 m at sites with no previous black rail records. During our surveys, we used a cassette tape of recorded black rail calls broadcast at a volume of 90 dB (1 m from the speakers) using a stereo cassette tape player (Optimus model SCP-88 or SCP-104, RadioShack Corporation, Fort Worth, Texas, USA) attached to a pair of amplified speakers (Optimus model AMX-4, RadioShack Corporation, Fort Worth, Texas, USA). We taped the speakers together, placed them on the ground at the marsh edge, and faced them toward the marsh. We recorded all black rails, Yuma clapper rails (*Rallus longirostris yumanensis*), Virginia rails (*Rallus limicola*), soras (*Porzana carolina*), least bitterns (*Lxyobrychus exilis*), and American bitterns (*Botaurus lentiginosus*) detected during a 6-min survey at each survey point, as well as all individuals detected while surveyors moved between survey points (either before or after the 6-min survey period at each point). We did not conduct surveys when wind speed was consistently >25 km/hr or during periods of heavy rain.

Passive Versus Call-broadcast Surveys

Our 6-min survey at each point consisted of a 3-min passive survey segment followed by a 3-min period of call broadcast. During both 3-min periods, we recorded all rails and bitterns that we saw or heard calling, whether each individual bird was detected previously during the survey (i.e., at a previous survey point), the distance to each bird detected, and the type(s) of vocalization heard. The 3-min broadcast sequence consisted of 3 1-min segments of 30 sec of black rail calls (15 sec of "*kic-kic-kerr*" [*kickee-doo*] calls and 15 sec of "*grr*" calls) followed by 30 sec of silence. We separated the 6-min survey period into 7 segments (the 3-min passive period, the first 30-sec call period, the first 30-sec silent period, the second 30-sec call period, etc.). We recorded whether each bird was detected during each of the 7 survey segments. We compared the number of individuals of each species that we detected during the 3-min passive segment with the number detected during the 3-min call-broadcast segment using paired *t*-tests (distribution of differences approximated a normal distribution).

We compared 2 measures of temporal variation (standard deviation and coefficient of variation) in number of black rails detected between passive and call-broadcast surveys on a subset of survey routes that we surveyed multiple times. Temporal variation in numbers detected is an important consideration when choosing among potential survey methods because low temporal variation in detection probability provides greater power to detect population change. Call broadcast is assumed to decrease temporal variation in number of birds detected compared to passive surveys in marsh birds (Glahn 1974, Ribic et al. 1999), yet this assumption has not been tested. Hence, we compared standard deviation and coefficient of variation in numbers counted between passive surveys and call-broadcast surveys using data from points where ≥1 black rail was detected on 1 or more replicate surveys.

Morning Versus Evening Surveys

We conducted paired morning and evening surveys (either on the same day or on consecutive days) on 17 survey routes (226 points surveyed during both morning and evening) where we knew black rails occurred. We varied the order that we conducted the paired morning and evening surveys so that we did not always conduct 1 survey prior to the other. We compared the effectiveness of morning versus evening surveys for detecting black rails using 2 approaches. First, we compared the mean number of black rails detected per point between morning and evening surveys using paired *t*-tests. We included possible repeat detections of individual rails (i.e., 1 individual detected at 2 adjacent survey points) in this analysis because we were interested in whether detection probability of individual black rails was greater during morning or evening periods. Second, we compared the proportion of survey points at which we detected black rails between paired morning and evening surveys (n = 226 points) using a chi-square analysis.

Diurnal Changes in Black Rail Detection Probability

Detection probability can differ between morning and evening periods but can also vary among hourly time intervals during both the morning and evening. Understanding how detection probability varies with time of day is important prior to developing standardized monitoring protocols so that effective daily survey windows can be identified. Hence, we compared the proportion of points where at least 1 black rail was detected across 5 1-hr time periods in the morning (0500–0600, 0600–0700, 0700–0800, 0800–0900, 0900–1000 hr) and 4 1-hr time periods in the evening (1630–1730, 1730–1830, 1830–1930, 1930–2030 hr) using contingency table analyses. We conducted the analysis using (1) all survey data (n = 2,385 morning survey points and 373 evening survey points), and (2) only data from survey routes where at least 1 black rail was detected sometime during the season (n = 1,443 morning survey points and 254 evening survey points).

Effects of Broadcast Volume on Number of Birds Detected

We compared the effect of broadcast volume on detection probability of black rails by conducting paired surveys (1 using 90 dB volume and the other using 70 dB volume at 1 m in front of the speaker) on consecutive days along 20 survey routes (310 survey points) known to contain black rails. We alternated the order in which we conducted the paired 70 dB and 90 dB surveys, so we did not always conduct 1 survey prior to the other. We compared the mean number of black rails detected per point between 90 and 70 dB surveys using paired *t*-tests. We did not remove repeats of individual birds detected at >1 survey point for this analysis because we were interested in whether detection probability of individual black rails was greater during 90 dB surveys. We compared the proportion of survey points where we detected black rails between 90 and 70 dB surveys using a chi-square analysis. We repeated the analysis for each of 3 survey segments: the 3-min passive segment, the 3-min call-broadcast segment, and the interval before or after each 6-min survey period.

Observer Detection Probability

At 228 points, we conducted double-observer surveys (Nichols et al. 2000) to estimate observer bias associated with our survey efforts. Rather than a primary and secondary observer at each point, both observers recorded all rails and bitterns they detected separately. We used this approach because we were recording detections of only 5 target species, all detections were aural, all target species were relatively rare, and observers recorded the type of call given and the detection time for each bird detected. These circumstances made it relatively easy for us to determine which birds were detected by which observer(s) after each 6-min survey was complete. We used these data to estimate observer detection probabilities of black

Table 1. Results of paired *t*-tests comparing the average number of marsh birds detected during an initial 3-min passive survey and a subsequent 3-min call-broadcast survey in Arizona and southern California, USA, 2000 and 2001. The call broadcast only included calls of California black rails (*kic-kic-kerr* and *grr*). Only points at which at least 1 bird was detected were included in the analysis for each species.

	Black rail $n = 624$	Clapper rail $n = 540$	Sora $n = 105$	Virginia rail $n = 748$	Least bittern $n = 552$
Passive	0.97 ± 0.03	1.34 ± 0.05	0.82 ± 0.06	1.12 ± 0.03	0.97 ± 0.03
Call broadcast	1.10 ± 0.03	1.08 ± 0.05	0.63 ± 0.06	0.97 ± 0.03	0.70 ± 0.03
	$t = 3.7$, $P < 0.001$	$t = 4.5$, $P < 0.001$	$t = 1.8$, $P = 0.08$	$t = 3.6$, $P < 0.001$	$t = 6.2$, $P < 0.001$

rails and compared these probabilities between passive and call-broadcast surveys. Observer #1 and observer #2 conducted observer bias trials at 88 survey points, and observer #1 and observer #3 conducted observer bias trials at 140 survey points. Observer #2 and observer #3 did not conduct any observer bias surveys together due to logistical constraints associated with other aspects of our study.

We estimated observer detection probability (p) of black rails associated with each unique pair of observers (e.g., observer #1 and #2) using the equations: $p_1 = (x_{11}x_{22} - x_{12}x_{21})/(x_{11}x_{22} + x_{22}x_{21})$ and $p_2 = (x_{11}x_{22} - x_{12}x_{21})/(x_{11}x_{22} + x_{11}x_{12})$, where x_{11} = the total number of black rails detected by observer #1, x_{22} = the total number of black rails detected by observer #2, x_{12} = the number of black rails detected by observer #1 but not detected by observer #2, and x_{21} = the number of black rails detected by observer #2 but not detected by observer #1 (Nichols et al. 2000). Hence, we obtained 4 estimates of observer detection probability for black rails: observer #1 with observer #2, observer #1 with observer #3, observer #2 with observer #1, and observer #3 with observer #1. We averaged these 4 estimates for an overall estimate of observer detection probability for black rails. We compared observer detection probability of black rails between passive and call-broadcast segments using contingency table analysis. We estimated the cumulative probability of detection with × replicate surveys as $(1 - (1 - p)^x)$, where p is the average detection probability associated with a single survey. We sought to identify optimal dates to conduct surveys by examining consistency among wetlands in seasonal peak of number of black rails detected, and we examined seasonal changes in the relative frequency of 3 common black rail calls (*kic-kic-kerr*, *grr*, and *churt*) using contingency table analysis.

RESULTS

We conducted surveys at 1,670 distinct survey points and detected 136 black rails in areas along the lower Colorado River, at Morro Bay, and throughout Imperial Valley in California. We also detected 418 Yuma clapper rails, 220 Virginia rails, 99 soras, 242 least bitterns, and 11 American bitterns. We conducted a single survey at 1,410 points and 2–11 replicate surveys at 260 points. Including our replicate surveys and birds already counted on a previous survey, we recorded 1,012 black rail detections on 675 of the 2,828 6-min black rail surveys. We saw a black rail at only 4 survey points, and all 4 of these birds also were detected aurally.

Passive Versus Call-broadcast Surveys

Call broadcast increased the number of black rails detected by 13% compared to passive surveys (Table 1). Considering all points in which at least 1 black rail was detected, we detected an average of 0.97 birds per point during the 3-min passive portion of the survey and an average of 1.10 birds per point during the 3-min call-broadcast portion of the survey (Table 1). Conversely, detection probability of other rails and bitterns was lower on the call-broadcast segment; broadcasting black rail calls decreased the number of other marsh birds detected by an average of 21% when compared to passive surveys (Table 1). Within the call-broadcast period, detection probability of all species (except soras) was higher during the 3 30-sec silent periods compared to the 3 30-sec call-broadcast periods (Table 2). The number of new black rails detected declined with time throughout the 6-min survey period (Fig. 1). Standard deviation in number of black rails detected was higher (0.73 vs. 0.65; $t = 2.6$, $P = 0.011$) but coefficient of variation was lower (1.43 vs. 1.61; $t = 3.4$, $P = 0.001$) on call-broadcast surveys compared to passive surveys (Table 3).

Morning Versus Evening Surveys

We detected more black rails on evening surveys (0.78 black rails per point) compared to the corresponding paired morning surveys (0.64 black rails per point; $t = 1.96$, $n = 225$, $P = 0.051$). The difference was most pronounced during the call-

Table 2. Results of paired *t*-tests comparing the average number of marsh birds detected during 3 30-sec calling periods and 3 30-sec intervening silent periods during 3-min call-broadcast survey periods in Arizona and southern California, USA, 2000 and 2001. The call broadcast only included calls of California black rails (*kic-kic-kerr* and *grr*). Only points at which at least 1 bird was detected during the call-broadcast survey segment were included in the analysis for each species.

	Black rail $n = 516$	Clapper rail $n = 357$	Sora $n = 56$	Virginia rail $n = 509$	Least bittern $n = 324$
Silent segments	1.17 ± 0.03	1.39 ± 0.05	0.53 ± 0.08	1.10 ± 0.04	0.89 ± 0.03
Call segments	0.82 ± 0.03	1.11 ± 0.05	0.74 ± 0.08	0.80 ± 0.03	0.72 ± 0.04
	$t = 10.0$, $P < 0.001$	$t = 5.2$, $P < 0.001$	$t = 1.5$, $P = 0.14$	$t = 6.4$, $P < 0.001$	$t = 3.4$, $P = 0.001$

broadcast segment of the survey ($t = 2.28$, $n = 225$, $P = 0.023$). The proportion of survey points in which we detected black rails also was greater during evening surveys (0.535) compared to the corresponding paired morning surveys (0.358; $\chi^2 = 5.26$, $P = 0.022$). However, wind speed exceeded 25 km/hr on 42% of 57 evenings during our study (compared to only 1% of 75 morning surveys; $\chi^2 = 35.1$, $P < 0.001$), so we frequently had to cancel evening surveys.

Diurnal Changes in Black Rail Detection Probability

The proportion of points in which we detected black rails varied among hourly time periods in the morning for both the entire data set and when we restricted our analysis to include only survey routes where we detected black rails (Fig. 2). Detection probability increased from 0500–0600 hr to 0600–0700 hr and then declined as the morning progressed (Fig. 2). In contrast, the proportion of points where we detected black rails did not differ among hourly time periods in the evening (Fig. 2). Hence, the window for optimal survey timing was narrower during morning surveys.

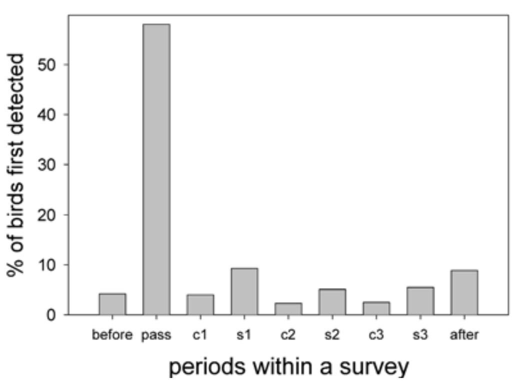

Fig. 1. Percent of marsh birds first detected during each of 9 periods during standardized surveys in Arizona and southern California, USA, 2000 and 2001: (1) before the observer initiated the 6-min survey, (2) during the 3-min passive segment of the survey (pass), (3) during the first 30 sec of call broadcast (c1), (4) during the subsequent 30 sec of silence (s1), (5) during the second 30 sec of call broadcast (c2), (6) during the subsequent 30 sec of silence (s2), (7) during the third 30 sec of call broadcast (c3), (8) during the final 30 sec of silence (s3), and (9) after the 6-min survey period.

Effects of Broadcast Volume on Number of Birds Detected

We found no significant difference in the number of black rails detected on 90 dB surveys compared to 70 dB surveys. The number of black rails detected on paired 70 and 90 dB surveys was very similar during the passive ($t = 0.2$, $P = 0.810$) and call-broadcast ($t = 0.4$, $P = 0.705$) segments of the survey. We tended to detect more black rails while traveling between survey points during 90 dB surveys compared to 70 dB surveys (0.8 and 0.68 black rails detected/point, respectively), but the difference was not significant ($t = 1.5$, $P = 0.128$). The proportion of survey points in which we detected black rails did not differ ($\chi^2 = 0.11$, $P = 0.736$, $n = 574$) between 70 dB (125 of 287 points) and 90 dB (121 of 287 points) surveys. We detected more black rails during the 70 dB survey on 9 of the routes, more black rails during the 90 dB survey on 9 routes, and the same number of black rails for the 2 surveys on 2 routes.

Observer Detection Probability

During their 88 observer bias surveys, observer #1 detected 11 black rails that observer #2 missed

Table 3. Results of paired *t*-tests comparing 2 measures of temporal variation (standard deviation and coefficient of variation) in number of black rails counted between passive surveys and call-broadcast surveys in Arizona and southern California, USA, 2000 and 2001. Analysis included 146 points in which ≥1 black rail was detected on ≥1 replicate survey.

	SD in no. of black rails detected (± SE)	CV in no. of black rails detected (± SE)
Passive surveys	0.65 ± 0.04	1.61 ± 0.07
Call-broadcast surveys	0.73 ± 0.04	1.43 ± 0.07
	$t = 2.6$, $P = 0.011$	$t = 3.4$, $P = 0.001$

(x_{12}), observer #2 detected 13 black rails that observer #1 missed (x_{21}), and 65 black rails were detected by both observers. Hence, observer #1 detected 76 (x_{11}) and observer #2 detected 78 (x_{22}) of the 89 birds that vocalized during their double-observer surveys. During their 140 observer bias surveys, observer #1 detected 17 black rails that observer #3 missed (x_{13}), observer #3 detected 28 black rails that observer #1 missed (x_{31}), and 44 black rails were detected by both observers. Hence, observer #1 detected 61 (x_{11}) and observer #3 detected 72 (x_{33}) of the 89 birds that vocalized during their double-observer surveys. Observer detection probability was 83.3 and 61.1% for observer #1, 85.5% for observer #2, and 72.1% for observer #3. The average observer detection probability of black rails was 75.5% across all 3 observers. Two observers conducting simultaneous surveys detected the same number of black rails at 75% of the 228 survey points. Most (51%) of the discrepancies were not whether, but how many, black rails were detected at a particular point. Average observer detection probability of black rails was similar during the passive (73%) and call-broadcast segments (72%).

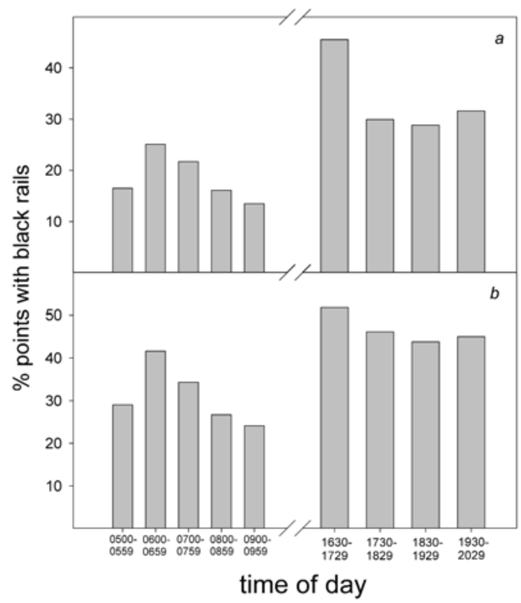

Fig. 2. Proportion of survey points at which we detected black rails among 1-hr time periods for both morning and evening surveys in Arizona and southern California, USA, 2000 and 2001: (a) includes all survey points, (b) includes only those survey points along routes where at least 1 black rail was detected.

Seasonal Variation in Calling Behavior and Detection Probability

The seasonal peak in number of black rails detected varied among survey locations (Fig. 3). Although we recorded peak counts for many routes in late June through late July, we also conducted more replicate surveys during this period, and just as many of those replicate counts were similar or lower than counts from March–May (Fig. 3). Hence, we found no consistent seasonal peak in detection probability across locations. Most of the birds detected from March through June (approx 80%) gave the *kic-kic-kerr* call (Fig. 4). In March through June, *grr* and *churt* calls were less common. In July, the *grr* and *churt* calls became more frequent and the *kic-kic-kerr* call (given by only 55% of birds detected) became less frequent ($\chi^2 > 69$, $P < 0.001$; Fig. 4). Most *grr* (79%) and *churt* (72%) calls were detected close to the broadcast source (<50 m from the surveyor) compared to *kic-kic-kerr* calls (30% were <50 m).

DISCUSSION

Passive Versus Call-broadcast Surveys

Broadcasting black rail calls during surveys increased the vocalization probability of black rails. However, the use of call-broadcast methods to elicit response of target marsh birds has a cost in that call broadcast causes a reduction in detection probability of other species. Conspecific call broadcast also increases vocalization probability of other species of marsh birds (Conway and Gibbs 2001), but effects of call broadcast on nontarget species has been ignored in previous studies. Our approach may have underestimated the magnitude that call broadcast increases detection probability of black rails and decreases detection probability of nontarget species because birds during the passive segment may have been influenced by the calls broadcast at the previous point(s). Ways to alleviate this problem for future studies include increasing the distance between adjacent points or conducting paired passive and call-broadcast surveys on consecutive days.

Detection probability was higher during intervening silent periods compared to the 30-sec periods that calls were broadcast. Hence, if call broadcast is used during marsh bird surveys, protocols should include intervening silent periods. Although standard deviation in numbers detected was higher during call-broadcast compared to passive surveys, coefficient of variation in numbers detected was lower. Future studies evaluating

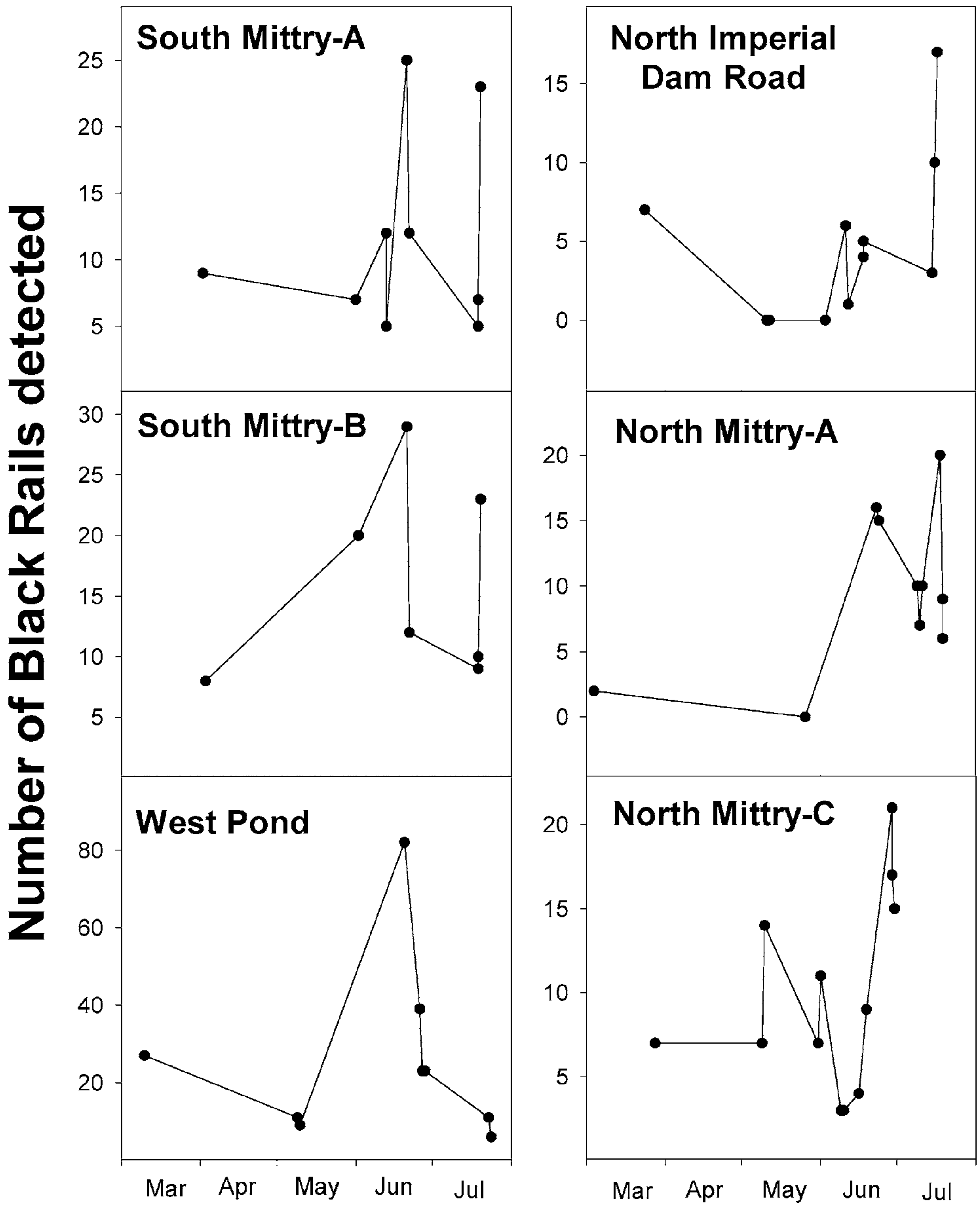

Fig. 3. Seasonal peak in number of black rails detected at 6 locations in Arizona and southern California, USA. West Pond is in California southwest of Imperial Dam, North Imperial Dam Road Marsh is in Arizona between Imperial Dam and Imperial Dam Road, and North and South Mittry Lake are in Arizona between Imperial Dam Road and Laguna Dam. Points represent the number of black rails detected during replicate surveys (Mar–Jul 2000).

the effectiveness of call-broadcast should appreciate that coefficient of variation is the more appropriate measure of variation. High temporal variation in detection probability diminishes our ability to detect population change.

Morning Versus Evening Surveys

The number of black rails we detected was higher during evening surveys compared to paired morning surveys, but we often had to cancel evening surveys due to high wind. Previous studies comparing effectiveness of evening and morning marsh bird surveys have reported conflicting results. Repking (1975) found morning surveys to be more effective, Flores and Eddleman (1991) reported that black rails were slightly more responsive during evening surveys, and Spear et al. (1999) and Tecklin (1999) reported no difference between morning and evening survey results. Eastern black rails (*Laterallus jamaicensis jamaicensis*) in Florida, USA, vocalized more readily during morning surveys (63% vocalization probability) compared to evening surveys (37% detection probability; Legare et al. 1999). For other species of marsh birds, evening surveys have proven more effective in some studies (Rabe and Rabe 1985, Tacha 1975, Johnson and Dinsmore 1986), whereas morning surveys have proven more effective in other studies (Cashen 1998). Relative effectiveness of morning and evening surveys probably varies regionally and differs among marsh bird species. Future comparisons between the effectiveness of morning and evening surveys should consider differences in proportion of days with suitable weather conditions.

Diurnal Changes in Black Rail Detection Probability

The daily peak in vocalization probability was narrower during morning surveys compared to evening surveys. In contrast, the daily peak in black rail vocalization probability was shorter in the evening compared to the morning in San Francisco Bay (Spear et al. 1999). Amount of hourly variation in detection probability during both evening and morning surveys may vary regionally and change as the season progresses. We conducted more evening surveys later in the season (Jun and Jul) because of logistical constraints and weather. Hence, our conclusions based on duration of diurnal peak in vocalization probability may have differed had we been able to conduct more evening surveys in March–May.

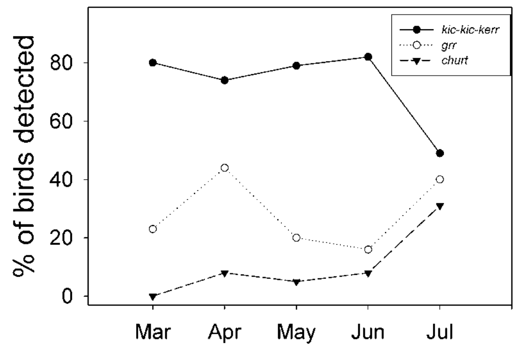

Fig. 4. Seasonal variation in the proportion of each black rail detected that elicited each of 3 calls (*kic-kic-kerr*, *grr*, and *churt*) during surveys in Arizona and southern California, USA, 2000 and 2001.

Effects of Broadcast Volume on Number of Birds Detected

Broadcast volume had little effect on detection probability of black rails. Future survey efforts should attempt to standardize broadcast volume, but moderate temporal and spatial variation in broadcast volume probably will not sacrifice the explanatory power of black rail survey results.

Observer Detection Probability

Few survey efforts make any attempt to estimate components of detection probability. For strictly vocal surveys such as ours, 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) and observer detection probability (the probability that the observer hears and records an individual bird that vocalizes during the survey period; Conway and Gibbs 2001). No previous authors have estimated observer detection probability associated with marsh bird survey efforts. Observer detection probability was relatively high (75.5%) and did not differ between passive and call-broadcast survey segments. The double-observer method (Nichols et al. 2000) overestimates observer detection probability to some unknown degree because one must assume that at least 1 observer does not make any mistakes in species identification. For example, if 1 observer tends to mistakenly record a bird when none actually called (or misidentifies the species of a bird detected), that observer's detection probability for that species will be biased high, and the detection probability of the other observer will be biased low.

Relative to our estimates of observer detection probability, vocalization probability often is low in black rails (20–50%; Legare et al. 1999) and other marsh birds (40% for Yuma clapper rails, 31% for American bitterns, and 13% and 25% for least bitterns; Conway et al. 1993, Conway and Gibbs 2001, Bogner and Baldassarre 2002). Hence, replicate surveys are needed in local areas to assure high probability of detecting resident birds. If vocalization probability is 50% (Legare et al. 1999) and observer detection probability is 75.5% (hence, $p = 0.5 \times 0.755 = 0.3775$), then one would need to conduct 5 replicate surveys to ensure >90% detection probability of a resident black rail. However, if vocalization probability is only 20% (Legare et al. 1999), 15 replicate surveys would be needed to ensure >90% detection probability. The increase in overall detection probability gained by an increased number of replicate surveys must be tempered by the possibility of birds becoming habituated to call broadcast with more frequent replicate surveys.

Seasonal Variation in Calling Behavior and Detection Probability

We were unable to document a consistent seasonal peak in detection probability for black rails. Seasonal change in detection probability of black rails has been reported in some studies (Legare 1996, Spear et al. 1999) but not in other studies (Tecklin 1999). Some studies have reported 2 seasonal peaks in numbers of marsh birds detected: 1 in early breeding when adult vocalization probability is highest and another later in the season coinciding with the start of calling by juvenile birds (Conway and Gibbs 2001). High daily variation in vocalization probability of black rails overwhelms or masks any seasonal pattern in peak calling activity. Better information regarding the function of the different black rail calls would help us to interpret seasonal changes in number of vocalizations.

Our results suggest that the vocal repertoire of black rails is relatively constant across the breeding season; the proportion of black rails detected that gave *kic-kic-kerr*, *grr*, and *churt* calls was surprisingly constant from March through June. However, *kic-kic-kerr* calls were less common in July and *grr* and *churt* calls were more common. Repking and Ohmart (1974) also reported that the *kic-kic-kerr* call was more common and the *grr* call less common in March and April compared to June–August in 1973, but this pattern was not repeated the following year (Repking 1975). The *kic-kic-kerr* call can be heard by surveyors from a much greater distance compared to the other calls (Tecklin 1999) and is thought to be given primarily by males (Reynard 1974, Wilbur 1974, Legare et al. 1999). The increase in *grr* and *churt* calls in August may reflect juvenile birds beginning to vocalize. Indeed, an increase in numbers of black rails detected in late summer is often observed (Flores and Eddleman 1991, Legare et al. 1999, Spear et al. 1999) and may reflect the onset of vocal development in hatch-year birds (Spear et al. 1999).

MANAGEMENT IMPLICATIONS

The rarity of visual detections and the high temporal variation in numbers counted during our replicate surveys pose difficulties in using count data to estimate black rail population trends. Because black rails are rarely seen and difficult to capture, vocal survey methods are the best means available to provide estimates of black rail population trends, and standardized methods are needed. The detection probability of black rails declined dramatically as the morning progressed, and the number of new black rails detected declined throughout our 6-min survey period. Hence, relatively short surveys at a greater number of points may be the most efficient approach for monitoring population change in black rails. For future surveys, we recommend an initial passive segment (which allows detection of other marsh birds) followed by a short call-broadcast segment (which increases black rail detection probability).

Forty-one percent of the black rails we detected were within 50 m of the survey point. Short spacing between adjacent survey points will increase detection probability, but will limit the amount of area that an observer can cover in 1 day. A short distance between adjacent survey points also results in increased observer bias because individual birds can be heard at multiple survey points, and each surveyor must make subjective decisions regarding which calls are coming from new individuals. Birds also move toward the broadcast, making individual birds difficult to distinguish if points are close together (Legare et al. 1999). Future survey efforts should consider these trade-offs when choosing spacing between survey points.

California black rails vocalize primarily at dawn and dusk. For future black rail surveys, we recommend that observers identify particular surveys routes as either morning or evening survey routes based on local conditions and constraints. Including both morning and evening surveys into a standardized monitoring protocol will provide added flexibility and more potential survey hours for field personnel. Standardized surveys should target the prehatching period (late Mar–mid-Jun; Flores and Eddleman 1993, Spear et al. 1999), and replicate surveys should be completed prior to the time when juveniles begin vocalizing. Observers will have to conduct 5–15 replicate surveys (depending on vocalization probability in their region) to obtain >90% detection probability. Hence, we recommend that black rail surveys in the southwestern United States be conducted from 21 March through 15 May, and observers conduct ≥5 replicate surveys each year.

We recommend that standardized surveys be repeated annually to better estimate population trends of black rails. Based on the results of our replicate surveys at locations with black rails, we developed a standardized black rail survey protocol (Conway et al. 2002). Annual black rail surveys in the southwestern United States should be combined with ongoing Yuma clapper rail survey efforts in the region to be most efficient.

Recording information on vegetation at each survey point on future surveys will allow us to correlate black rail population trends with changes in abundance of emergent habitat in the region. Quantifying habitat at each survey point will also allow us to identify areas in which habitat restoration projects might be most effective for reversing local declines in black rails. Replicating our survey effort in future years will provide information on trends in black rail habitat in the southwestern United States and help land managers adjust current or implement new management plans that benefit black rails so that populations might increase to the point of delisting.

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LITERATURE CITED

ALLEN, J. A. 1900. The little black rail. Auk 17:1–8.

ARIZONA GAME AND FISH DEPARTMENT. 1988. Threatened native wildlife of Arizona. Arizona Game and Fish Department, Phoenix, Arizona, USA.

BOGNER, H. E., AND G. A. BALDASSARRE. 2002. The effectiveness of call-response surveys for detecting least bitterns. Journal of Wildlife Management 66:976-984.

CALIFORNIA DEPARTMENT OF FISH AND GAME. 2003. State and federally-listed endangered and threatened animals of California. California Department of Fish and Game, Sacramento, California, USA.

CASHEN, S. T. 1998. Avian use of restored wetlands in Pennsylvania. Thesis, The Pennsylvania State University, University Park, Pennsylvania, USA.

CONWAY, C. J., W. R. EDDLEMAN, S. H. ANDERSON, AND L. R. HANEBURY. 1993. Seasonal changes in Yuma clapper rail vocalization rate and habitat use. Journal of Wildlife Management 57:282–290.

———, AND J. P. GIBBS. 2001. Factors influencing detection probabilities and the benefits of call-broadcast surveys for monitoring marsh birds. Final Report. U.S. Geological Survey, Patuxent Wildlife Research Center, Laurel, Maryland, USA.

———, C. SULZMAN, AND B. E. RAULSTON. 2002. Population trends, distribution, and monitoring protocols for the California black rail. Technical report (Heritage Program IIPAM Grant # I99010). Arizona Game and Fish Department, Phoenix, Arizona, USA.

DIARIO OFICIAL DE LA FEDERACION. 2002. Norma Oficial Mexicana NOM-059-ECOL-2001, Proteccion ambiental-Especies nativas de Mexico de flora y fauna silvestres-Categoriosde riesgo y especificaciones para su inclusion, exclusion o cambio-Lista de especies en riesgo. Secretaria de Medio Ambiente y Recursos Naturales, 6 Marzo 2002. [In Spanish.]

EDDLEMAN, W. R., R. E. FLORES, AND M. L. LEGARE. 1994. Black rail (*Laterallus jamaicensis*). Number 123 *in* A. Poole and F. Gill, editors. The birds of North America. The Birds of North America, Philadelphia, Pennsylvania, USA.

EVENS, J. G., G. W. PAGE, S. A. LAYMON, AND R. W. STALLCUP. 1991. Distribution, relative abundance and status of the California black rail in western North America. Condor 93:952–966.

FLORES, R. E., AND W. R. EDDLEMAN. 1991. Ecology of the California black rail in southwestern Arizona. Final report. Arizona Game and Fish Department, Phoenix, Arizona, USA.

———, AND ———. 1993. Nesting biology of the California black rail in southwestern Arizona. Western Birds 24:81–88.

GLAHN, J. F. 1974. Study of breeding birds with recorded calls in north-central Colorado. Wilson Bulletin 86:206–214.

GUSTAFSON, J. R. 1987. Five-year status report for California black rail. Technical report. Nongame Bird and Mammal Section, California Department of Fish and Game, Sacramento, California, USA.

JOHNSON, R. R., AND J. J. DINSMORE. 1986. The use of tape-recorded calls to count Virginia rails and soras. Wilson Bulletin 98:303–306.

KERLINGER, P., AND D. S. WIEDNER. 1991. Vocal behavior and habitat use of black rails in south Jersey. Records of New Jersey Birds 16:58–62.

LATTA, M. J., C. J. BEARDMORE, AND T. E. CORMAN. 1999. Arizona Partners-In-Flight Bird Conservation Plan. Technical Report 142. Arizona Game and Fish Department, Phoenix, Arizona, USA.

LEGARE, M. L. 1996. The effectiveness of tape playbacks in estimating population densities of breeding black rails (*Laterallus jamaicensis*) in Florida. Thesis, University of Rhode Island, Kingston, Rhode Island, USA.

———, W. R. EDDLEMAN, P. A. BUCKLEY, AND C. KELLY. 1999. The effectiveness of tape playback in estimating black rail density. Journal of Wildlife Management 63:116–125.

MITSCH, W. J., AND J. G. GOSSELINK. 2000. Wetlands. John Wiley & Sons, New York, New York, USA.

NICHOLS, J. D., J. E. HINES, J. R. SAUER, F. W. FALLON, J. E. FALLON, AND P. J. HEGLUND. 2000. A double-observer approach for estimating detection probability and abundance from avian point counts. Auk 117:393–408.

RABE, M. L., AND D. L. RABE. 1985. Playback recordings as a population census technique for soras and Virginia rails. Midwest Fish and Wildlife Conference 47:66–67.

REPKING, C. F. 1975. Distribution and habitat requirements of the black rail (*Laterallus jamaicensis*) along the lower Colorado River. Thesis, Arizona State University, Tempe, Arizona, USA.

———, AND R. D. OHMART. 1974. Completion report on the density and distribution of the black rail (*Laterallus jamaicensis*) along the lower Colorado River (Davis Dam to the Mexican Boundary), 22 February 1974. Technical report. Contract Number 7625-575-15-8. Arizona Game and Fish Department, Phoenix, Arizona, USA.

———, AND ———. 1977. Distribution and density of black rail populations along the lower Colorado River. Condor 79:486–489.

REYNARD, G. B. 1974. Some vocalizations of the black, yellow and Virginia rails. Auk 91:747–756.

RIBIC, C. A., S. LEWIS, S. MELVIN, J. BART, AND B. PETERJOHN. 1999. Proceedings of the marsh bird monitoring workshop. Administrative report. U.S. Fish and Wildlife Service, Region 3, Fort Snelling, Minnesota, USA.

SPEAR, L. B., S. B. TERRILL, C. LENIHAN, AND P. DELEVORYAS. 1999. Effects of temporal and environmental factors on the probability of detecting California black rails. Journal of Field Ornithology 70:465–480.

TACHA, R. W. 1975. A survey of rail populations in Kansas, with emphasis on Cheyenne Bottoms. Thesis, Fort Hays State College, Fort Hays, Kansas, USA.

TECKLIN, J. 1999. Distribution and abundance of the California black rail (*Laterallus jamaicensis coturniculus*) in the Sacramento Valley region with accounts of ecology and call behavior of the subspecies. Technical report. Contract Numbers FG6154WM and FG6154-1WM. California Department of Fish and Game, Sacramento, California, USA.

TODD, R. L. 1970. Nongame investigations. Progress report. Project W-53-R-20. Arizona Game and Fish Department, Phoenix, Arizona, USA.

———. 1980. A breeding season 1980 survey of clapper rails and black rails on the Mittry Lake Wildlife Area, Arizona. Technical report. Federal Aid Project W-53-R-30, Work Plan 5, Job 1. Arizona Game and Fish Department, Phoenix, Arizona, USA.

U.S. FISH AND WILDLIFE SERVICE. 2002. Birds of conservation concern 2002. Division of Migratory Bird Management, Arlington, Virginia, USA.

WILBUR, S. R. 1974. The literature of the California black rail. Special scientific report-wildlife 179. Patuxent Wildlife Research Center, U.S. Fish and Wildlife Service, Laurel, Maryland, USA.

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