

Response of Hawaiian Moorhens to broadcast of conspecific calls and a comparison with other survey methods

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ABSTRACT. Accurate population surveys are critical for effective management of species of conservation concern. Traditional visual and aural surveys are ineffective for behaviorally cryptic species such as rails, but incorporating call-broadcast into surveys can increase their detection rate. From 2004 to 2006, we surveyed wetlands ($N = 67$) on Kauai and Oahu for endangered Hawaiian Moorhens (*Gallinula chloropus sandvicensis*) with the goal of comparing the effectiveness of visual and aural observations to that of call-broadcast surveys. We evaluated six different Hawaiian Moorhen calls, including the “squeal” call of young moorhens. We also compared the results of surveys conducted using the broadcast of Hawaiian Moorhen calls to those of extended time (75 min) surveys and surveys where the calls of the North American subspecies of moorhen (*G. c. cachinnans*) were broadcast. We found that broadcast of Hawaiian Moorhen calls increased detection rates by 56% on Kauai and 30% on Oahu. Territorial and chick-distress calls elicited the greatest response. We also found a nonlinear positive relationship between the estimated population of Hawaiian Moorhens at a wetland and the improvement in detection due to call-broadcast, suggesting social facilitation of responses. Survey periods of 60 min produced results similar to those obtained using call-broadcast. However, long survey periods require more time than call-broadcast surveys and increase the likelihood of double counting individuals. Broadcast of the calls of the North American subspecies of moorhen failed to increase detection rates above those obtained using visual and aural surveys. Our results suggest that the population of Hawaiian Moorhens is larger than previously estimated, but is likely well below the 2000 individuals recommended for removal from the Endangered Species list. We recommend the use of call-broadcast during surveys of Hawaiian Moorhens to improve estimates of population sizes and trends.

Sinopsis. Respuesta de *Gallinula chloropus sandvicensis* a grabaciones de llamadas de conespecíficos y comparación con otros métodos de muestreo

El determinar con exactitud los números poblacionales es un asunto crítico para el manejo efectivo de especies en donde hay preocupación por su conservación. Tradicionalmente, los muestreos visuales y auditivos son inefectivos para especies de patrones de conducta crípticos, tales como gallaretas, pero incorporando grabaciones de sus llamadas a los muestreos, se puede incrementar su detectabilidad. De 2004–2006 muestreamos anegados ($N = 67$) en Kauai y Oahu con la finalidad de comparar la efectividad de conteos visuales, auditivos y utilizando grabaciones para hacer estimados de las poblaciones de la amenazada *Gallinula chloropus sandvicensis*. Evaluamos seis llamadas diferentes producidas por el ave, incluyendo el “squeal” de individuos jóvenes. También comparamos los resultados de censos conducidos utilizando las grabaciones de la gallareta a aquellas de periodos extendidos (75 minutos) y censos en donde se utilizó la llamada de la subespecie norteamericana (*G. c. cachinnans*). Encontramos que el utilizar grabaciones de la gallareta hawaiana se incrementó la tasa de detección en 56% en Kauai y en un 30% en Oahu. Las llamadas territoriales y de sufrimiento de pichones produjeron la mayor respuesta. También encontramos una relación no-lineal positiva entre el estimado poblacional de aves en anegados y una mejora en la detección utilizando grabaciones, lo que sugiere facilitación social de la respuesta. Muestreos por periodos de 60 minutos produjeron resultados similares, a los obtenidos utilizando grabaciones. Sin embargo, periodos largos de muestreo requieren más tiempo que los muestreos utilizando grabaciones, e incrementan la posibilidad de doble conteo de individuos. El uso de grabaciones de la subespecie norteamericana, fallaron en incrementar la tasa de detección, en comparación con los obtenidos con la utilización de conteos visuales o auditivos. Nuestros resultados sugieren que la población de gallaretas hawaianas es más grande que lo previamente estimado, pero que está por debajo de los 2000 individuos que es el número recomendado para remover a la especie de la lista de animales en peligro de extinción. Recomendamos el uso de grabaciones durante los censos de gallaretas hawaianas para mejorar los estimados y estudiar sus tendencias poblacionales.

Key words: endangered species, *Gallinula chloropus sandvicensis*, secretive, survey, waterbirds

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The Hawaiian Islands currently support six endemic waterbird species or subspecies, and all are endangered (U.S. Fish and Wildlife Service 2004a, 2004b, 2005). As a result of human activities, wetlands in Hawaii have been lost and fragmented (Shallenberger 1977, Coleman 1981, Griffin et al. 1989, Reed et al. 1994), and extinction risk of birds dependent on this habitat has been exacerbated by the introduction of exotic predators and wetland plants (Schwartz and Schwartz 1949, Coleman 1981, U.S. Fish and Wildlife Service 2005). Of the Hawaiian waterbird species, Hawaiian Moorhens (*Gallinula chloropus sandvicensis*) are the least studied and have the smallest population (U.S. Fish and Wildlife Service 2005). Hawaiian Moorhens have been extirpated from Maui, Molokai, and the island of Hawaii, but populations persist on Oahu and Kauai (U.S. Fish and Wildlife Service 2005). Long-term population data reveal a generally increasing trend for moorhens on both islands (Reed et al. 2007), but populations have likely been underestimated because moorhens are secretive and difficult to detect (Chang 1990, Engilis and Pratt 1993).

Accurate population estimates are critical for determining population trends (Sutherland 1996), species-habitat relationships (Fielding and Haworth 1995), population viability (Beissinger and Westphal 1998), and effects of proposed management actions (Newbold and Eadie 2004). Conversely, nonspecific survey methods may lead to inaccurate estimates of population size or trends, potentially resulting in a failure to detect a declining population (VanderWerf et al. 2006). Investigators studying secretive waterbirds now consider nonspecific visual and aural surveys, such as those used in the biannual Hawaiian waterbird counts, to be insufficient for estimating populations of these birds (Conway and Gibbs 2005). However, broadcasting vocalizations to elicit responses can dramatically improve detection of these cryptic species (Kaufmann 1988, Gibbs and Melvin 1993, Conway and Gibbs 2005).

Nagata (1983) attempted to use call-broadcast to survey Hawaiian Moorhens, but birds reportedly did not respond. This lack of response might have been because calls from the North American subspecies (*G. c. cachinnans*) were used. In addition, Nagata (1983) did not report the specific call type used, and studies of other species indicate that responses to different call

types can vary (Cashen 1998, Tecklin 1999). Given the need for more accurate estimates of Hawaiian Moorhen populations and the increasing use of call-broadcast to survey marsh birds, our objectives were to (1) compare the results of passive surveys to those using call-broadcast, (2) compare the results of call-broadcast surveys and extended-time passive surveys (Chang 1990), (3) compare the results of passive surveys to surveys using broadcast of the calls of North American Moorhens, (4) determine if social facilitation (i.e., moorhen alone vs. in a group) might affect the number responding to call-broadcast, and (5) revise estimates of the size of the Hawaiian Moorhen population if we could establish a relationship between the results of passive versus call-broadcast surveys.

METHODS

We conducted surveys at Hanalei National Wildlife Refuge (Hanalei NWR) on Kauai. Hanalei NWR includes 25 wetlands (29.4 ha; range 0.3–5.5 ha). We conducted surveys on Oahu at wetlands throughout the island (Table 1). Oahu wetlands differed in management levels and intended function, ranging from James Campbell National Wildlife Refuge (James Campbell NWR) that is managed for endangered waterbirds to golf course ponds managed for aesthetic value. We selected wetland sites based on accessibility.

For all surveys, we used 50-m fixed-radius point counts, with centers of survey points at least 100 m apart. Survey points were placed to maximize the area covered in a wetland. We surveyed 18 points in wetlands on Kauai in 2004. On Oahu, we surveyed 61 points in 42 ponds at 20 wetland complexes in 2005 (we defined a wetland complex as a collection of ponds where adjacent ponds' perimeters were <50 m apart). On Oahu in 2006 we surveyed 49 of the 61 points from 2005; these points were distributed across 36 ponds at 16 wetland complexes. See Table 1 for number of survey points per wetland. Survey points where no birds were detected during any of the surveys were omitted from our analyses because comparisons of the relative efficacy of survey methods were not possible if no birds were present.

We surveyed birds from 31 March to 21 April 2004 on Kauai and from 22 March to 22 July 2005 and from 1 June to 1 August

Table 1. Characteristics of wetlands surveyed and estimated populations of Hawaiian Moorhens^a.

Site	Geographic coordinates (deg° min' sec ^{''})	Adult population size estimated from call-broadcast ^b	Wetland type	Number of ponds	Number of survey points	Wetland area (ha)
Ki'i	21° 41' 11" N, 157° 55' 15" W	29.6 ± 1.7	Refuge	10	12	38.3
Hamakua	21° 23' 2" N, 157° 44' 30" W	18.5 ± 1.4	Restored	1	4	7.2
Ka'elepulu	21° 22' 31" N, 157° 44' 19" W	14.2 ± 2.7	Restored	1	1	0.6
Waimea	21° 38' 25" N, 158° 3' 40" W	5.6 ± 1.3	Botanical garden pond	4	4	6.3
Turtle Bay	21° 45' 56" N, 157° 58' 51" W	4.0 ± 1.0	Golf course	4	5	18.5
Kawainui	21° 23' 40" N, 157° 45' 25" W	3.8 ± 0.8	Flood control	1	6	< 8
Ho'omaluhia	21° 23' 22" N, 157° 47' 58" W	2.8 ± 1.4	Reservoir	1	3	12.9
Carlos' Lotus	21° 35' 12" N, 158° 6' 34" W	2.3 ± 0.6	Private aqua- culture	1	1	0.5
Coconut Grove	21° 41' 42" N, 157° 58' W	1.5 ± 1.7	Refuge	1	3	14.9
Waihe'e	21° 27' 40" N, 157° 50' 30" W	1.0 ± 1.4	Unmanaged	1	1	3.0
Punamano	21° 41' 47" N, 157° 58' 21" W	1.2 ± 1.5	Refuge	1	2	15.3
Ukoa	21° 36' 11" N, 158° 5' 45" W	1.2 ± 0.6	Unmanaged	1	4	38.7
Apoka'a	21° 21' 53" N, 158° 1' 23" W	0.5 ± 0.9	Unmanaged	1	1	2.8
Pouhala	21° 22' 43" N, 158° 24" W	0.3 ± 0.6	Restored	1	2	42.0
Hono'uli'uli	21° 21' 24" N, 158° 1' 10" W	0	Refuge	2	2	7.78
Apua	21° 30' 34" N, 157° 50' 14" W	0	Unmanaged	1	1	1.31
Hawai'i Prince	21° 19' 33" N, 158° 18" W	0	Golf course	3	3	13.73
Salt Lake	21° 21' 18" N, 157° 54' 28" W	0	Golf course	1	2	8.82
Waiawa	21° 23' 12" N, 157° 58' 57" W	0	Refuge	2	2	14.3
Kuilima	21° 41' 42" N, 157° 59' 25" W	0	Sewage treatment plant	4	1	5.00
Hanalei	22° 12' 15" N, 159° 29' 53" W	Not estimated	Refuge	25	18	29.4

^aAll wetlands were on Oahu except for Hanalei National Wildlife Refuge on Kauai.

^bMean ± 1 SD.

2006 on Oahu. Wetlands were surveyed three times each year, with visits 5–12 d apart. Stage of the breeding cycle can influence response rates to call-broadcast (Bogner and Baldassarre 2002), but we were unable to control for this because Hawaiian Moorhens breed year-round (Byrd and Zeillemaker 1981, U.S. Fish and Wildlife Service 2005). On Kauai, surveys were conducted between 06:00 and 10:00, which is thought to be the peak calling time (Brewster 1891). Because we wanted to determine if there was a difference in moorhen detection between morning and evening surveys, we replicated surveys in mornings and evenings at each pond in 2005 (Oahu), resulting in six surveys per

point that year. Morning surveys were conducted between 07:00 and 10:00, and evening surveys between 16:00 and 19:00. Because we found no difference in the number of moorhens detected in the morning and evening in 2005 (see Results), we conducted surveys during both time periods in 2006.

Our survey protocol followed recommendations for evaluating passive and call-broadcast methods (Walther and Hohman 1999, Conway and Gibbs 2005, Kirkpatrick et al. 2007). At each survey point, we recorded spontaneous visual and aural detections of moorhens for 5 min (passive survey), followed by call-broadcast surveys. Visual and aural monitoring continued

while broadcasting a single 10-s recording of each call (described below). There was a 5-s pause between each call, resulting in the duration of the total broadcasting time of 1 min. The observer continued monitoring for 3 min after completion of the call-broadcast. Vocalizations broadcast on Kauai (2004) included two adult calls recorded by Pratt (1995) that we call the “yelp” and “peeping” vocalizations (see Results for sonograms). These calls were broadcast repeatedly for 1 min as just described. During call-broadcast for the first two survey periods on Oahu (2005; period 1: 22 March–20 April, Period 2: 3 May–7 June), we broadcast four adult vocalizations (yelp, cluck, squawk, and cackle calls; Table 2) that we recorded on Oahu at the Waimea Valley Audubon Center. In July 2005 at the James Campbell NWR, we recorded a fifth call (squeal call of chicks). Consequently, the final 2005 survey period (20 June–22 July) and all 2006 surveys included the five vocalizations during call-broadcast surveys. We randomized the order of presentation of the five calls for all surveys in 2006 to minimize the likelihood of call order affecting responses (Brenowitz 1981, Falls et al. 1990). During surveys, we noted the general locations of individual birds to minimize the likelihood of double counting individuals. Recordings were made using a Sennheiser ME-62 Shotgun microphone and Sony MZ-R37 mini-disc recorder. Sonograms of moorhen vocalizations were created using Raven Lite 1.0 (Build 9, Update 8; Charif et al. 2006).

We compared the results of call-broadcast surveys to those of two other survey methods in 2006. The first alternative survey method was

the use of longer passive observations. Chang (1990) reported that 120-min surveys were needed to detect all Hawaiian Moorhens in a wetland, whereas 70-min surveys detected 80% of the individuals and 90-min surveys detected 92%. We conducted 75-min passive surveys at 10 points, one at each of 10 ponds, on days when we did not conduct call-broadcast surveys. During each survey, individual birds were identified and their movements mapped. Times of first observation and each subsequent movement were recorded to decrease the likelihood of double counting birds. At the end of each 75-min survey, we estimated the minimum number of adult moorhens at each pond. We compared these results to the number of moorhens detected using the call-broadcast protocol at the same ponds.

A second alternative survey method involved broadcasting three distinct calls of the North American subspecies of the Common Moorhen. Recordings used were those available for the North American Marsh Bird Monitoring Program (Conway and Nadeau 2006). Using the calls of North American Common Moorhens, we surveyed the same 10 ponds that were surveyed using the extended-time observation protocol and used the same protocol as when broadcasting the calls of Hawaiian Moorhens. We recorded the number of birds that responded and how they responded (i.e., vocalizing, approaching in the direction of the speaker, or scanning) after we broadcast each call.

To determine if social facilitation influenced moorhen responses to call-broadcast, we regressed the number of additional birds detected via call-broadcast (dependent variable) versus estimated population size (the number of adult moorhens in a wetland detected during the passive observation periods) (independent variable) and density (estimated population size divided by total wetland area). We defined social facilitation as a nonlinear relationship between population size (or density) and number of additional responses to call-broadcast, with a higher proportional response associated with larger population size (or density). We fit linear, exponential, and second- and third-order polynomial models to the data. With the exception of the exponential model, the intercept was set at the origin (i.e., at a wetland without moorhens there can be no increase in detection).

Table 2. Social context of Hawaiian Moorhen vocalizations used during call-broadcast surveys on Oahu and Kauai.

Vocalization	Social context
Cluck	Most common call; given in at least eight social situations
Yelp	Alarm call
Squawk	Advertising-call (but see Bannor and Kiviat [2002])
Cackle	Territorial advertisement
Squeal	Chick distress call
Peeping	Adult-chick interaction call

Social context descriptions are after Cramp and Simmons (1980) and Bannor and Kiviat (2002).

Table 3. Comparison of null (linear) model fit to the data in Figure 3, relating estimated population size from passive detection (x) to number of additional Hawaiian Moorhens detected using call playback (y), with alternative models of a socially facilitated response.

Model	r^2	ΔAIC_c
$y = 0.5117x - 0.0748x^2 + 0.0034x^3$	0.97	0.00
$y = -0.0389x + 0.0198x^2$	0.88	4.10
$y = e^{0.1313x}$	0.90	12.69
$y = 0.2964x$	0.81	20.39

For each model, with the exception of the exponential, the trend-line was constrained to pass through the origin.

Consequently, we revised range-wide winter population size estimates from the biannual Hawaiian waterbird surveys (1995–2004) using two approaches. First, we simply increased population estimates using the mean increase resulting from the results of our call-broadcast surveys on Oahu (see Results). Second, we used the equation for the first polynomial relationship shown in Table 3 and Figure 3.

We conducted our analyses using the Statistical analysis system (SAS Institute 2003). We used paired t -tests to compare (1) detections of moorhens during the 2005 morning and evening surveys for both the passive and call-broadcast portions, and (2) the overall effectiveness of call-broadcast versus passive surveys. In addition, to determine if an increase in detection resulting from call-broadcast was due to just surveying the additional 4.25 min, we used a paired t -test to compare the mean number of birds detected in 2006 during the call-broadcast period with the number of birds detected during the same amount of time during the extended time surveys (from 5.00 to 9.25 min during the survey). We determined if there was a year effect on detections due to call-broadcast using analysis of covariance (ANCOVA). We used a chi-square analysis to determine if moorhen vocalizations differed in their ability to elicit responses, and used an analysis of variance (ANOVA) to test for an effect of call order on moorhen responses to call-broadcast. To determine if there was an island effect on detection due to call-broadcast, we used a t -test. We used regression analysis to determine if social facilitation influenced detection of moorhen

during call-broadcast, and we compared model fit using Akaike's information criterion corrected for sample size (AIC_c) (Burnam and Anderson 2002). We present values as means \pm 1 SD.

RESULTS

In 2005 (Oahu), the mean number of moorhens detected between morning and evening using passive ($t_{32} = 0.0$, $P = 1.0$) and call-broadcast ($t_{32} = 0.9$, $P = 0.4$) methods did not differ. We also found no difference across years in the number of moorhens detected using call-broadcast on Oahu (ANCOVA; $F_{1,53} = 0.2$, $P = 0.6$), so we averaged survey results from morning and evening surveys from 2005 and across years for analyses.

On Oahu, broadcast of Hawaiian Moorhen calls resulted in the detection of significantly more birds per point (mean = 0.55 ± 0.44 , or 30.4%) than passive surveys ($t_{36} = 7.6$, $P < 0.01$). Based on these results, we then estimated the size of moorhen populations at each wetland (Table 1). The number of moorhens detected during call-broadcast was also greater than the number detected during extended-time surveys ($t_{32} = 2.7$, $P = 0.01$). In addition, we found no difference between islands in the number of individuals detected using call-broadcast ($t_{48} = 0.0$, $P = 1.0$).

On Kauai, mean detection of moorhens in refuge wetlands after call-broadcast increased by 0.55 ± 0.50 (56.3% increase, $t_{10} = 3.6$, $P < 0.01$) birds per survey point. On Kauai, we detected 18 additional moorhens using call-broadcast, with 11% responding either during or immediately after playback of the "yelp" call, 22% during or immediately after the "peeping" call, and the rest after the entire series of both calls had been broadcast during the final period of observation. Broadcast surveys on Oahu involved 4–5 call types (Fig. 1), and we found differences in the effectiveness of different calls in eliciting responses. During the first two survey periods in 2005, we recorded 86 responses after broadcast. The "cackle" elicited 88% of those responses, while each of the other calls elicited 6% or less ($\chi^2_5 = 184.6$, $P < 0.01$; Fig. 2). In the third survey period, the "squeal" (that had not been recorded previously) and the "cackle" calls elicited a combined 78% of the 36 responses, whereas the "yelp" elicited the remaining eight responses ($\chi^2_6 = 27.6$, $P < 0.01$). In 2006,

the “cackle” call elicited 11% and the “chick-distress” call elicited 70% of the 64 responses ($\chi^2_6 = 102.3, P < 0.01$). We attributed a response to a specific call if the response occurred during the broadcast of that specific call or immediately (within 5 s) after its broadcast.

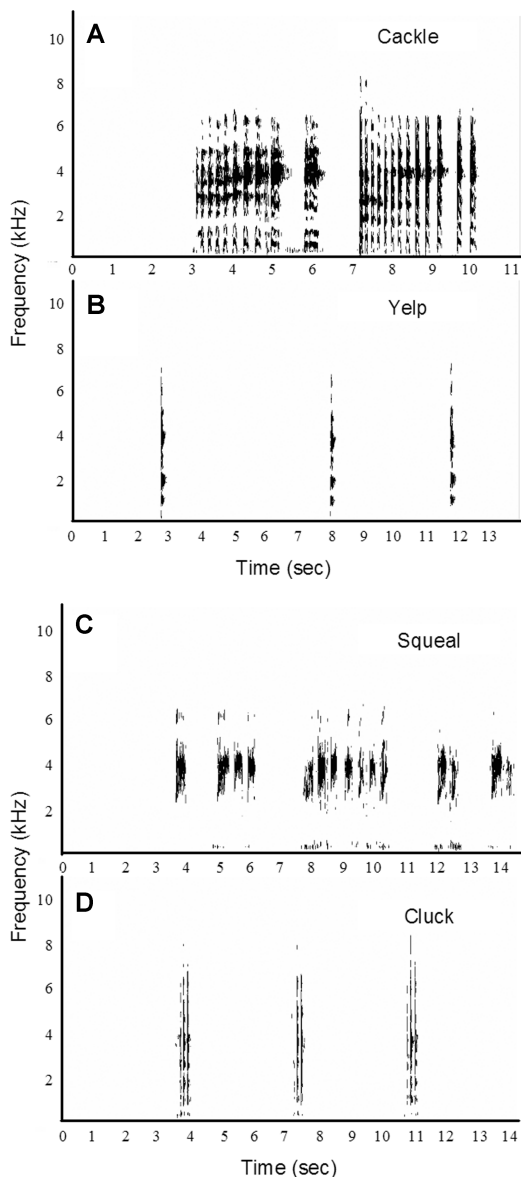


Fig. 1. Sonograms of Hawaiian Moorhen vocalizations: (A) cackle, (B) yelp, (C) squeal, (D) cluck, (E) squawk, and (F) peeping. Time (s) is on the x-axis and frequency (kHz) on the y-axis.

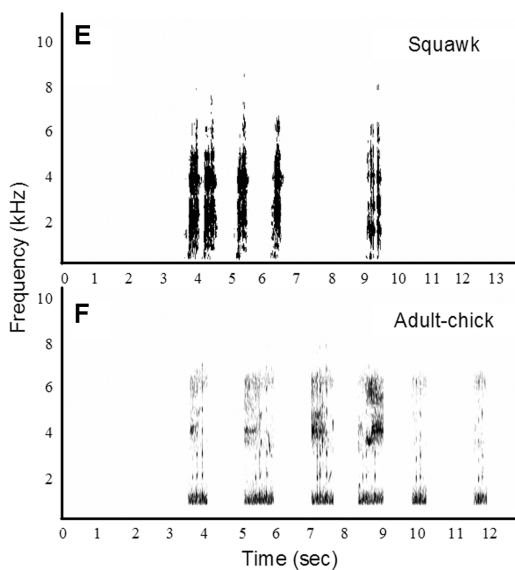


Fig. 1. Continued

If we detected additional responses during the 3 min of observation following the completion of call-broadcast, then we did not attribute these responses to any specific call. The order in which calls were broadcast did not influence moorhen responses ($F_{4,76} = 0.4, P = 0.8$).

After 60 min of passive observation, we found no difference ($t_5 = 0.9, P = 0.42$) in the number of birds detected using extended-time (mean = 5.0 ± 3.3 birds/survey point) and call-broadcast (5.8 ± 4.5) protocols and no additional birds

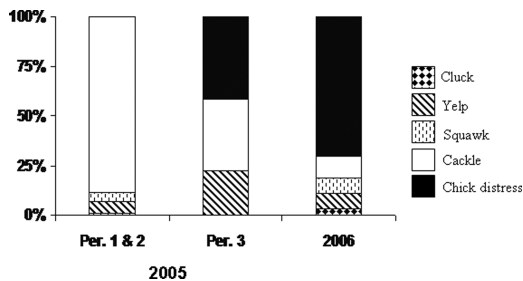


Fig. 2. Percentage of responses by Hawaiian Moorhens on Oahu generated by each call type: (A) 2005: periods 1 and 2 (Per. 1 and 2), when only four call types were used (Period 1: late March–late April, and Period 2: early May–early June), (B) 2005: period 3 (Per. 3) (5 call types used; Period 3: late Jun–late Jul), and (C) 2006: all periods (5 call types used).

were detected after 60 min of observation. At four of 10 ponds, no birds were detected using either extended-time surveys or call-broadcast surveys.

Broadcasting calls of the North American subspecies of moorhen resulted in no more detections than during passive surveys (mean = 2.3 ± 2.1). During broadcast of the calls of the North American subspecies, eight birds detected during passive observation responded by vocalizing, scanning, or moving in the direction of the speaker. Hawaiian birds responded to only two of three different mainland vocalizations calls that, to us, sounded similar to the calls of Hawaiian Moorhens ("cackle" and "yelp"). No responses were noted in response to broadcast of the most dissimilar call, the "giddy-up" call.

We found no relationship between the number of additional birds detected during call-broadcast and population density ($r^2 < 0.01$, $P = 0.9$). However, there was a strong relationship with estimated population size (Fig. 3). All four models produced a significant fit to the data, but there was evidence of social facilitation in the responses to call-broadcast based on local population size. All nonlinear models had a significantly better fit than the linear model and, of the models tested, the third-order polynomial best fit the data, showing a strong increase in response associated with increasing population size ($r^2 = 0.97$, $P < 0.01$; Table 3).

Our revised population estimates increased the range-wide population estimates from a

range of 161–395 individuals (265 ± 74) (from the biannual Hawaiian waterbird surveys) to a range of 210–515 individuals (346 ± 96) (increase based on call-broadcast results alone), and 203–456 individuals (324 ± 83) (increase based on the first polynomial equation; Table 3). For the socially facilitated response, we assumed that all local population estimates of greater than 21 individuals showed that same improvement from call-broadcast as populations of 21 individuals.

DISCUSSION

By broadcasting the calls of Hawaiian Moorhens, we detected significantly more birds and found evidence of social facilitation in response to call-broadcast. On Oahu, increased detection due to call-broadcast was positively associated with population size, but not population density. At the wetland with the largest population (Ki'i), as many as seven birds (compared to one or two, typically) responded to the squeal that chicks utter when threatened. Our results suggest that previous underestimates of Hawaiian Moorhen populations were greatest where populations were largest. Thus, using call-broadcast may be most important in wetlands with larger populations.

The cackle and squeal calls were the most effective in eliciting responses in our study. Although birds are known to respond to the distress calls of adults (e.g., Hill 1986) and chicks (Radford and Blakey 2000), we have not found reports of their use in call-broadcast surveys (Conway and Nadeau 2006). Because the chick distress call was so effective during surveys on Oahu, using distress calls might also improve the effectiveness of broadcast surveys for other species. Chick distress calls may be especially useful for extending the survey season if birds in later stages of breeding become less responsive to calls associated with territorial defense (Rehm and Baldassarre 2007).

Observations of 60 min produced results similar to those using call broadcast to detect moorhens. However, disadvantages of long surveys include the greater time required to complete surveys and the possibility that birds could move among wetlands and increase the likelihood of double counting individuals. In addition, moorhens have been observed moving



Fig. 3. Relationship between estimated local population size (based on passive observations alone) and the number of additional Hawaiian Moorhens detected using playback (see Model 1 in Table 2 for equation).

quickly between wetlands separated by a dike (D. DesRochers, pers. obs.), and adults are known to relocate chicks when disturbed (H. Gee, pers. obs.).

Our results suggest that the population of Hawaiian Moorhens is larger than previously estimated, but is likely well below the 2000 individuals recommended for removal from the Endangered Species list (U.S. Fish and Wildlife Service 2005). Assuming the exponential relationship depicted in Figure 3 (Model 1 in Table 3) is accurate statewide, it could be used to improve previous range-wide population estimates. Because of the exponential nature of the relationship, however, it would be inappropriate to extrapolate the equation to populations of more than 21 individuals.

Overall, our results indicate that incorporating call-broadcast methods into the biannual waterbird surveys in Hawaii would increase detection rates of moorhens and improve estimates of population sizes and trends. Improved estimates of population sizes form the basis for management decisions for poorly studied species (Allen et al. 2004) and have proved valuable for evaluating population status and trends of behaviorally cryptic species elsewhere (Kearns et al. 1998, Lor and Malecki 2002, Conway and Simon 2003, Kirkpatrick et al. 2007), including the Mariana subspecies of the Common Moorhen (*G. c. guami*; Takano and Haig 2004). We recommend the use of cackle, squeal, and yelp calls in call-broadcast surveys for moorhens because these calls elicited the greatest response (vocalizations used in our study are available for download at <http://ase.tufts.edu/biology/labs/reed/res-pub-suppl.html>). We recommend a minimum of 5 min for passive observation because this allows birds to adjust to the presence of an observer (Bibby et al. 2000). Finally, it is important to establish the relationship between moorhen call responses and population status. For example, high response rates might mean a large breeding population size or a large population of unmated males (Tyler and Green 1996). To this end, we suggest that call-broadcast surveys be conducted at regular intervals during the year, particularly where the breeding stage of birds is known, to determine if or how responsiveness varies throughout the annual cycle.

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