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Estimating Detection Probabilities and Site Occupancy Rates of Three Anuran Species Using Call Surveys in Haenam Gun, Korea

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ABSTRACT: We investigated the distribution of three anuran species, Three-striped pond frogs (*Rana nigromaculata*), Bullfrogs (*Rana catesbeiana*), and Narrow-mouthed toads (*Kaloula borealis*), in an administrative district, Haenam Gun, Junnam Province, Korea using volunteer call surveys. Twenty-eight volunteer call surveyors were assigned to each 2 × 2 km^2 survey plot. Call surveys on whether the species are present or not were conducted for 5 minutes between 30 minutes after sunset and the midnight on rice fields and ponds from 10 April to 28 August in 2005. Depending on species, call surveys were carried out at seven to 28 plots with average 8.4 to 10.7 visits per the plot. We calculated the detection probabilities and occupancy rates of the three species using four models with three covariates: temperature, humidity, and the amount of water at the habitat. The model average detection probabilities of three anuran species of *R. nigromaculata, R. catesbeiana,* and *K. borealis* were 0.53, 0.74, and 0.41 respectively, and the site occupancy rates of them were 0.93, 0.94, and 0.86 respectively. Our results indicate that *R. nigromaculata, R. catesbeiana,* and *K. borealis* are common in Haenam Gun.

Key words: Anuran species, Call survey, *Kaloula borealis*, *Rana catesbeiana*, *Rana nigromaculata*, Site occupancy rate

INTRODUCTION

The declines of amphibian populations are worldwide for the past several decades (Cooke 1972, Wake 1991, Alford and Richards 1999, Houlahan et al. 2000). Several factors for the amphibian declines have been suggested such as habitat destruction and modification, invasive species, chemical contaminants, and global climate change (Blaustein and Wake 1990, Storfer 2003). To elucidate the status of amphibian populations and the causes of such declines, extensive monitoring efforts have been made (Bell et al. 2004, Pellet and Schmidt 2005).

Call survey monitoring of amphibian populations based on volunteers is mainly used to cover a wide range of areas with low costs and with ease (McDiarmid and Donnelly 1994, Campbell et al. 2002, MacKenzie 2005, Pellet and Schmidt 2005). From the call surveys, site occupancy probabilities as well as metapopulation dynamics with colonization and extinction rates and turnover rates can be examined. Recently, MacKenzie et al. (2002) developed a method to allow unbiased estimation of detection probability and site occupancy rate of the species using call survey data. For this method, volunteers need to perform multi-visits at a site and need to collect several covariances such as temperature and humidity information.

The goals of this study were to investigate regional distribution of three anuran species, Three-striped pond frogs (*Rana nigromaculata*), Bullfrogs (*Rana catesbeiana*), and Narrow-mouthed toads (*Kaloula borealis*), within an administrative district, Haenam Gun, Junnam Province, Korea. In this paper we estimated site occupancy rates and detection probabilities of the three species based on repeated surveys of a site within a breeding period and calculated the least number of visits necessary to confirm the absence of a species at a site. This is the first documentation of large-scale monitoring programs in Korea a step toward developing statistical models to reflect the current status of the three species as well as to predict environmental changes with long-term surveys.

MATERIALS AND METHODS

Study Area and Survey Methods

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Call surveys were conducted by volunteers of Haenam high school students. In order to help volunteers discriminate among anuran calls, we provided a published booklet, which contains morphological, physiological, ecological, and acoustic information on amphibian species and methods of anuran call monitoring. A schoolteacher trained students to discriminate *R. nigromaculata, R. catesbeiana,* and *K. borealis'*s calls. Total 31 volunteers participated in this study and we analyzed the data of 28 volunteers due to incomplete data records of three students.

Volunteers surveyed anuran calls once per week for *R. nigromaculata* and *R. catesbeiana* from 10 April to 28 August in 2005 and for *K. borealis* from 24 April to 7 August in 2005 in Haenam Gun, Junnam Province, Korea. Thus weather conditions were differed between the two breeding periods of three species: mean temperature ± standard deviation were 22.4 ± 4.2 (range, 9–[illegible]) for *R. nigromaculata* and *R. catesbeiana* while 23.0 ± 3.0 (range, 17–23); mean humidity ± standard deviation were 66.5 ± 14.1 (range, 32–[illegible]) for *R. nigromaculata* and *R. catesbeiana* while 69.7 ± 11.5 (range, 47–[illegible]). We divided the Haenam Gun area into 2 × 2 km^2 plots: total 150 survey plots of which more than 50% areas were land were produced. Out of total 150 plots, 28 plots (19%) for *R. nigromaculata*, 18 plots (12%) for *R. catesbeiana*, and 7 plots (5%) for *K. borealis* were covered (Fig. 1). Surveyors heard anuran calls for 5 min between 30 minutes after sunset and the midnight on rice fields or on ponds and recorded the following information: five-level calling index (0 - no calls detected; 1 - calls detected from one male; 2 - calls detected from two to five males; 3 - calls detected from six to ten males; 4 - calls detected from more than ten males), weather, temperature, humidity, and three-level water index on the field (0 - less amount of water than usual; 1 - usual amount of water; 2 - more amount of water than usual). In this study to estimate site occupancy rates, we reassigned five-level calling index into either presence (1) or absence (0).

Fig. 1. Map of anuran call survey locations in Haenam Gun, Junnam Province, Korea. The study area was divided into 150 plots with a 2 × 2 km^2 plot, where 28 plots for *R. nigromaculata*, 18 plots for *R. catesbeiana,* and seven plots for *K. borealis* were surveyed by volunteered observers.

Data Analysis

We calculated, first, naïve site occupancy rates (the number of detected plots divided by total study plots per species) and, second, weekly call detectability across study plots to overlook species detectability in Haenam Gun areas before entering data into a monitoring analysis program. In order to obtain the average plots of detected species per week, we calculated the sum of weekly rates of the detected over the total plots and divided the sum by the number of survey weeks, for which we used data from 17 April to 31 July for *R. nigromaculata* and *R. catesbeiana* and from 1 May to 31 July for *K. borealis* due to not enough numbers of surveyors. Then, we estimated detection probabilities and site occupancy rates with program PRESENCE (available from http://www.proteus.co.nz), with which we consulted the data analysis modeled by MacKenzie et al. (2002). This program uses AIC (Akaike's Information Criterion) to select the most appropriate covariance model explaining the survey data; models in a candidate set were ranked by △AIC (the difference between the model with the lowest AIC and the given model); model weights (*w;* relative likelihood of each model), indicating the degree of relative support of a model, were calculated; and then, we obtained model average estimates of detection probability based on the model weights (Burnham and Anderson 2002). Since this model assumes that sites are "closed" within a breeding season, we removed the data of the first and the last week surveys so that we confirmed the existence of the species within the survey plot during the survey periods.

We developed four models using three covariates to predict detection probability for each species: we assumed detection probability was constant (*p*), or detection probability was associated with temperature, humidity, or three-level water index. To reveal how many visits are necessary to confirm the absence of a species at a site with 95% confidence, the following equation was applied (Pellet and Schmidt 2005):

$$N_{min} = -\frac{\log(0.05)}{\log(1-p)}$$

Where: N_{min} is the number of visits; p is estimated mean detection probability.

RESULTS

Rana nigromaculata

Surveyors visited their survey plots average 10.6 (range 4～16) times per plot including missing observations 45% (238 out of total 532 visits) for *R. nigromaculata*: the species was detected at least once at 26 out of 28 sites (0.93) which represents naïve site occupancy rates; and an average of 0.66 plots per week, where detectability was more than the average from 1 May to 25 June and peaked from 5 to 11 June (Fig. 2). Four models with three covariates showed similar weight (w, Table 1). The overall estimated site occupancy rates ($\hat{\psi}$) were similar to naïve site occupancy rates (0.93). As estimated mean detection probability of the models is 0.53, minimum four visits are necessary to confirm that the species is absent.

Rana catesbeiana

Surveyors visited their survey plots average 10.7 times (range 4～16) including missing observations 44% (150 out of total 342 visits) for *R. catesbeiana*: the species was detected at least once at 17 of 18 sites (0.94); and an average of 0.65 plots per week, where detectability was more than the average from 22 May to 2 July except for one week of 12～18 June and peaked from 5 to 11 June (Fig. 2). One model with Water as a covariate indicated that *R. catesbeiana* was more likely detected with increasing the amount of water (Fig. 3). Except that, all models showed similar estimates of site occupancy rate ($\hat{\psi}$). As estimated mean detection probability of the models is 0.74, minimum three visits are necessary to confirm that the species is absent.

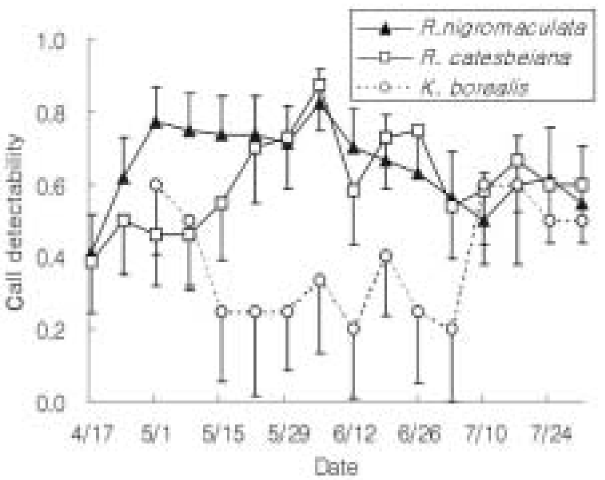

Fig. 2. Weekly means (± SE) of the call detection probabilities of the three anuran species measured by volunteer based large-scaled call surveys.

Table 1. Summary of models on parameter estimations of site occupancy rates and detection probabilities in the three species. ΔAIC is the difference between the model with the lowest AIC and the given model; w is the Akaike weight; $\hat{\psi}$ is the estimated proportion of sites occupied; SE ($\hat{\psi}$) is the standard error of $\hat{\psi}$; $\hat{p}$ is the estimated detection probability.

Model	ΔAIC	w	$\hat{\psi}$	SE ($\hat{\psi}$)	$\hat{p}$
Rana nigromaculata					
Ψ(.) p(Temperature)	0.00	0.330	0.929	0.049	0.41
Ψ(.) p(Water)	0.12	0.310	0.929	0.049	0.43
Ψ(.) p(.)	0.46	0.262	0.929	0.049	0.71
Ψ(.) p(Humidity)	2.42	0.098	0.929	0.049	0.80
Model averaged					0.53
Rana catesbeiana					
Ψ(.) p(Water)	0.00	0.853	0.945	0.054	0.79
Ψ(.) p(.)	4.98	0.071	0.944	0.054	0.64
Ψ(.) p(Temperature)	5.96	0.043	0.944	0.054	0.38
Ψ(.) p(Humidity)	6.54	0.032	0.944	0.054	0.39
Model averaged					0.74
Kaloula borealis					
Ψ(.) p(Humidity)	0.00	0.357	0.857	0.133	0.30
Ψ(.) p(.)	0.10	0.340	0.858	0.132	0.48
Ψ(.) p(Temperature)	1.40	0.177	0.857	0.132	0.32
Ψ(.) p(Water)	2.06	0.127	0.858	0.132	0.66
Model averaged					0.41

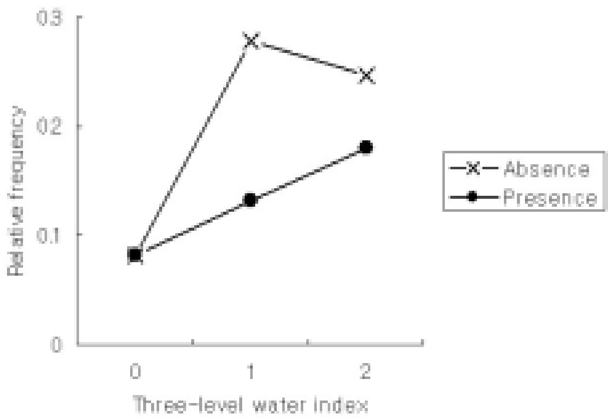

Fig. 3. Relative frequency of absence and presence of *R. catesbeiana* for the three-level water index in Haenam areas over the study period.

Kaloula borealis

Surveyors visited their survey plots average 8.4 times (range 5～14) including missing observations 38% (37 out of total 98 visits) for *K. borealis*: the species was detected at least once at 6 of 7 sites (0.86); and an average of 0.39 plots per week, where detectability was more than the average for two weeks from 1 May and for four weeks from 10 July and peaked for two weeks from 10 July (Fig. 2). All models showed similar estimates of site occupancy rate ($\hat{\psi}$). As estimated mean detection probability is 0.41, minimum six visits are necessary to confirm that the species is absent.

DISCUSSION

This study showed that detection probabilities varied among species but the site occupancy rates ($\hat{\psi}$) were constantly high among the four models in each species indicating that *R. nigromaculata, R. catesbiana,* and *K. borealis* are common in Haenam Gun. In addition, naïve site occupancy rates were also high for the three species. The difference between site occupancy rates and naïve site occupancy rates was zero or less than within the range of the standard error of each model, so that we suppose all plots we surveyed were found where the species existed. However, as the estimates of site occupancy rate and detection probability with presence/absence surveys are reasonable only for large-scale surveys (Yoccoz et al. 2001, Bailey et al. 2004), relatively limited survey areas for *K. borealis*, seven out of total 150 effective survey plots (5%), may lead to overestimate those values for this species. For *K. borealis*, we may need further large-scale surveys in the future.

The results of this study may implicate that anuran call surveys of the three species using the models of MacKenzie et al. (2002) are useful in Haenam Gun area in two ways: First, as shown in the simulation results by MacKenzie et al. (2002), when surveyors visited more than five times at a survey plot with greater than 0.3 of detection probability, site occupancy rates appeared to be unbiased. Since our call surveys were performed averages of 8.4～10.7 times per plot with larger than 0.41 detection probabilities, the estimates of the site occupancy rates must be accurate.

Second, averaged detection probabilities varied among the three species: 0.74 for *R. catesbeiana*, 0.53 for *R. nigromaculata*, and 0.41 for *K. borealis*. The various species detectability over the study plots may be correlated with overall calling activity; the weekly calling activity of *R. nigromaculata* and *R. catesbeiana* was relatively higher over the survey periods than that of *K. borealis*. The peaks of calling activity of both *R. nigromaculata* and *R. catesbeiana* appeared similarly in around 5 June but *R. nigromaculata* was active early and prolonged till the peak while *R. catesbeiana* steadily increased the calling activity till a calling peak. *K. borealis* showed a prominent later calling peak around 10 to 17 July, the raining season in summer, than other species (Fig. 2). The limited seasonal calling activity of *K. borealis* may be responsible for relatively low detection probabilities of *K. borealis* than others. Nevertheless, call detectability of the species was satisfactorily high to estimate site occupancy rates. In addition, a model including Water as a covariate well predicted call detectability of *R. catesbeiana* while others appeared to be little important to predict that of *R. nigromaculata* and *K. borealis*. Previous researches on model selection of other anuran species showed temperature mainly played a role as a covariate in detecting the presence of the species (MacKenzie et al. 2002, Royle 2004, Pellet and Schmidt 2005). However, various environmental covariates also predicted the species detectability well in various ways among species and between years (Schmidt 2005): for example, 'day' as a covariate best explained detection probability of *Alytes obstetricans* in 2001 while 'temperature' best explained in 2002.

To reduce time and cost and to increase the efficiency of call surveys, three recommendations may be useful for future surveys. First, since *R. catesbeiana* and *R. nigromaculata* can be confirmed to be absent at a site with minimum visits of 3～4 times, four times visiting can give reasonable data. In case of *K. borealis*, since the species is seasonal specific, even though it needs to visit at least six times, we may conduct four times visiting only corresponding to the raining season. Second, to improve the detection probabilities, mating call playback methods may increase the detectability of three anuran species (Sung et al. 2005). Sung et al. (2005) showed a case study on *R. nigromaculata* that playbacks of the mating calls induced call utterances of silent resident males and higher calling activity from other males. Third, as Pellet and Schmidt (2005) pointed out, if the relationship between detection probability and a covariate exists, it may be able to determine the relevant temperature zone for effective detectability. For example, models including temperature as a covariate best predicted the variation of detection probability of *Hyla arborea*, where the species were detected well on warm nights that will be a good condition for surveys (Pellet and Schmidt 2005).

In this study, we obtained volunteer based large-scaled survey data on presence/absence of the three species at a site in Haenam Gun areas. The two estimates of detection probabilities and the site occupancy rates may provide more valuable information on the spatial distribution of the three species as well as on the temporal variations over several years in revealing the population status at local as well as regional levels, if we keep preceding the surveys and extending the survey areas.

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