ASSESSMENT OF THE DETECTION PROBABILITY OF *QUASIPAA VERRUCOSPINOSA* (BOURRET, 1937) IN BACH MA NATIONAL PARK, THUA THIEN HUE PROVINCE

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Previous studies suggest that it is preferable to use a sampling method that involves multiple visits to sites (or patches) during the appropriate season in which a species can be detected (MacKenzie et al., 2002) and the ratio of sites that are occupied by the species is assessed in the face of imperfect detection (MacKenzie et al., 2003; Nichols et al., 2007). In these cases, sampling sites may represent separate habitat patches in a dynamic context of metapopulations or sampling units (quadrats) regularly visited as part of a large-scale monitoring program (MacKenzie et al., 2006) because the presence or absence of a species from a collection permits inference to the entire region of interest. Detection and non-detection models using multiple visits to each site is a useful method for assessment of the detection probabilities and interesting parameters, including determining the ratio of sites occupied by the target species.

Habitats in Bach Ma National Park have been manipulated and transformed, creating metapopulations of species in the entire national park, including the Granular Spiny Frog *Quasipaa verrucospinosa*. This species has been listed in the IUCN Red List as Near Threatened (NT) due to environmental degradation, habitat loss, global climate change, and overexploitation for consumption (Dijk and Swan, 2004). However, little is known about many aspects of the population ecology of *Q. verrucospinosa* in Vietnam and large-scale studies of occupancy models for this species are nonexistent. Information on site occupancy and microhabitat use in *Q. verrucospinosa* in primary and secondary forests of Bach Ma National Park is lacking.

In this study, we estimated site occupancy for *Q. verrucospinosa* in Bach Ma National Park in order to (1) compare occupancy and detection probabilities for two specific habitat types (primary and secondary forests); (2) to obtain an overall estimate of site occupancy for the entire national park; and (3) to determine the number of microhabitat use individuals. We examined the effects of site covariates, including temperature, humidity, and precipitation, on the occupancy and detection of frogs, and tested the hypothesis that differences among habitat typesresult in different levels of detection.

I. MATERIALS AND METHODS

The study area comprised of primary forests (ca. 32.2%; canopy is not fragmented), secondary forests and rehabilitation (54.0%; fragmented canopy), and administrative areas (13.8%; plantations; Hoang and Ngo, 2012; Nguyen et al., 2013). Seven surveys were conducted in primary and secondary forests of Bach Ma National Park during the breeding season of *Q. verrucospinosa*. A total of 77 sampling plots (35 sites in primary forestsand 42 sites in secondary forests)was set up, the area of each site is of 20 × 50 m (1000 m^2). We selected sampling sites that contained water bodies, either a part of a stream or marsh where *Q. verrucospinosa* are commonly active. The distance between two sites is about 300 m apart from each other. No addition, removal, or alteration of plots was made during the entire study period. We considered theprimary andsecondaryforest variables as site covariates to describe habitat occupancy.

We visited and sampled each plot once every two weeks. At night, two people walked slowly with a roughly equal pace along the plot, and visually searched for frogs using spotlights from 19:00 to 02:00 h for 50 m. We searched for *Q. verrucospinosa* in the water where they were visible and reachable, on land up to 10 m away from the stream or the marsh, and on tree trunks and vegetation. We also adopted the auditory survey method (Duellman and Trueb, 1994) of using calls to detect Q. verrucospinosa and to count hidden individuals at each site.

To determine site occupancy, it is necessary to simply record whether an individual is detected "1" or not "0". We estimated the effect of the secondary forest variable (with strong disturbance) on occupancy and detection probability. Using field observations on forest canopy gathered prior to this study, we determined the level of the secondary forest variable at each site, and a covariate of secondary forest was defined as "1" if the site showed evidence of the fragmentation of canopy and "0" otherwise (primary forest). We also recorded air temperature (T), relative humidity (RH), and precipitation (P) at each site for every visit. These variables were considered sample covariates to estimate detection and presence probabilities, respectively. In order to identify microhabitat use of *Q. verrucospinosa*, when a frog was detected, we noted the position of each individual as the following: underwater, terrestrial, or arboreal.

We used the program PRESENCE (Hines, 2006) and single-season occupancy patterns to estimate occupancy and detection probabilities. This pattern assumes that sites or patches were closed to changes in occupancy between the first and last surveys of a given sampling season (i.e., no colonization or extinction events within the sampling season), and detection of the target species at a site is independent of detecting the species at other sites (MacKenzie et al., 2002, 2003). We used the following parameters of interest for the present study: ψ is the probability of a site occupied by *Q. verrucospinosa* and $p_j$is the probability of detecting the species during the j^{th} survey given that it is present. Two models were performed in this study: the first model that assumes that occupancy and detection probabilities with respect to *Q. verrucospinosa* are constant across sites and surveys [denoted $\psi(.)p(.)$] and the second model assumes constant occupancy among sites, but detection probabilities are allowed to vary among seven survey occasions [denoted $\psi(.)p$(survey)].

We used the Akaike Information Criteria for small sample size (AIC_c), the differences in the Akaike Information Criteria for a particular model when compared to the top-ranked model (ΔAIC_c), the AIC model weight (*w*), the number of parameters for each model (*N*), and twice the negative log-likelihood value ($-2l$), to establish the process of model selection (Burnham and Anderson, 2002). All models with AIC differences of < 2 have a substantial level of empirical support and should be considered when making statistical inferences or reporting parameter estimates of thebest models.

We used PRESENCE 3.1 (USGS-Patuxent Wildlife Research Center, Maryland, USA) and SPSS 16.0 (SPSS Inc., Chicago, Illinois, USA) for Windows 7 to analyze the data of microhabitat use, and set the significance level at$P \leq 0.05$ for all analyses. To test the number of individuals using microhabitats and among surveys, we used the one-way analysis of variance (ANOVA). We used theχ^2 tests to examine the significance level between the first model $\psi(.)p(.)$ and the second model $\psi(.)p$(survey) through the seven surveys. We tested the possible effects of climatic factors (air temperature, relative humidity, and precipitation) on the detection of individuals using multiple regression analyses. All data are presented as mean ± 1 SE (unless otherwise noted).

II. RESULTS AND DISCUSSION

The granular spiny frog*Q. verrucospinosa* was detected at least once at 31 of the 77 sites, yielding an overall naïve occupancy estimate of 0.4026, clearly indicating that detection probabilities are less than one. There conceivably can be a number of locations where *Q. verrucospinosa* frogs were present but simply never detected during the seven survey occasions. Our detection-corrected occupancy estimates by a site in the primary and secondary forests of the national park ranged from 0.143-0.714 (average naïve occupancy = 0.35 ± 0.032). The proportion of sites occupied by *Q. verrucospinosa* from the constant model ψ(.)*p*(.) was 0.4331 (SE = 0.0612). The second model assumes that all sites have the same occupancy probability, but that *p* can vary among the seven survey occasions. This is true despite that at each observed occasion, *p* is the same at all sites. The proportion of sites occupied based on the second model of ψ(.)*p*(survey) was 0.4328 (SE = 0.0611).

The estimated occupancy probability is very similar in both models (0.4331 and 0.4328 from the first and secondary models, respectively). When estimating occupancy probabilitiesincluding only the two models [(ψ(.)*p*(.) and ψ(.)*p*(survey)], both models give essentially the same results, and both are about 8% larger than the naïve occupancy estimate suggesting that *Q. verrucospinosa* was never detected at one in every seven surveys. However, we believe that *Q. verrucospinosa* frogs are likely more abundant in primary forest locations than in secondary forest locations (Table 1). The model-averaged estimate of occupancy probability between primary and secondary forest habitat categories was 0.433 (SE = 0.061).

Table 1

Summary of AIC model selection procedure for *Quasipaa verrucospinosa* from 77 sites in the primary and secondary forests of Bach Ma National Park

Model	*K*	AIC_c	ΔAIC_c	*w*	–2*l*	SF_1	±SE
ψ(PF), *p*(sur, temp, humi, rain)	12	322.33	0.00	0.242	300.33	-	-
ψ(PF), *p*(temp, humi, rain)	5	322.45	0.12	0.228	314.45	-	-
ψ(PF), *p*(temp, humi, rain, SF)	6	323.39	1.06	0.143	313.39	-	-
ψ(SF), *p*(temp, humi, rain)	5	324.05	1.72	0.102	314.05	–0.549	0.727
ψ(SF), *p*(sur, temp, humi, rain)	12	324.12	1.79	0.099	300.12	–0.401	0.781
ψ(PF), *p*(sur, temp, humi, rain, SF)	13	324.19	1.86	0.095	300.19	-	-
ψ(SF), *p*(temp, humi, rain, SF)	6	325.36	3.03	0.053	313.36	–0.221	1.141
ψ(SF), *p*(sur, temp, humi, rain, SF)	13	326.06	3.73	0.038	300.06	–0.341	0.910
ψ(SF), *p*(SF)	3	352.95	30.62	0.000	344.95	–0.219	1.562
ψ(PF), *p*(SF)	3	354.83	32.50	0.000	348.83	-	-
ψ(PF), *p*(sur, SF)	10	360.85	38.52	0.000	342.85	-	-
ψ(SF), *p*(sur, SF)	10	362.83	40.50	0.000	342.83	–0.225	1.555
ψ(SF), *p*(.)	3	371.27	48.94	0.000	365.27	–1.929	0.555
ψ(SF), *p*(sur)	9	381.26	58.93	0.000	363.26	–1.928	0.554
ψ(.), *p*(.)	2	383.14	60.81	0.000	379.14	-	-
ψ(.), *p*(survey)	8	393.13	70.80	0.000	377.13	-	-

Notes: *ΔAIC_c is the difference in AIC value for a particular model when compared with the top-ranked model; w is the AIC model weight; K is the number of parameters; –2l is twice the negative log-likelihood value; SF_1 is the value of the coefficient for the secondary forest variable with respect to its effect on occupancy probability); SE is the associated standard error; PF = primary forest; SF = secondary forest; temp = temperature; humi = humidity; rain = rainfall; sur = survey*.

When examining the results in which parameter estimates only have the two models [ψ(.)*p*(.) and ψ(.)*p*(survey)], a difference of 9.99 ΔAIC_c units between these two models [with the AIC weight value of 0.993 in the model ψ(.)*p*(.)] shows that the model ψ(.)*p*(.) is the "best" model. However, the second model [ψ(.)*p*(survey)] still has a reasonable relative level of support (the AIC model weight value of 0.007) and there is further evidence of this second model to pursue inference. We examined a likelihood proportion of the null hypothesis of detection probability being constant and the alternative hypothesis that detection probability differs among the seven survey occasions. The test statistic for this is 379.14 – 377.13 = 2.01 (Table 1), compared to the χ^2distribution with 8 – 2 = 6 degrees of freedom, by the linear interpolation, resulting in a significant level of $P = 0.933$. Thus, there is insufficient evidence to reject the null hypothesis in this study.

Testing the global model (the model with the most parameters) from the candidate set (Table 1), the model ψ(secondary forest)*p*(survey, temperature, humidity, precipitation, secondary forest), does not show any evidence of over-dispersion (weighted $\hat{c}$ = 0.436), indicating insufficient evidence of the poor model fit using 10,000 bootstrap iterations. As a result, the adjustment has been made to the model selection procedure (AIC) and parameter assessments to estimate the details of this parsimonious process of model selection. Individual site estimates of detection probabilities through the seven survey occasions at the primary and secondary forests from the model [ψ(.)*p*(survey)]that is shown in Table 2. Detectability varied among surveys and possibly among sites with previously disturbed and undisturbed histories (Figure 1).

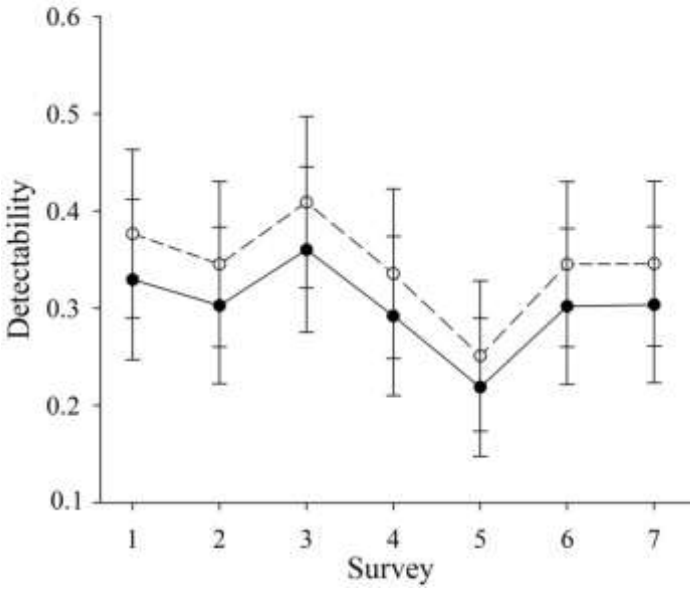

Figure 1: **Estimating the average pattern of detectability across surveys and among sites with different disturbance histories of *Quasipaa verrucospinosa*. Undisturbed habitat (broken line, open circles) and disturbed habitat (solid line, filled circles)**

Our candidate set of models contained the sixteenmodels that ranked according to AIC. There was no single model that was demonstrably better than the others. As a general rule, the six top models are separated by less than 2.0 AIC units, which means that these models have substantial support and should be considered when reporting parameter estimates or making inferences (Table 1). The AIC model weight (*w*) was distributed across a number of models, indicating that a number of models may be reasonable for our collected data. In terms of model weights, the *p*(temperature, humidity, precipitation) models have 90.9% of the total, providing clear evidence that weather condition is an important factor in terms of accurately modelling detection probabilities. In terms of comparing hypotheses, the hypothesis that the detection probability varied among weather conditions, therefore, has much greater support than the hypothesis that it was constant. Many of the top-ranked models also contained the factor "survey" for detection probabilities, providing evidence that the survey occasions differed in their ability to find *Q. verrucospinosa* in the sites; a combined model weight for *p*(survey) models is 43.6% of the total. There was substantially less support for the hypothesis that the level of the secondary forest variable affected detection probabilities for *Q. verrucospinosa*, with a combined model weight of 23.8% (Table 1).

Table 2

Detection probabilities from the model [ψ(.)*p*(survey)] for *Q. verrucospinosa* from 77 sites in primary and secondary forests of Bach Ma National Park.

Survey	Probability	Standard Error	95% Confidence Interval
1	0.362	0.086	0.2150 – 0.5393
2	0.332	0.084	0.1919 – 0.5099
3	0.393	0.087	0.2399 – 0.5696
4	0.321	0.085	0.1794 – 0.5044
5	0.241	0.075	0.1238 – 0.4150
6	0.331	0.084	0.1914 – 0.5092
7	0.331	0.084	0.1914 – 0.5092

The primary forest model ranked first among the set of models that accounted for differences in the survey, temperature, humidity, and precipitation to explain occupancy, and detection probabilities were approximately 2.5 times more likely than the next best model (evidence ratio [Akaike weight of top model/Aikaike weight of second best model] = 2.45). A model including temperature, humidity, and precipitation from primary forest sites ranked secondly among the set of models to explain the probability of occupancy and detectability were about 2.3 times more likely than the next competing model from secondary forest sites (evidence ratio [0.228/0.102] = 2.25).

In terms of occupancy probability, based upon rankings and AIC model weights, the results are somewhat conclusive about the effect of secondary forest sites (28.8%) on the ψ(primary forest) model. The combined weight for the ψ(primary forest) models was 70.8%, and the ψ(secondary forest) models was 20.1% (Table 1). The coefficient value for the secondary forest variable with respect to its effect on occupancy probability, the eight AIC selection models showing the negative SF values (all values $\hat{a}_2 < 0$), indicating certain evidence that the probability of occupancy is higher at the primary forest sites than at the secondary forest sites (Table 1).

In terms of the overall estimate of site occupancy based upon the top-ranked modelψ(secondary forest)*p*(survey, temperature, humidity, precipitation), an average from theestimated occupancy probabilities for the primary forest sites (35 sites) and the secondary forest sites (42 sites), an overall estimate based on the influence of the secondary forest variable was $\{(35 \times 0.6475 + 42 \times 0.5516)/(35 + 42)\} = 0.5952$, with an SE value of 0.114. This is approximately 48% larger than the naïve occupancy estimate (the fraction of sites where *Q. verrucospinosa* was detected) of 0.4026. However, this is about 9% smaller than the occupancy estimate in the "best" model ψ(primary forest)*p*(survey, temperature, humidity, precipitation) of 0.6321 (SE = 0.078). Clearly, accounting for detection probability has increased the estimated level of occupancy as expected.

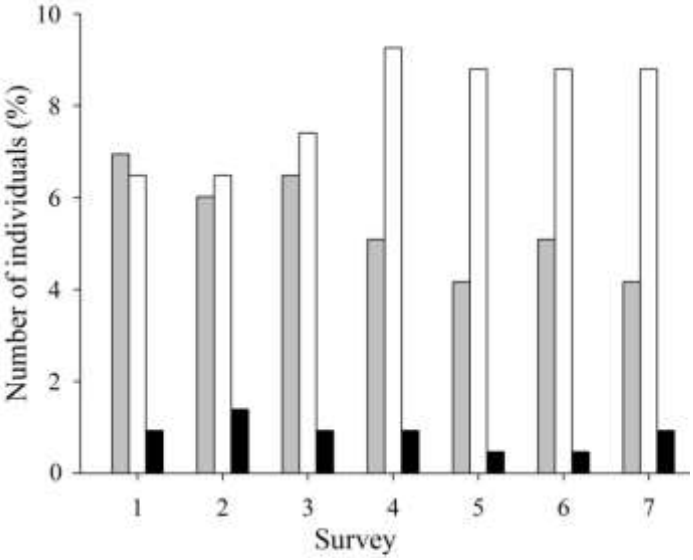

Figure 2: **Microhabitat use in *Quasipaa verrucospinosa* from Bach Ma National Park, central Vietnam. The underwater habitat (gray bars), terrestrial habitat (white bars) and arboreal habitat (black bars)**

An overall estimate of microhabitat use in *Q. verrucospinosa* showed that the number of frogs using the terrestrial habitat (121, 56.0%) was higher than the underwater habitat (82, 38.0%) or the arboreal habitat (13, 6.0%). The number of individuals was significantly different among three habitat types ($F_{2,20}$ = 101.581, P< 0.001; Fig. 2). In total, we found 216 individuals during the seven surveys. The number of individuals was found among seven survey occasions were not significantly different ($F_{6,75}$ = 0.94, P= 0.472). Multiple regression results for possible effects of air temperature, relative humidity, and precipitation on the detectionof individuals were significant among surveys (r^2 = 0.139, $F_{3,251}$ = 27.92, P< 0.001).

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ĐÁNH GIÁ XÁC SUẤT PHÁT HIỆN LOÀI ẾCH GAI SẦN *QUASIPAA VERRUCOSPINOSA* (BOURRET, 1937) Ở VƯỜN QUỐC GIA BẠCH MÃ, TỈNH THỪA THIÊN-HUẾ

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TÓM TẮT

Chúng tôi đã tiến hành đánh giá xác suất phát hiện loài *Quasipaa verrucospinosa* ở quy mô lớn tại Vườn Quốc gia Bạch Mã sử dụng mã hóa dữ liệu phát hiện "1" và không phát hiện "0" đối với mỗi điểm qua nhiều lần khảo sát. Từ mô hình tốt nhất so với các mô hình khác, chúng tôi đã đánh giá được tỷ suất chiếm cứ điểm khi liên kết với các yếu tố ảnh hưởng là 0,632, cao hơn tỷ suất chiếm cứ điểm thuần túy là 0,403 (tăng khoảng 57%). Các khu rừng nguyên sinh là môi trường sống quan trọng của loài *Q. verrucospinosa*. Dưới dạng tầm ảnh hưởng của mô hình AIC thì nhiệt độ, độ ẩm và lượng mưa chiếm 90,9% tầm ảnh hưởng đến xác suất phát hiện loài.