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Original Article

Modeling the Distribution of the Ota's Bent-toed Gecko (*Cyrtodactylus otai*)

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Abstract: The Ota's bent-toed gecko (*Cyrtodactylus otai*) was discovered in isolated karst outcrops of Hang Kia Commune, Mai Chau District, Hoa Binh Province, in 2015 and in Chieng Yen Commune, Van Ho District, Son La Province in 2017, in northwestern Vietnam. This gecko is both an endemic and endangered species of Vietnam, and its known range to date is restricted to a severely fragmented and small regions. Hence, to identify more populations and to better understand the distribution patterns of this cryptic species, we conducted field surveys in surrounding regions of the type localities from 2020 to 2023. We discovered eight new populations for *C. otai*, and expanded the known range of the species in Van Ho District (Son La Province) and Mai Chau District (Hoa Binh Province). We used species occurrence data from previous studies and our field surveys to model the gecko's distribution using MaxEnt. The model results showed that the distribution of *C. otai* may include other nature reserves in surrounding regions, such as Pu Hu and Pu Luong (Thanh Hoa), and Ngoc Son – Ngo Luong (Hoa Binh). Based on the model results, there is a possibility that the Ota's bent-toed gecko also occur in nearby Lao regions. Therefore, future research and conservation initiatives may focus their efforts in such areas to look for new populations of the Ota's bent-toed gecko, as well as to assess the distribution, habitat, and ecological patterns of this poorly known reptile.

Keywords: Cyrtodactylus otai, MaxEnt, Species Distribution Modeling.

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1. Introduction

The Ota's Bent-toed Gecko *Cyrtodactylus otai* Nguyen, Le, Pham, Ngo, Hoang, Pham & Ziegler, 2015, was originally described from Hang Kia Commune, within Hang Kia - Pa Co Nature Reserve (NR), Mai Chau District, Hoa Binh Province, northwestern Vietnam [1]. Two years later this species was also recorded in the neighboring area, Chieng Yen Commune within Xuan Nha NR, Van Ho District, Son La Province, Vietnam [1-2]. This species was found on tree branches, cliffs, or rock crevices in limestone forests (Figure 1) [1-2]. The Ota's Bent-toed Gecko is classified as Endangered in the IUCN Red List (2018) because of habitat destruction and this species has both an extent of occurrence and area of occupancy below 200 km^2 [3].

Figure 1. A female Ota's Bent-toed Gecko, recorded during our field surveys.

Species distribution modeling (SDM) is a method that identifies possible relationships between species occurrences and affecting environmental variables [4], and it has been proven to be helpful in studying population and distribution patterns of elusive and little-known species [5]. SDM can help to uncover distributions for newly discovered species [6], plan nature reserves that incorporate potential effects of climate changes on vulnerable taxa [7], reveal new species lineages whose other common morphological or genetic traits may be

inconclusive [8], and understand effects of important abiotic factors on species distribution [9]. Therefore, many SDM approaches have been developed, and among the most commonly used is Maximum Entropy (MaxEnt) [5, 10]. MaxEnt has been shown to be capable of producing good predictive performance even with a low number of available records, and it can determine hidden interactions between environmental variables [11]. Hence, MaxEnt has been recommended as a standard tool for studying species distribution [10, 12].

In this paper, we collected occurrence records of the Ota's Bent-toed Gecko from previous studies and our field surveys and constructed MaxEnt models to generate a distribution map and help advance understanding and conservation measures for this recently discovered gecko species.

2. Methods

2.1. Field Surveys

Field surveys were conducted at 10 sites in Chieng Xuan, Chieng Yen, Long Luong, and Van Ho communes, Van Ho District, Son La Province; Xuan Nha Commune, Moc Chau District, Son La Province; Cun Pheo, Pa Co, Hang Kia, Thung Khe, and Xam Khe communes, Mai Chau District, Hoa Binh, Province between 2020 and 2023. Individuals were observed between 19:00 and 22:00 h on tree branches, limestone cliffs, or rock crevices, approximately 0.2–3.5 m above the ground, at elevations between 800 and 1250 m a.s.l. with disturbed karst forest of medium/small hardwoods and shrubs on the mountain slope and corn fields in the valleys. For taxonomic identification, a few individuals were collected for morphological analysis and were released at the collecting sites [13].

2.2. Data Pre-processing

Records of the Ota's Bent-toed Gecko from published papers, field reports, and proceedings

were also collated. All records were then integrated and cleaned as suggested by Chapman (2005) [14]. To reduce spatial autocorrelation issues, we used the spThin package [15] in R [16] to thin out localities within five kilometers distance [7]. This created the final set of eight localities as the input data for MaxEnt model. We used 19 bioclimatic variables at 30-arcsec resolution available at the WorldClim 2.1 database [17], and restricted the extent by using a two-degree buffer around the minimum convex polygon of the occurrence localities [18].

2.3. Model Construction and Evaluation

We ran all analyses in MaxEnt version 3.4.4 [5]. We used all feature classes' combinations, and tested a range of regularization multipliers values from 0.5 to 10.0 with increments of 0.5. All other parameters followed recommendations from MaxEnt developers [19]. We then used the jackknife method, recommended for models with a low number of occurrence records, to construct MaxEnt models [20]. To assess model performance and select the optimal one, we used the 10% omission rate threshold to select models that showed the least overfitting. From this set, we then chose the models with the highest Area Under the Curve (AUC) values. The last set of models was then selected based on the Akaike information criterion, which balances complexity with model fitness [21]. For the final model, we used the 10% training presence threshold to classify between suitable and unsuitable areas for the Ota's Bent-toed Gecko [20].

3. Results and Discussions

3.1. New Population Localities Discovery for the Ota's Bent-toed Gecko

The Ota's Bent-toed Gecko was previously known only from type locality in Hang Kia Commune, Mai Chau District, Hoa Binh Province and Chieng Yen Commune, Van Ho District, Son La Province [1-2]. In this study, we discovered additional records of the species in surrounding areas, including Cun Pheo, Thung Khe, Pa Co, and Xam Khe communes, Mai Chau District, Hoa Binh Province; Van Ho, Long Luong and Chieng Xuan communes, Van Ho District; and Xuan Nha Commune, Moc Chau District, Son La Province (Figure 2). The distance from the new records to the type locality ranged from approximately 5 to 40 kilometers.

3.2. Potential Distribution for the Ota's Bent-toed Gecko

For the SDM, MaxEnt models showed reasonable prediction power for the distribution of the Ota's Bent-toed Gecko, with average AUC values > 0.93. The best model had the regularization multiplier value of 2.0 and a combination of linear, quadratic, and hinge feature classes, and AUC value of 0.954. All final models were quite similar in terms of predicting the overall distribution of *C. otai* with only trivial differences in the edge locations of the species.

However, the regularization multiplier value of 2.0 for the optimal model means that the final model was slightly overfitted. The final prediction should therefore be carefully interpreted as "high potential zones", and it may exclude regions that are likely to be suitable for the Ota's Bent-toed Gecko, especially in the edge areas. The total climatically suitable distribution area of the geckos is estimated at about 9,000 km^2; but similar to other bioclimatic-based models, our results do not account for possible human impacts and other biotic interactions on the actual range of *C. otai*. Hence, it is likely to overpredict where human activities are prevalent, and interpretation of the results in such areas should be done with caution.

The current potential distribution range of the Ota's Bent-toed Gecko can be broadly divided into three regions, with one main region around the discovery locations, and two smaller breakaway regions. In particular, the main region is the area around Son La, Hoa Binh, and Thanh Hoa provinces, and comprises protected areas such as Hang Kia – Pa Co and Ngoc Son – Ngo Luong (Hoa Binh Province), Xuan Nha

(Son La Province), and Pu Hu and Pu Luong (Thanh Hoa Province). A small part is found in the northern part, covering parts of Son La and Phu Tho provinces, and is separated from the main part by the Black River.
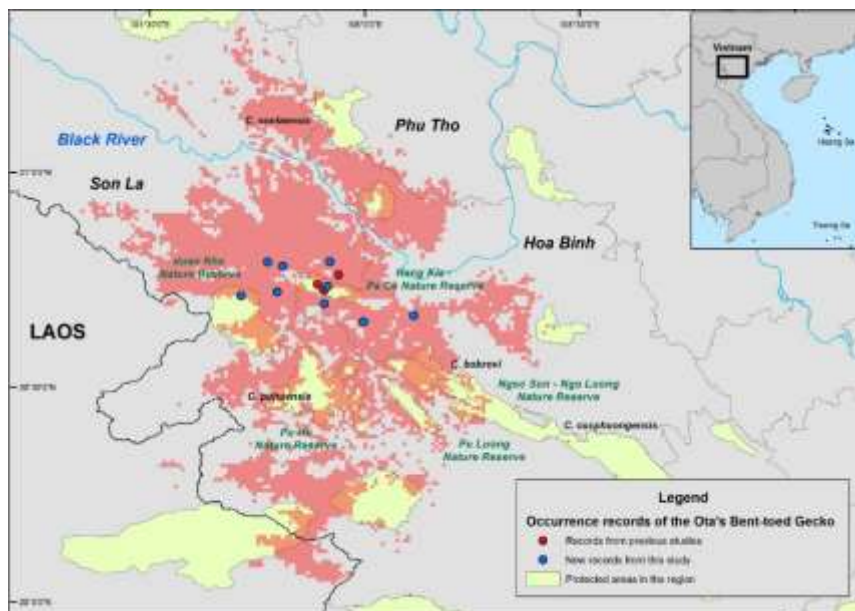

Figure 2. Potential distribution of the Ota's Bent-toed Gecko.

The second breakaway region is in the southern side of the main region, covering part of Thanh Hoa Province. There are no natural barriers and obstacles at the breakaway location, but the transition zone from Pu Hu NR to the second region is also the transition from the karst formation in Hoa Binh – Thanh Hoa to the flatter delta terrain of the Ma River. This region also includes a small part in Laos.

3.3. Discussions

Because our models were based mostly on bioclimatic variables, and did not account for possible biotic interactions, the suitable areas, especially areas near the edge or the breakaways, may even support other closely related species (Figure 2). This phenomenon has also been suggested for other taxa [22].

In our modeling process, we did not include any topographic or hydrologic variables when constructing the models. Despite that fact, our results still showed that the Black River and the karst formation play a significant role as a zoogeographical barrier for the Ota's Bent-toed Gecko (Figure 2). Therefore, the Black River and karst formation in the northern part of Vietnam, besides their geographic impacts, do have other influences on the distributions of herpetofauna. Other studies have proposed that while the Black River, in combination with karst systems, might promote speciation in some species, the ecological divergence in downstream areas could help maintain the species diversification [23-25].

4. Conclusion

In this study, we combined occurrence records of the Ota's Bent-toed Gecko from literature and our field survey data to construct MaxEnt models for the species distribution. The optimal MaxEnt model showed reasonable prediction power with average AUC values > 0.85, and the best model had an AUC value of

0.869. The model results suggest that *C. otai* is mostly distributed in Son La, Hoa Binh, and Thanh Hoa provinces, Vietnam. Therefore, protected areas in these regions, especially those that form a relatively large and semi-continuous forest such as Hang Kia – Pa Co NR (Hoa Binh Province) and Xuan Nha NR (Son La Province), Ngoc Son – Ngo Luong NR (Hoa Binh Province) and Pu Luong and Pu Hu NRs (Thanh Hoa Province), may support important populations of the gecko. Future research and conservation initiatives should focus their efforts on such areas to find new populations of the Ota's Bent-toed Gecko, as well as address the outstanding taxonomic issues of this reptile clade.

Acknowledgements

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