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Research Article

Unveiling the impact of human influence on species distributions in Vietnam: a case study using babblers (Aves: Timaliidae)

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Abstract

As developing countries give priority to economic growth, the effects of development threaten natural habitats and species distributions. Over the course of two decades, Vietnam has rapidly developed, especially in the expansion of agricultural production. However, no study has quantitatively measured the effects of recent human impact on the effects of past species distributions in Vietnam. We use locality data collected from multiple natural history collections, including several in Vietnam, to infer past species distributions. We assess habitat availability of five common babbler species (Aves: Timaliidae) using distribution models with data prior to rapid development that followed political reform. Overlaying the Global Human Influence Index with predicted distributions highlights the human impact on these distributions. Three important patterns emerge: (1) human impact influences common Timaliidae distributions similarly, (2) widespread species distributions show higher fragmentation due to human influence compared to narrowly distributed species in Vietnam, and (3) less than 20% of distributions overlap with nationally declared protected areas. We emphasize that conservation efforts should not only prioritize individual species, but also focus efforts on a regional scale, and that the use of museum data can be highly informative in conservation analyses. There are current obstacles to enforcing conservation of Vietnam's already fragmented habitats, but our results suggest there is still time to reevaluate conservation approaches.

Keywords: babblers; human influence index; Maxent; species distribution modeling; Timaliidae; Vietnam

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Introduction

Vietnam is home to 90 million people while also harboring megadiverse natural habitats for thousands of species. The country's diversity of habitats—from the remnant chain of the Himalayas in the North to the jagged, narrow Central Annamite mountain range that encompasses the Kon Tum Plateau, to the lowlands of the Mekong Delta—explains in part its high species richness and endemism. However, researchers are only recently refocusing attention on the nation's biodiversity after many years of political turmoil. Within the last decade alone, hundreds of species from all taxonomic groups have been discovered, including new and remarkable large mammals such as the saola (*Pseudoryx nghetinhensis*) [1, 2]. As scientists continue to identify new organisms, they are also continuously rediscovering species thought to be extinct for decades. Very recent sightings of species such as the Grey-crowned crocias (*Crocias langbianis*), the Thorel pitcher plant (*Nepenthes thorelii* Lecomte), and the Angel's kikri snake (*Oligodon macrurus)* demonstrate the uncertain status of biodiversity within this country [3–7]. Although these species are threatened by the nation's recent economic growth [8, 9], there is still hope that enough habitat will remain to prevent the extinction of many rare and undiscovered species.

Between 1971 and 1984, there was a drastic decrease in Vietnam's agricultural area, likely caused by the U.S.-Vietnam war that terminated in 1975, followed by rapid urbanization during the recovery from this conflict [10]. However, after the 1986 implementation of *đổi mới* (a series of government economic reforms and strategies), Vietnam became a competitive player in the agricultural world market. In addition to being the third largest global rice exporter, Vietnam also swiftly moved to the top as a major coffee exporter by the year 2000, second only to Brazil [2, 11, 12]. Between 1994 and 2005, agricultural area has doubled and conversion to agriculture is currently the primary cause of deforestation [10, 13]. For example, coffee plantations are largely responsible for a 4.6% decrease in forest cover between 2000 and 2010 in the Central Highlands, which harbor the highest number of endemic species in the country [13]. Vietnam's goal of becoming a competitive player in world markets has thus taken a toll on the nation's valuable natural habitats.

Here, we combine species distribution models with an index of human influence to quantify the impact of rapid environmental change on relatively common, widely distributed species. Our goal is to demonstrate how locality data can be leveraged to quantify threats to common species that are usually not targeted in conservation assessments. If distributions of commonly observed species are fragmented, the impact may be even more severe for those species with narrow and endemic distributions and insufficient data. Using locality data collected prior to rapid economic development, we estimate distributions as they were before the Vietnamese economic boom and demonstrate the value of readily available information in conservation [14, 15]. We also show how human impact measures can help highlight regions in which natural ecosystems have been greatly disrupted for a particular taxonomic group.

We selected species of the Timaliidae family (commonly known as babblers) for this study because these birds are a large, diverse family and are a significant component of Southeast Asian avifauna [2, 16]. Although babblers are widespread throughout Vietnam and the Indochinese Peninsula, they are restricted to forested habitat and are not normally found in croplands. We also analyzed the extent to which the distribution of these babblers lies in protected areas, discussing issues of conservation implementation of particular importance within Vietnam. The methods we apply can readily be deployed to assess threats in other megadiverse developing countries.

Methods

Species and Locality Data

Five Timaliidae species were selected: *Alcippe peracensis* (common name: Mountain Fulvetta; 45 unique localities), *Garrulax chinensis* (Black-throated Laughingthrush; 111), *Garrulax leucolophus* (White-crested Laughingthrush; 287), *Pellorneum albiventre* (Spot-throated Babbler; 49), and *Pomatorhinus ruficollis* (Streak-breasted Scimitar Babbler; 220). All populations are categorized by the IUCN as species of "Least Concern" and are widespread throughout Southeast Asia. Although most have not yet been quantified, populations of these species have been deemed "declining," except for *P. albiventre* and *P. ruficollis,* which are noted as "stable" [17]. Specimen locality data were collected for five species from 15 museums, including five institutions within Vietnam (Access to specimens: American Museum of Natural History [New York, USA], Natural History Museum [Tring, UK], Bombay Natural History Society [Mumbai, India], Field Museum of Natural History [Chicago, USA], Muséum National d'Histoire Naturelle [Paris, France]; Raffles Museum of Biodiversity Research [Singapore]; Nationaal Natuurhistorisch Museum, Naturalis [Leiden, Netherlands]; National Museum of Natural History [Washington, USA], Yale Peabody Museum [New Haven, USA], Zoological Museum Amsterdam, and Vietnam's collections: Institute of Ecological and Biological Resources, Hanoi; University of Sciences, Department of Zoology, Hanoi; University of Forestry, Biodiversity Center, Hanoi; and University of Teachers, Museum of Biology, Hanoi). Presence data consisted of samples collected from 1878 – 1971; these points represent species distributions prior to the rapid industrialization and development of Vietnam. After locality data were georeferenced (locality data and specimen IDs available upon request), duplicate locations were removed. We included all sampling localities throughout Southeast Asia in building species distribution models (SDMs) because of limited presence data for Vietnam.

Habitat Data

Bioclimatic and altitude data for Southeast Asia were downloaded from the WorldClim database [18] at a 2.5' spatial resolution. We performed a principal components analysis with a random sampling of 10,000 points of the multi-layer raster object to identify the most informative, independent bioclimatic predictors for this region. The first four principal components (explaining 99% of the variance; Appendix 1-1) were chosen for use in the species distribution models and included temperature seasonality (BIO4), altitude, annual precipitation (BIO12), and precipitation of the wettest quarter (BIO16). The inclusion of altitude as a variable derives from the extreme topographic variation, from two distinct mountain ranges to the Mekong Delta. Vietnam's distinctive topography and expanse of 16 degrees of latitude allow for the extreme variations in climate and precipitation throughout the country.

Distribution Modeling

Species distribution models were inferred using a maximum entropy approach implemented in Maxent 3.3.3 [19, 20]. This approach is robust to variable sample sizes and performs well compared to other presence-only techniques [21–23]. The default optimization settings were used to construct the SDMs with accuracy evaluated by assessing the area under the curve (AUC) of the receiver-operating characteristic (ROC) plot [19]. To test each model, 20% of the data from each run were selected at random by Maxent and compared to the remaining 80% of the data. Five replicates were carried out to ensure consistency across runs. Finally, cut-off thresholds for areas predicted as 'suitable' and 'unsuitable' were determined according to equated entropy of threshold and non-threshold distributions as provided by Maxent. The distributions were trimmed to show ranges within Vietnam.

Human Impact Influence & Protected Areas

To infer how human impact on the environment affects species distributions, we used the Global Human Influence Index (HII) version 2 (1995-2004) [24]. HII incorporates variables such as human population pressure (population density), human land use and infrastructure (e.g. land use/land cover), and human access (e.g. roads & railroads) and is measured on a scale of 0-64, in which 64 indicates the highest possible human influence. The layer was cropped to the predicted distributions for each species and overlaid onto a map of Vietnam. To determine what area of the predicted species distribution falls within conservation areas, we used the most recent GIS dataset incorporating the national parks and reserves in Vietnam [25] and extracted the percent overlap of distribution with protected areas. We assessed differences in HII score among species distributions using a Wilcoxon Rank Sum test comparing the percent overlap of distribution of each HII score for each species pair.

Results

Niche Modeling Analyses

Similar outputs of each Maxent model for the five species showed that the Temperature Seasonality BIOCLIM variable (BIO4) was the most informative in predicting each species' distribution in the absence of human influence. All predicted distributions were similar to other published ranges of these birds, although the latter are at a rougher scale [26] and show high sensitivity (AUC > 0.95 for all). See Appendix 1-2 Maxent results.

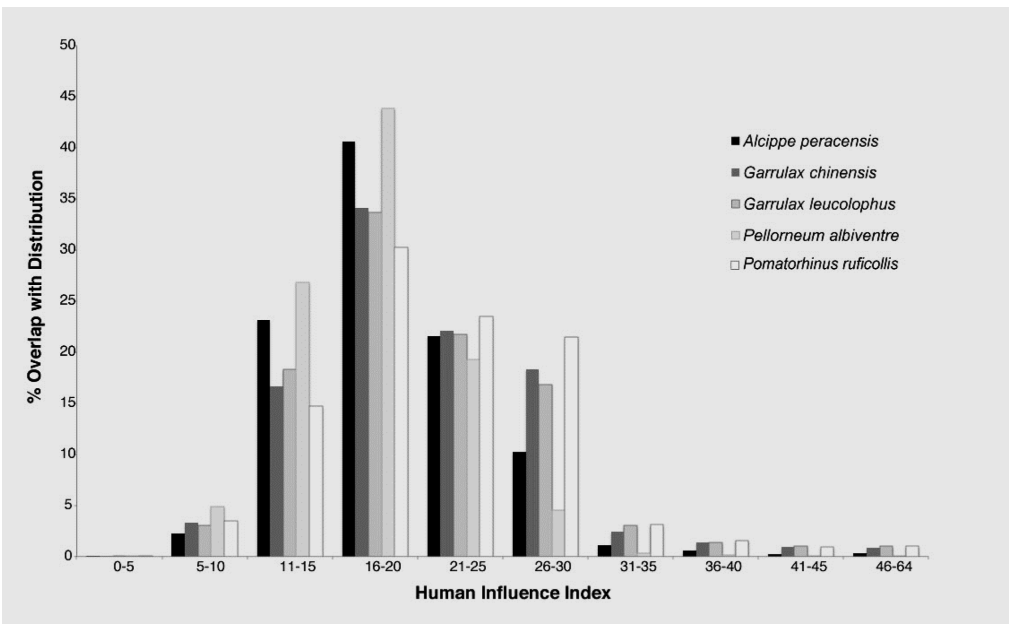

Fig. 1. Percentage of overlap of the predicted distribution of five species of babblers with the Human Influence Index (HII) in Vietnam. The HII is measured on a scale of 0-64, with 64 indicating highest levels of human influence.

Human Influence Analyses

For each of the 5 species distributions, the highest values of predicted species presence overlapped with HII values between 16-20 on a scale of 0-64 (Fig. 1). The percent overlap of distribution with each score of human influence shows a positively skewed pattern in which maximum percentage of distribution overlap for all species falls within human influence levels that are not severe. We then analyzed the percent of species distribution overlap with Vietnam's protected areas and found that there were no distributions that were more than 21% protected (*A. peracensis* 19.0%, *G. chinensis* 14.5%, *G. leucolophus* 14.7%, *P. albiventre* 20.1%, and *P. ruficollis* 14.0%).

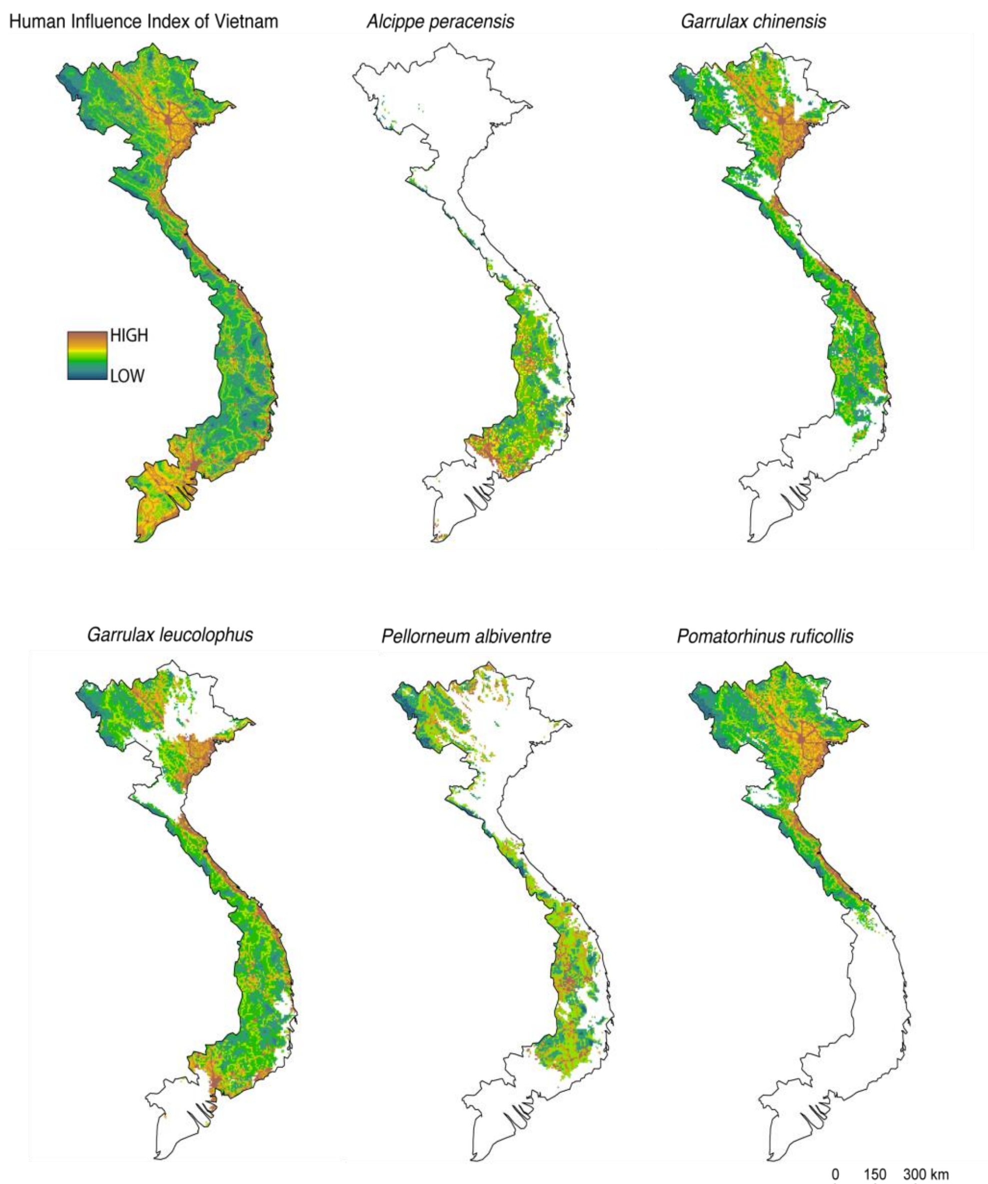

Fig. 2. HII of Vietnam clipped to the distributions of five Timaliidae species.

Results of the differences of each HII overlap with distributions between species (Appendix 1-3) show that the proportion of the distribution of *P. albiventre* overlapping with high HII is significantly less than the other four species. *G. chinensis* and *G. leucolophus* (two widely distributed species) have distributions with large amounts of overlap with high human influence, fragmenting the projected distributions particularly in northern and coastal regions (Fig. 2). *P. ruficollis*, a species widely distributed in Northern regions of Vietnam, has a distribution that is highly fragmented by human influence, particularly in the regions in the northeast corner of the country where the capital city Hanoi is located. *A. peracensis*, a widespread species in the Southern portion of Vietnam, also exhibits a higher overlap with high HII levels than *P. albiventre*. *P.albiventre*, a common species restricted to the western region of the country, has yet to experience high overlap with high levels of human influence.

Discussion

Vietnam is presently faced with the challenge of balancing agricultural and economic development with the preservation of its environment. The present study uses species presence data documented prior to Vietnam's economic reform to identify the degree to which common species of low conservation priority are affected by human influence in Vietnam. Using distributions of common species allowed us to visualize regions of high human impact throughout the country that may highlight areas of high priority for rarer and more vulnerable species, which lack thorough sampling data. We also quantified the proportion of these distributions that are recognized as protected areas. Three important patterns emerge from our analyses: (1) the equivalent effects of human influence on differently distributed species, (2) higher fragmentation of widely distributed species than those that are more narrowly distributed, (3) and only about one-fifth of these estimated distributions are protected.

First, our results show five different species with very different predicted habitat distributions are all currently facing similar human influence indices. Because human influence is affecting biodiversity to similar degrees in different regions of this country, conservation and protected area focus should be on regions of high impact rather than on particular species in Vietnam. Although there are numerous documented successful re-establishments of species that were once endangered, local population diversity (i.e. number of populations) is decreasing a thousand times more rapidly than numbers of species [14, 27]. Distributions of each babbler species in this study are influenced by human activity at levels ranked between 16-20. While these levels may not appear alarming at first, we argue that these results show that now is the time for urgent action. As Vietnam continues to urbanize and expand its agricultural areas, there is a highly probable increase in levels of human influence that overlap with suitable species' habitats. What makes the situation in Vietnam of particular conservation focus is the fact that the development is happening now and action can still be taken.

Additionally, we show that species with widespread distributions are most likely to be affected by human growth and development. For example, *G. chinensis* and *G. leucolophus* have predicted habitat distribution throughout most of the country, and there is a high probability that these species were present within this distribution prior to Vietnam's rapid urbanization. However, the highest level of current human influence overlaps with these widespread species (particularly in the North and along the coast), and it is unlikely that these forested species remain in the high influence areas of these predicted distributions. *P. ruficollis*, a widely distributed bird in montane forests, has a predicted distribution throughout Northern Vietnam, and its range is known to extend northwards into China and the Himalayas. Yet disruption of its distribution by high human influence virtually slices the *P. ruficollis'* range into two fragments in Northern Vietnam. Similarly, *A. peracensis*, a common, widespread species with distribution extending throughout the southern peninsula, shows a higher proportion of its predicted presence overlapping with higher levels of HII.

P. albiventre, however, is predicted to have a much narrower distribution throughout western Vietnam, yet this bird's distribution has less human influence fragmenting its predicted habitat, partly because its range is restricted to areas of high elevation that remain difficult to farm. The low levels of HII within the West central region of Vietnam, particularly Quang Tri province, may also be explained by the excess of unexploded landmines that litter this region, which received the heaviest bombings during the U.S.-Vietnam war [2, 28]. The dangers posed to humans and reduced human access may have allowed flora and fauna to remain unaffected by high human impact [29]. However, these regions can continue to be unaltered only if the landmines do not detonate, which can hardly be seen as a positive influence for biodiversity [28, 29].

Another important finding of our study is that only 14-20% of predicted distributions overlap with protected areas, assuming that the land within these distributions inside protected areas is protected. Although these areas have been deemed "protected," Vietnam's management of national parks and nature reserves is centralized, creating a complex, bureaucratic system of administration in which the managing of the forests often falls into the hands of local and provincial authorities [30]. The effectiveness of these measures within parks and protected areas continues to be compromised by the large number of individuals living legally within the borders of these forests as well as the high levels of agriculture and human activity in close proximity to these regions. Poaching, logging, and resource acquisition from these protected areas are a major issue. Many populations and species abundances throughout Vietnam have declined dramatically since the end of the U.S.-Vietnam war, some even to extinction, due to these pressures [30–32].

Fig. 3. Species of Timaliiade used in this study. Photo credits: Thinh Ba Phung (center); Quang Hao Nguyen (bottom left); Nguyen Hoai Bao (remaining).

Implications for Conservation

A primary benefit from our analysis is the use of museum data to infer human impact on biodiversity. This source of inexpensive and noninvasive data can provide highly informative points of reference in niche-modeling analyses, which are useful in not only conservation studies, but also studies of invasive species, spread of diseases, and community structure and assemblage [33]. These data and methods are applicable to conservation biologists of any developing country, especially as the use of open source museum informatics tools continues to expand. Due to the urgency of conservation analyses for proper policy implementation, the use of existing knowledge found in museums and natural history collections can provide a basic source of information in conservation biology [14, 33] .

As Vietnam continues to grow economically, prompt efforts to protect species' habitats and reduce deforestation must be made or we may face yet another unfortunate case of failing to act in time to protect a region of extraordinary biological diversity (Fig. 3). We urge researchers to continue surveying and documenting species, but to do so in ways that will clearly highlight conservation issues at hand so that policymakers can understand the actions needed [15].Our results also suggest that it is not too late to begin to prioritize and protect Vietnam's exceptional environment with further research using readily available data to develop effective measures of conservation. We argue that patterns in our results are relevant to other developing countries undergoing similar changes, highlighting that a rapid increase in human impact on species distributions is measurable and affects biodiversity similarly.

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Appendix

1-1 Principal components analysis of the BIOCLIM layers showing the standard deviation and the cumulative percentage of the variance held by each respective component.

	σ	Cumulative % Var
[PC1] BIO4: Temperature Seasonality	4952.9	91.8%
[PC2] Altitude	1208.0	97.3%
[PC3] BIO12: Annual Precipitation	785.3	99.6%
[PC4] BIO16: Precipitation of the Wettest Quarter	245.1	99.8%

1-2 Maxent results of species distribution models for five Timaliidae species.

Species	Area under curve (AUC) value
Alcippe peracensis	0.932
Garrulax chinensis	0.933
Garrulax leucolophus	0.885
Pellorneum albiventre	0.963
Pomatorhinus ruficollis	0.892

1-3 Results of Wilcoxon Rank Sum test comparing the overlap of distribution with HII between each species pair. W test-statistic is presented in the top table and p-values are listed in the lower table. Significant results ($p < 0.05$) are highlighted in yellow.

W	*A. peracensis*	*G. chinensis*	*G. leucolophus*	*P. albiventre*	*P. ruficollis*
A. peracensis	1104.5	1052	926	1372	1045
G. chinensis		1104.5	1019	1425.2	112.5
G. leucolophus			1104.5	1550	1204
P. albiventre				1104.5	842.5
P. ruficollis					1104.5

p-value	*A. peracensis*	*G. chinensis*	*G. leucolophus*	*P. albiventre*	*P. ruficollis*
A. peracensis	1	0.694	0.178	0.042	0.655
G. chinensis		1	0.502	0.015	0.901
G. leucolophus			1	0.001	0.454
P. albiventre				1	0.047
P. ruficollis					1