SHORT COMMUNICATIONS

The Condor 109:437–441

POTENTIAL EFFECTS OF CLIMATE CHANGE ON ELEVATIONAL DISTRIBUTIONS OF TROPICAL BIRDS IN SOUTHEAST ASIA

Kelvin S.-H. Peh[1]
School of Geography, University of Leeds, Leeds, LS2 9JT, United Kingdom

Abstract. An analysis of the elevational distributions of Southeast Asian birds over a 28-year period provides evidence for a potential upward shift for 94 common resident species. These species might have shifted their lower, upper, or both lower and upper boundaries toward a higher elevation in response to climate warming. These upward shifts occurred regardless of habitat specificity, further implicating climate warming, in addition to habitat loss, as a potentially important factor affecting the already imperiled biotas of Southeast Asia.

Key words: disturbance, elevational limit, elevational range, global warming, Southeast Asia.

Efectos Potenciales del Cambio Climático en las Distribuciones Altitudinales de Aves Tropicales en el Sudeste de Asia

Resumen. Un análisis de la distribución altitudinal de las aves del sudeste asiático a lo largo de un período de 28 años evidencia un desplazamiento potencial hacia arriba de 94 especies residentes comunes. Estas especies podrían haber desplazado sus límites inferiores, superiores o ambos hacía elevaciones mayores en respuesta al calentamiento climático. Estos desplazamientos hacia arriba se dieron independientemente de la especificidad de hábitat, implicando más aún al calentamiento climático, además de la pérdida de hábitat, como un factor potencialmente importante que afecta a las ya deterioradas biotas del sur de Asia.

A variety of species have recently been observed to have changed their elevational and latitudinal distributions (Grabherr et al. 1994, Parmesan et al. 1999). Many field studies and predictive spatial modeling have provided strong evidence that these range shifts are likely the result of climate warming (Root 1988, Parmesan 1996, Pounds et al. 1999). Current global changes in climate have aroused considerable interest in the distributional patterns of and conservation strategies for native species (Parmesan 1996, Pounds et al. 1999). Recent studies have examined a variety of taxa including plants (Bakkenes et al. 2002), dung beetles (Menendez and Gutiérrez 2004), butterflies (Wilson et al. 2005), amphibians (Pounds et al. 2006), birds (Bohning-Gaese and Lemoine 2004), and mammals (Cameron and Scheel 2001, Thuiller et al. 2006). However, to my knowledge, these studies have been carried out mostly in temperate and Neotropical regions and there has not been a study of the effects of global climate change on species distribution patterns in Southeast Asia.

Southeast Asia has warmed by at least 0.3°C in the past two decades and temperatures are projected to increase by 1.1–4.5°C by the year 2070 (Intergovernmental Panel on Climate Change 2006). There is an urgent need to assess the sensitivity of wildlife communities in this region to climate change. The aim of this paper is to present and discuss the apparent upward extension in the elevational ranges of nearly 100 Southeast Asian bird species as a possible reaction to global climate change. Given the dearth of distributional studies on tropical communities, this paper on elevational range shifts in tropical birds is important because the effects of climate change on tropical species are poorly understood.

METHODS

I compared data from two field guides of Southeast Asian birds that were published 25 years apart (King et al. 1975, Robson 2000) to determine the number of species that had changed their elevational ranges. King et al. (1975) compiled comprehensive information on the distributions of Southeast Asian birds based on official field reports and research papers

---

Manuscript received 27 April 2006; accepted 30 November 2006.

[1] E-mail: geokp@leeds.ac.uk

published prior to 1971. The field guide by Robson (2000) is a follow-up to the original work of King et al. (1975), covering the same region with species distribution information updated through 1999. Both field guides include species from Burma, Cambodia, Laos, peninsular Malaysia, Thailand, and Vietnam, and provide the maximum and minimum limits of elevation for most species. I noted an elevational change only if there was a shift of more than 100 m in one or both of the upper and lower elevational boundaries. I excluded migratory birds from my data analyses.

Since habitat disturbance may be a possible confounding factor (Nair et al. 2003), and to verify that any elevational change in distribution was due to climate warming and not habitat disturbance, I reanalyzed the data excluding species with high habitat specificity (i.e., species restricted to only one habitat type, such as broad-leaved evergreen forest). This method was based on the assumption that species with lower habitat specificity would also be less sensitive to changing land use (Brook et al. 2003) and could maintain their elevational limits by adapting to new habitat types such as second growth.

The sampling methodologies and sample sizes used for the determination of the birds' elevational ranges by King et al. (1975) and Robson (2000) are unknown. Thus, a weakness with the dataset is that it is not clear whether the change in ranges documented by the field guides represents a true change in elevational limits, or simply better biological knowledge. Unless the true ranges of all species were known by 1975, it is not easy to distinguish whether the upward extension of known ranges is due to a genuine expansion into higher areas or simply to birds being sighted in these more inaccessible areas for the first time. To address this problem, as well as controlling for habitat specificity, I restricted the reanalysis to species that are relatively abundant in Southeast Asia, excluding rare and uncommon species. Abundance status followed King et al. (1975) and Robson (2000). Because abundant species were easily observable in Southeast Asia between 1971 and 1999, I make the assumption that they were more commonly seen and thus better studied. Hence, the elevation data obtained from the field guides should be reliable, and the publication bias for these species should be minimal (Møller and Jennions 2001). However, the results should be interpreted in light of these assumptions. I included common but localized species in the analysis in order to not exclude most of the mountain-top endemics. Since species restricted to small areas presumably require less area to be surveyed to document the extent of their ranges, data on common local endemics should not be less reliable than those for more widespread species.

As an independent check on the quality of the field guide data, I compared the distributional information from Robson (2000) against species accounts in the *Handbook of the Birds of the World* volumes 1–5 (del Hoyo et al. 1992, 1994, 1996, 1997, 1999) that do not cite Robson (2000) or King et al. (1975). I used the Wilcoxon matched pairs signed ranks test to determine if the distributional information on lower and upper elevational limits was substantially different between the *Handbook of the Birds of the World* volumes and Robson (2000).

To test if range expansions were associated with an upward extension (i.e., either or both of the upper and lower elevational limits shifted higher), I used the 'goodness-of-fit' χ^2 test with Yates' correction for continuity to compare the number of species that shifted their range boundaries upward or downward. Since native birds may be forced to occupy less disturbed habitats, which in general are found at a greater relative abundance as elevation increases, it was essential to evaluate statistically the proportion of undisturbed habitats in montane versus lowland areas. I used forest cover as a surrogate for undisturbed habitats. Although I did not have detailed information on the forest cover in montane and lowland areas of the Southeast Asian mainland, I compiled forest cover data for 18 Southeast Asian islands (Brooks et al. 1999) and assumed that this was representative of forest loss in the Southeast Asian region. I employed a Mann-Whitney U-test to determine whether montane areas had a higher proportion of undisturbed habitat (i.e., forest cover) than lowland areas. I performed all statistical tests using MINITAB version 13.2 (Minitab 2000).

RESULTS

I analyzed the data on distributional changes over 28 years for the 485 resident bird species for which data for both upper and lower elevational boundaries were available (Table 1). The overall patterns of elevational range changes among the species could be categorized as follows: (1) increase in elevational range (27%); (2) decrease in elevational range (17%); (3) upward shift of both upper and lower boundaries (2%); and (4) stable in elevational range (54%). After habitat specificity and rarity were controlled for, 31% of the 306 species that were relatively common habitat generalists shifted their elevational ranges upward. Eighty-four species (28%) extended their upper elevational limit by 399 ± 263 SD m (range: 105–1525 m), while the lower boundary remained stable (Table 1). Seven species showed an upward shift in their lower elevational limit. Only three species shifted both their upper and lower boundaries upward. The association between the observed elevational range changes and upward shift was highly significant ($\chi^2_1 = 23.9$, $P < 0.01$). Two subsets of 139 and 74 bird species were used for comparing the lower and upper elevational limits, respectively, given in Robson (2000) vs. *Handbook of the Birds of the World*. Elevational limits for these species given in *Handbook of the Birds of the World* were not significantly different from those in Robson (2000; lower limits: $z = -1.3$, $P > 0.05$; upper limits: $z = -1.9$, $P > 0.05$). The mean proportion of undisturbed habitat in montane areas (62%) was significantly greater than that in lowlands (33%; $W = 418.5$, $P < 0.01$).

DISCUSSION

A significant proportion of species that changed their elevational ranges between 1971 and 1999 shifted

TABLE 1. Elevational shifts in upper and lower distributional boundaries of resident Southeast Asian birds over a 28-year period. Changes in elevational limits were determined by comparing distributions in King et al. (1975) and Robson (2000), and the number of species showing each pattern of change is given. Groups likely affected by climate warming are denoted with an asterisk. Common species were those used in a reanalysis that excluded habitat-specific and rare species. Habitat-specific species were defined as species restricted to only one habitat type, and rare species were those with a status of "rare" or "uncommon" in King et al. (1975) and Robson (2000).

Boundary		Number of species		
Upper	Lower	Total	Common	
Upward	Upward	9	3	*
Upward	Stable	112	84	*
Upward	Downward	8	4	
Stable	Upward	16	7	*
Stable	Stable	264	169	
Stable	Downward	10	5	
Downward	Upward	5	2	
Downward	Downward	61	32	
Total		485	306	
Incomplete data		318		

their upper boundaries higher. It is likely that the observed shifts toward higher elevations were in response to climate warming, given that: (1) the shifts coincided with a period of climate warming (Intergovernmental Panel on Climate Change 2006); (2) the cool upper boundaries shifted higher in association with climate warming (Thomas and Lennon 1999); and (3) wide-scale population expansions of Southeast Asian birds are unlikely because they are under constant pressure of habitat loss (Castelletta et al. 2000, Brook et al. 2003, Sodhi et al. 2005) and many have declining populations as a result (Sodhi et al. 2006).

After controlling for habitat specificity and rarity, I still found that 84 species (17% of the species with known elevational ranges) extended their upper boundaries, lending support to the idea that the upward shift in elevation for most species may be primarily associated with climate warming. Further indirect evidence that climate change might be the cause is that although all habitat loss would have occurred on the lower slopes first, only seven species (Mountain Bamboo Partridge [*Bambusicola fytchii*], Blue-throated Barbet [*Megalaima asiatica*], Little Cuckoo Dove [*Macropygia ruficeps*], Grey Treepie [*Dendrocitta formosae*], Lesser Racket-tailed Drongo [*Dicrurus remifer*], Chestnut-bellied Nuthatch [*Sitta castanea*], and Grey-headed Parrotbill [*Paradoxornis gularis*]), after habitat-specificity and rarity were taken into account, shifted their lower distributional boundaries upward while maintaining their uppermost elevational limits.

Additional support is provided by the three common species (Little Forktail [*Enicurus scouleri*], Brown Bush Warbler [*Bradypterus luteoventris*], and Russet Sparrow [*Passer rutilans*]) that shifted both their upper and lower elevational boundaries upward. These species do not exhibit any obvious phylogenetic bias, as they are from different families that include members that were not observed to change their elevational ranges. Their lack of habitat specificity suggests that climate warming was likely one of the main forces driving the shifting of their elevational distributions.

However, direct anthropogenic pressure may also be one of the main drivers of elevational change in distribution. Unprecedented habitat destruction now underway in Southeast Asia may force bird species with high habitat specificity to expand their ranges to occupy less disturbed habitats. While some ranges may be expanding because populations are increasing, others may be expanding due to human pressure, which might cause bird densities in their former ranges to be lowered. Therefore, the species might still be present in lower numbers, resulting in no shift in lower elevational limits, while the majority of individuals are being forced upward and away from direct human pressure. Although montane areas in Southeast Asia have been experiencing extensive degradation (Aldrich et al. 2001), there is a relationship between the extent of degradation and elevation, with lowland areas suffering the worst impacts and the very highest areas suffering the least.

Care should be exercised in the interpretation of my results, because the dataset based on two field guides is potentially subject to biases by the respective authors in how they made their determinations of species ranges. For example, in comparing two highly respected field guides for butterflies of Europe, one can easily see that the earlier field guide by Higgins and Riley (1970) displays consistently larger range sizes for a particular species than the later guide by Tolman and Lewington (1997). This is likely due to a simple difference in criteria for inclusion: Higgins and Riley (1970) included unverified sightings that were published but not necessarily accompanied by a specimen, whereas Tolman and Lewington (1997) required a physical specimen for the site to be included in the range map. Although both Robson (2000) and King et al. (1975) used official field reports and research papers, such analogous differences in data selection may still be expected to exist in the two bird guides. These potential problems with data quality are inherent and cannot be fully addressed (even after the precautionary measure of analyzing the dataset of common species only).

Nevertheless, my analysis of the elevational distribution of Southeast Asian birds over a 28-year period, based on a comparison of two highly respected field guides, shows that 94 common resident species seem to have shifted their lower, upper, or both lower and upper boundaries higher. I suggest that this observation might be in response to climate warming. These upward shifts occurred regardless of habitat specificity, further implicating climate warming as an important causal factor. My findings suggest that climate warming may be yet another important factor affecting the already imperiled biotas of Southeast Asia. Potential effects of climate change (e.g., temperature, rainfall patterns, and seasonality) on tropical ecosystems are largely unknown. Clearly, more research is needed to better understand climate-mediated impacts on tropical biotas, because changes in species distributions and community composition in sensitive ecosystems can lead to extinction (Markham 1998, Anciães and Peterson 2006).

This paper benefited greatly from the comments of Barry W. Brook, Ben King, Cagan H. Sekercioglu, Charlotte A.-M. Yap, David S. Dobkin, Jake Dwyer, Jonathan Eyal, Lian Pin Koh, Navjot S. Sodhi, and Thalia Sachtleben.

LITERATURE CITED

ALDRICH, M., C. BILLINGTON, M. EDWARDS, AND R. LAIDLAW [ONLINE]. 2001. Tropical montane cloud forests: an urgent priority for conservation. World Conservation Monitoring Center Biodiversity Bulletin 2. <http://www.eldis.org/static/DOC4859.htm> (1 April 2006).

ANCIÃES, M., AND A. T. PETERSON. 2006. Climate change effects on Neotropical manakin diversity based on ecological niche modeling. Condor 108: 778–791.

BAKKENES, M., J. R. M. ALKEMADE, F. IHLE, R. LEEMANS, AND J. B. LATOUR. 2002. Assessing effects of forecasted climate change on the diversity and distribution of European higher plants for 2050. Global Change Biology 8: 390–407.

BOHNING-GAESE, K., AND N. LEMOINE. 2004. Importance of climate change for the ranges, communities and conservation of birds. Advances in Ecological Research 35:211–236.

BROOK, B. W., N. S. SODHI, AND P. K. L. NG. 2003. Catastrophic extinctions follow deforestation in Singapore. Nature 24:420–423.

BROOKS, T. M., S. L. PIMM, V. KAPOS, AND C. RAVILIOUS. 1999. Threat from deforestation to montane and lowland birds and mammals in insular South-east Asia. Journal of Animal Ecology 68:1061–1078.

CAMERON, G. N., AND D. SCHEEL. 2001. Getting warmer: effect of global climate change on distribution of rodents in Texas. Journal of Mammalogy 82:652–680.

CASTELLETTA, M., N. S. SODHI, AND R. SUBARAJ. 2000. Heavy extinctions of forest avifauna in Singapore: lessons for biodiversity conservation in Southeast Asia. Conservation Biology 14: 1870–1880.

DEL HOYO, J., A. ELLIOTT, and J. SARGATAL [EDS.]. 1992. Handbook of the birds of the world. Vol 1. Ostrich to ducks. Lynx Edicions, Barcelona.

DEL HOYO, J., A. ELLIOTT, and J. SARGATAL [EDS.]. 1994. Handbook of the birds of the world. Vol 2. New World vultures to guineafowl. Lynx Edicions, Barcelona.

DEL HOYO, J., A. ELLIOTT, and J. SARGATAL [EDS.]. 1996. Handbook of the birds of the world. Vol 3. Hoatzin to auks. Lynx Edicions, Barcelona.

DEL HOYO, J., A. ELLIOTT, and J. SARGATAL [EDS.]. 1997. Handbook of the birds of the world. Vol 4. Sandgrouse to cuckoos. Lynx Edicions, Barcelona.

DEL HOYO, J., A. ELLIOTT, and J. SARGATAL [EDS.]. 1999. Handbook of the birds of the world. Vol 5. Barn-Owls to hummingbirds. Lynx Edicions, Barcelona.

GRABHERR, G., M. GOTTFRIED, AND H. PAULI. 1994. Climate effects on mountain plants. Nature 369:448.

HIGGINS, L. G., AND N. R. RILEY. 1970. A field guide to the butterflies of Britain and Europe. Collins, London.

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE [ONLINE]. 2006. The regional impacts of climate change. <http://www.ipcc.ch> (1 April 2006).

KING, B., M. WOODCOCK, AND E. C. DICKINSON. 1975. A field guide to the birds of South-east Asia. Collins, London.

MARKHAM, A. 1998. Potential impacts of climate change on tropical forest ecosystems. Climatic Change 39:141–143.

MENENDEZ, R., AND D. GUTIÉRREZ. 2004. Shifts in habitat associations of dung beetles in northern Spain: climate change implications. Ecoscience 11:329–337.

MINITAB. 2000. Minitab release 13.2. Minitab, Inc., State College, PA.

MØLLER, A. P., AND M. D. JENNIONS. 2001. Testing and adjusting for publication bias. Trends in Ecology & Evolution 16:580–586.

NAIR, U. S., R. O. LAWTON, R. M. WELCH, AND R. A. PIELKE [ONLINE]. 2003. Impact of land use on Costa Rican tropical montane cloud forests: sensitivity of cumulus cloud field characteristics to lowland deforestation. Journal of Geophysical Research – Atomospheres 108, (D7):Article No. 4206. <http://blue.atmos.colostate.edu/publications/pdf/R-245.pdf> (1 April 2006).

PARMESAN, C. 1996. Climate and species' range. Nature 382:765–766.

PARMESAN, C., N. RYRHOLM, C. STEFANESCU, J. K. HILL, C. D. THOMAS, H. DESCIMON, B. HUNTLEY, L. KAILA, J. KULLBERG, T. TAMMARU, W. J. TENNENT, J. A. THOMAS, AND M. WARREN. 1999. Poleward shifts in geographical ranges of butterfly species associated with regional warming. Nature 399:579–583.

POUNDS, J. A., M. R. BUSTAMANTE, L. A. COLOMA, J. A. CONSUEGRA, M. P. L. FOGDEN, P. N. FOSTER, E. LA MARCA, K. L. MASTERS, A. MERINO-VITERI, R. PUSCHENDORF, S. R. RON, G. A. SANCHEZ-AZOFEIFA, C. J. STILL, AND B. E. YOUNG. 2006. Widespread amphibian extinctions from epidermic disease driven by global warming. Nature 439:161–167.

POUNDS, J. A., M. P. L. FOGDEN, AND J. H. CAMPBELL. 1999. Biological response to climate change on a tropical mountain. Nature 398:611–615.

ROBSON, C. 2000. A guide to the birds of South-east Asia. New Holland, London.

Root, T. 1988. Environmental factors associated with avian distributional boundaries. Journal of Biogeography 15:489–505.

Sodhi, N. S., L. P. Koh, and B. W. Brook. 2006. Southeast Asian birds in peril. Auk 123:275–277.

Sodhi, N. S., M. C. K. Soh, D. M. Prawiradilaga, Darjono, and B. W. Brook. 2005. Persistence of lowland forest birds in a recently logged area in central Java. Bird Conservation International 15:173–191.

Thomas, C. D., and J. J. Lennon. 1999. Birds extend their ranges northwards. Nature 399:13.

Thuiller, W., O. Broennimann, G. Hughes, J. R. M. Alkemade, G. F. Midgley, and F. Corsi. 2006. Vulnerability of African mammals to anthropogenic climate change under conservative land transformation assumptions. Global Change Biology 12:424–440.

Tolman, T., and R. Lewington. 1997. Butterflies of Europe. Princeton University Press, Princeton, NJ.

Wilson, R., D. Gutiérrez, J. Gutiérrez, D. Martinez, R. Aqudo, and V. J. Monserrat. 2005. Changes to the elevational limits and extent of species ranges associated with climate change. Ecology Letters 8:1138–1146.