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Conservation status affects elevational gradient in bird diversity in the Himalaya: A new perspective

Prakash Kumar Paudel [a,b,*], Jan Šipoš [c]

[a] Nepal Academy of Science and Technology, GPO Box 3323, Khumaltar, Lalitpur, Nepal
[b] Center for Conservation Biology, Kathmandu Institute of Applied Sciences, PO Box 23002, Kathmandu, Nepal
[c] Faculty of Science, University of Ostrava, 71000 Ostrava, Czech Republic

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ABSTRACT

Understanding diversity patterns along altitudinal gradients, and their underlying causes are important for conserving biodiversity. Previous studies have focused on climatic, energetic, and geographic variables (e.g., mid-domain effects), with less attention paid to human-induced habitat modifications. We used published data of bird distributions along an elevational gradient (0–4900 m) in the Nepalese Himalaya and interpolated species presence between elevational limits. The relationship between species richness and environmental variables was analyzed using generalized linear models. A low plateau relationship between bird richness and elevation was observed, with a main peak at intermediate elevations (2800 m). Across the total gradient, interpolated bird species richness had a unimodal relationship to maximum monthly precipitation and a linear response to seasonal variation in temperature, proportion of forest cover, and proportion of protected area. In lower elevations (0–2800 m), interpolated species richness had a positive and linear response to the proportion of Ramsar sites and a unimodal response to habitat heterogeneity. At higher elevations (2900–4900 m), interpolated bird richness had a positive linear response to monthly variation in temperature and a negative linear response to proportion forest cover. We conclude that factors related to human management are important drivers of elevational gradients in bird species richness.

1. Introduction

Altitudinal gradients of species diversity have recently been a focus of biogeographical research in the Himalaya. Many such studies have reported a hump-shaped relationship between species richness and elevation, with a peak of species richness at intermediate elevations between 1500 and 3250 m (e.g. Grytnes and Vetaas, 2002; Bhattarai et al., 2004; Bhattarai and Vetaas, 2006; Vetaas and Grytnes, 2002; Grau et al., 2007; Baniya et al., 2010; Acharya et al., 2011). Various hypotheses have been proposed to explain the observed altitudinal richness patterns. One of the most common hypotheses is the mid-domain effect (MDE) (Colwell et al., 2004; McCain and Grytnes, 2010). The MDE suggests that a hump-shaped relationship between species richness and elevation is statistically inevitable when ranges of species are randomly placed within a bounded geographical domain (e.g., "hard boundaries" where mountain tops are the upper boundaries and valley bottoms are the lower boundaries) (Colwell and Lees, 2000). In contrast, environmental factors such as patch size, habitat

* Corresponding author at: Nepal Academy of Science and Technology, GPO Box 3323, Khumaltar, Lalitpur, Nepal. Tel.: +977 1 5547715; fax: +977 1 5547713.
E-mail address: pk.paudel@gmail.com (P.K. Paudel).

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heterogeneity, energy availability, and climatic variability have been proposed as explanations for observed altitudinal gradients in diversity (Rosenzweig, 1995; Körner, 2000; Hawkins et al., 2003). However, no attempt has been made to assess anthropogenic factors (e.g., protected area coverage, human population density, habitat heterogeneity, etc.) that might influence the observed distributional patterns of species richness across large gradients (see Grytnes and Vetaas, 2002; Hawkins et al., 2003; Storch et al., 2003; Bhattarai et al., 2004; Bhattarai and Vetaas, 2006; Grau et al., 2007; Baniya et al., 2010; Acharya et al., 2011; Wu et al., 2013). This is an important area of investigation because no region exists without human influences (Pimm et al., 1995) and high species richness is maintained in many areas by conservation measures such as establishing networks of protected areas (Chown et al., 2003).

Himalayan landscapes have a very high degree of heterogeneity, resulting from high elevational variation (<8848 m) over short distances (<200 km). The cumulative area of each elevational zones decreases with increasing altitude. The species–area relationship (SAR) predicts that as the area of a region increases the number of species will also increase (MacArthur and Wilson, 1967). This may result in having more species at low altitudes and therefore the effect of area must be considered in studies on elevational gradients of species richness (Rahbek, 1997; Brehm et al., 2007). Other non-biological factors such as the MDE have been suggested as important determinants of the species richness along elevational gradients (Colwell and Lees, 2000). However, little research has assessed anthropogenic factors that might relate to elevational gradients of species richness. Here we examine gradient of species richness accounting for possible environmental variables including human influences (e.g., climatic, habitat, energy, conservation practice, human disturbance—see Table 1).

Himalaya is a large mountain arc that extends for 2500 km from the Nanga Parbat mountain (8125 m) and the Indus River Gorge in the northwest to the Namche Barwa mountain (7756 m) and the Yarlungtsangpo–Brahmaputra River Gorge in the east (Ives, 2004). Nepal is situated in the central part of the Himalaya, and occupies about one-third of entire Himalayan range. Nepal has an extreme elevational gradient (67–8848 m) within a short distance (∼200 km) and therefore has received thorough attention from scholars, conservation practitioners and development agency personnel to support or refute conservation theories pertaining to Himalaya (Ives, 2004).

Studies on species richness along elevational gradients of the Nepalese Himalaya have been conducted on ferns (Bhattarai et al., 2004), lichens (Baniya et al., 2010), orchids (Acharya et al., 2011), trees (Bhattarai and Vetaas, 2006) and liverworts (Grau et al., 2007). No studies to our knowledge have compared possible drivers of species richness including human footprint intensity (e.g., human population density) and conservation status (protected areas). Birds are better studied than other taxonomic groups in terms of their habitat preferences and elevational limits (Both et al., 2006). Therefore, we seek to examine diversity patterns of birds along elevational gradients and assess the hypothesis that human actions define patterns of species diversity.

2. Materials and methods

2.1. Study area

The study covers Nepal (26°22′–30°27′N, 80°4′–88°12′E), a mountainous country in the central Himalaya. Physiographic divisions of Nepal are based on the three main mountain ranges, which have average altitudes increasing from south to north (Fig. 1). In the southern part of the Nepalese Himalaya is a flat lowland strip (25–32 km wide) called the Terai (Fig. 1). The physiography of the Terai is similar to the Indo-Gangetic plain and has a tropical climate at 60–300 m elevation. To the north of this flatland, the Siwalik hills rise abruptly to an elevation of 700–1500 m and are characterized by a subtropical climate. These constitute the youngest Himalayan range and are composed of sedimentary rock of Oligocene to Pleistocene ages (Hagen, 1969). North to the Siwaliks is the Mahabharat Range, which rises from 1500 to 2700 m elevation, and is characterized by a subtropical climate in the low altitudes and a temperate climate at higher altitudes. The midlands of Nepal lie north of the Mahabharat range at an average altitude of 2000 m. The Himalayas (3000–8000 m) are north of the midlands and consist of some of the highest peaks in the world (Fig. 1). Nepal alone claims eight out of the top ten tallest mountains in the world, including Mount Everest (8848 m). The Himalayan ranges grade into the Tibetan Plateau to the north, i.e. Trans-Himalayan zone, with a climate and vegetation similar to that of the Tibetan Plateau (Hagen, 1969). Therefore, Nepal provides a unique assemblage of different habitats and a great biodiversity within a small geographical area. It covers slightly less than 0.1% of the global land area but supports a disproportionately large diversity of plants and animals. The country's 118 ecosystems harbor over 2% of the flowering plants, 3% of the pteridophytes, and 6% of the bryophytes in the world's flora. The country also harbors 3.9% of the mammals, 8.9% of the birds, and 3.7% of the world's fauna of butterflies (Paudel et al., 2012).

2.2. Data sources

We used the bird distribution data from 'Birds of Nepal' (Grimmett et al., 2000) and 'The State of Nepal's Birds' (BCN and DNPWC, 2011). These are the most reliable and up-to-date sources and are based on extensive field studies. Altogether 867 birds species are recorded in Nepal (BCN and DNPWC, 2011), some of them are rare and lack detailed information (Carol Inskipp, pers. comm.). 'Birds of Nepal' by Grimmett et al. (2000) provides elevational ranges for 760 species of birds. Most of the rare birds of Nepal are described in the 'The State of Nepal's Bird' (BCN and DNPWC, 2011). Therefore, Grimmett