moisture retention, organic and green farming, vetiver for desert reclamation, natural carbon sinks and a host of other resources, manipulating multiple ecological forces to derive the maximum economic benefits, all hold promise for the nation. Food security will remain a national concern for the next 50 years and beyond.

We have to create proper infrastructure at the grassroots level for teaching science in India. Understanding science by witnessing productively successful application models in biofactories is a strong stimulus for the next-generation teens. 'There is no power for change greater than a child discovering what he or she cares about' stated Seymour Simon, whom the *New York Times* called the Dean of children's science. A rejuvenation of existing undergraduate and postgraduate science education system research is desperately wanting. The need for better training in science in India is urgent[9]. There is a great need to re-examine the structure of undergraduate courses. Curricula and examination systems leave little room for experimentation. The role of research project-based learning in undergraduate science courses needs to be explored in India. This is nearly impossible within the framework of a three-year programme, but would be feasible in a four-year course, bringing bachelor's degrees in science on par with the 'professional courses'[10]. Biology students need to graduate on the field with nature. Let us not look back, but look ahead and command a balance between nature and mankind; exploiting living resources within sustainable limits for the benefit of posterity.

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COMMENTARY

Tropical birds and climate change: lessons from the southern Eastern Ghats

R. J. Ranjit Daniels

Studies that have focused on the response of tropical birds to climate change have cautioned that these birds are more vulnerable than temperate birds[1,2]. Factors that make tropical birds more vulnerable are the overall higher species diversity of communities, smaller geographical ranges and the narrower thermal tolerances of species[2,3]. Tropical birds that live in the higher elevations face what has been described as 'mountain-top extinctions' as their suitable climate space (Grinnellian niche) shifts upslope with rising temperatures[1–3].

Generally, two types of response to climate change have been predicted for birds. One involves species moving up along an elevation gradient[1,2]. The other is dispersal towards higher latitudes[1]. A third pattern of dispersal may be local and across vegetation types. While there is some evidence that such lateral dispersal is possible in the South Indian tropics[4], little has been published on this. In fact, studies of tropical birds and their response to climate change as such have been scarce in the Asian tropics[5].

The hills of southern India may be ideal geographically for understanding the responses of tropical birds to climate change. These hills are believed to have originated at the same time and hence share similar geology[6,7]. However, traditional geographical classification of the Indian land mass has treated them as two distinct entities – the Eastern Ghats and the Western Ghats[8].

Distribution patterns of the birds in the Western Ghats are fairly well known[9]. However, the distribution patterns of birds in the Eastern Ghats are much less understood[10]. As in the Western Ghats, bird communities of the Eastern Ghats may have been shaped by prehistoric climate changes and what we see today as avifauna in these hilly landscapes could be the result of climate-induced dispersal and local extinctions[8,9]. Patchy distribution of some of the endemic birds, including the Malabar Parakeet and Rufous Babbler may lend support to this suggestion.

At a finer scale, habitat use by the birds in parts of the Western Ghats and southern Eastern Ghats has however shown rather opposing trends. In South India, dense forests are generally common in the Western Ghats with occasional patches in the Eastern Ghats. Contrary to predictions, it was observed that in Uttara Kannada (14–15°N; 74–75°E), one of the most forested districts in the Western Ghats, the most dense forests did not have the highest species richness of birds. Open forests and even plantations locally supported comparable or higher bird species richness[11,12]. Historical changes in the avifauna and the human-aided invasion of wide-ranging non-forest birds into the more open forests and associated plantations were identified as the reasons for the anomaly[9,11]. While a similar pattern of habitat use may be expected in the southern Eastern Ghats, a recently concluded

study in Tamil Nadu[4,10] (11–13°N; 77–79°E) reported the opposite; dense forests supported the highest species richness of birds when compared with open forests and associated plantations, or any other terrestrial habitat. What may be the reason? Does the difference in rainfall play a role?

The average rainfall in the Western Ghats is 2500 mm, while the Eastern Ghats of Tamil Nadu receives an annual average rainfall of less than 1000 mm. The southern Eastern Ghats is also warmer than the Western Ghats at comparable latitudes. It therefore seems possible that in drier and warmer landscapes, dense forests serve as refuges for birds and that is why the greatest bird species richness is observed in this habitat[4]. Does this observation offer some clue to what might happen to birds in the event that the South Indian tropics experiences climate warming?

The main difficulty in designing a study to reinforce this observation is that the present distribution pattern of the avifauna is the combined result of prehistoric climate change events and the more recent habitat transformations caused by human beings[8,9]. Examples of climate and human-limited geographical ranges may be seen in birds like the Nilgiri Pipit, a species endemic to the Western Ghats. According to a recent study[13], the range of the Nilgiri Pipit is restricted to elevations above 1900 m amsl. The Nilgiri Pipit was earlier known from elevations as low as 1000 m amsl[14]. The shrinking of the range has been attributed to climate change with a small probability that human-induced changes in its preferred habitat, the high altitude grasslands, may have had some role to play as well[13].

Like the Nilgiri Pipit, there are other endemic birds that are restricted to the higher elevations in the Western Ghats[9,14]. There have, however, been no efforts to analyse whether some of these species have already moved up along the altitudinal gradient and are faced with mountain-top extinction. The fact is that studies focused on high-altitude ecology in the Western Ghats are in general scarce[15].

Climate-induced altitudinal shift in birds of the Western Ghats, when observed in other species and wider areas, may raise an alarming signal. However, the pattern in itself is not different from what has been predicted[1,2]. Local habitat shift in birds as that observed in the drier and warmer Eastern Ghats of Tamil Nadu[4], has not been previously reported and discussed. The observation raises a few more questions.

The first question is whether there would be climate-induced local dispersal of land birds from non-forest habitats to forests? Such dispersal would involve major shifts in habitat use. Observations of habitat use by land birds in the Eastern Ghats of Tamil Nadu suggest that this might happen. For instance, at least 40 species of birds, including the Red-vented Bulbul, Common Iora and Common Tailorbird that are some of the most widespread and common birds in India, were all found using dense forests[10]. These are also the most abundant species in the Eastern Ghats of Tamil Nadu. Whether these invading birds might outcompete the typically forest birds under conditions of climate-induced stress is the other question.

It has been suggested that tropical lowland bird communities may lose their species richness as many of the species shift ranges higher up the elevation gradient in response to climate warming[2]. They may leave a void, as there are no species in the surrounding habitats that might fill the empty niches. This is an unlikely scenario in the South Indian tropics, where there is for most species of forest birds, a closely related non-forest counterpart. Good examples of forest–non-forest species pairs are Orange Minivet and Small Minivet, Nilgiri Flowerpecker and Pale-billed Flowerpecker, Common Indian Wood-shrike and Large Wood-shrike, etc. When birds from the open forests disperse into dense forests, closely related species in non-forest terrestrial habitats may move into the open forests. There is some evidence from the Western Ghats for such local shift in habitat use[11].

Upward dispersal of birds along an altitudinal gradient may be the most likely and inevitable consequence of climate change in the South Indian hills. Local shifts in habitat preference may drive non-forest terrestrial species to find refuge in forests. Thus, forests will be the preferred habitat for a large number of species of land birds under warmer climatic conditions. The importance of tropical forests as refuges for birds during the Pleistocene climate changes has been discussed at length by Haffer[16]. According to him, forest refuges had been of great significance to tropical birds during periods of prolonged dry and warm conditions during the pleistocene[16]. Efforts to increase the forest cover by way of conservation and restoration in the Eastern Ghats and the Western Ghats should be the ideal proactive step towards climate change mitigation in the South Indian tropics.

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