A cross-taxonomic comparison of bird and butterfly communities of Tamhini Wildlife Sanctuary, Maharashtra, India, spanning two decades

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Human disturbance can alter the structure and function of ecological communities. We studied the bird and butterfly communities of Tamhini Wildlife Sanctuary, Maharashtra, India, to understand the effects of changing land use and management in two decades. We replicated a previous study conducted between 1998 and 2001; sampling seven line transects every fortnight between April 2016 and April 2017. Species diversity increased for both taxa, and community composition was significantly different across studies. Generalist species witnessed a maximum increase in diversity, while some specialist guilds declined. While this study is limited in spatial scale, we highlight the effects of local changes in land use and management across trophic levels and the cascading effects on ecosystem function.

Keywords: Conservation management, functional diversity, indicator species, landscape change, wildlife sanctuary.

HABITAT modification and disturbance are major threats to biodiversity in the tropics. Large swaths of land have been converted for monoculture plantations and unsustainable logging practices threaten endemic species in biodiverse regions[1,2]. Large areas of pristine habitats that are required for the maintenance of diversity and ecosystem functioning are now scarce[3]. In the face of these threats, it is imperative that the management practices are dynamic and their efficacy can be monitored continuously.

The structure of ecological communities is determined by the interaction of global as well as local processes, namely speciation, dispersal, selection and drift[4]. Human activities such as converting land for agricultural use, logging and infrastructure development alter these processes resulting in the loss of diversity and, in the long run, the loss of ecosystem services as well[2,3]. Due to the complexity of interactions in ecological communities and the multifaceted nature of human activities, it is difficult to quantify the complete effects of human disturbance in pristine ecosystems[5].

While monitoring ecosystems pose a significant challenge, ecological indicators offer an economical solution. Ecological indicators are species with characteristics (such as sensitivity to pollutants or specific habitat requirements) relevant to monitoring the ecosystem functions of an area[6]. Their use has increased in the past few decades[7]. Indicator species can serve as useful indices for the selection of areas to be conserved and for the effective allocation of management resources[8]. They can also serve as feedback for the adaptive management of protected areas[9].

Monitoring multiple indicator taxa offers a more holistic overview of the effects of disturbance[10]. The efficacy of birds and butterflies as ecological indicators of human disturbance and habitat modification has been well studied[1,11–13]. In addition, the effects of disturbance on these taxa differ due to differences in their ecology. Birds have complex feeding habits and respond to changes in habitat structure. On the other hand, butterflies respond to local-level changes in parameters such as the composition of vegetation[14,15].

There are also considerable differences in the monitoring of community parameters. Measuring changes or differences in diversity can be misleading and responses may vary with the taxon. For example, Hill and Hamer[14] found that butterfly diversity may increase in response to site-level disturbance, whereas bird diversity reduces with increasing local disturbance[14]. Analysing the response of community components such as functional guilds can reveal specific patterns[13]. For example, insectivorous birds were disproportionately affected due to unsustainable logging[16].

The Western Ghats is a biodiversity-rich region threatened by encroachment through activities such as infrastructure development and agriculture[17]. In addition, many people in the region also depend on forest resources and non-timber forest products. The Western Ghats provides vital ecosystem services to much of western India[18,19]. The recently established Tamhini Wildlife Sanctuary (WLS) in the northern Western Ghats (National Green Tribunal of India, 2015)

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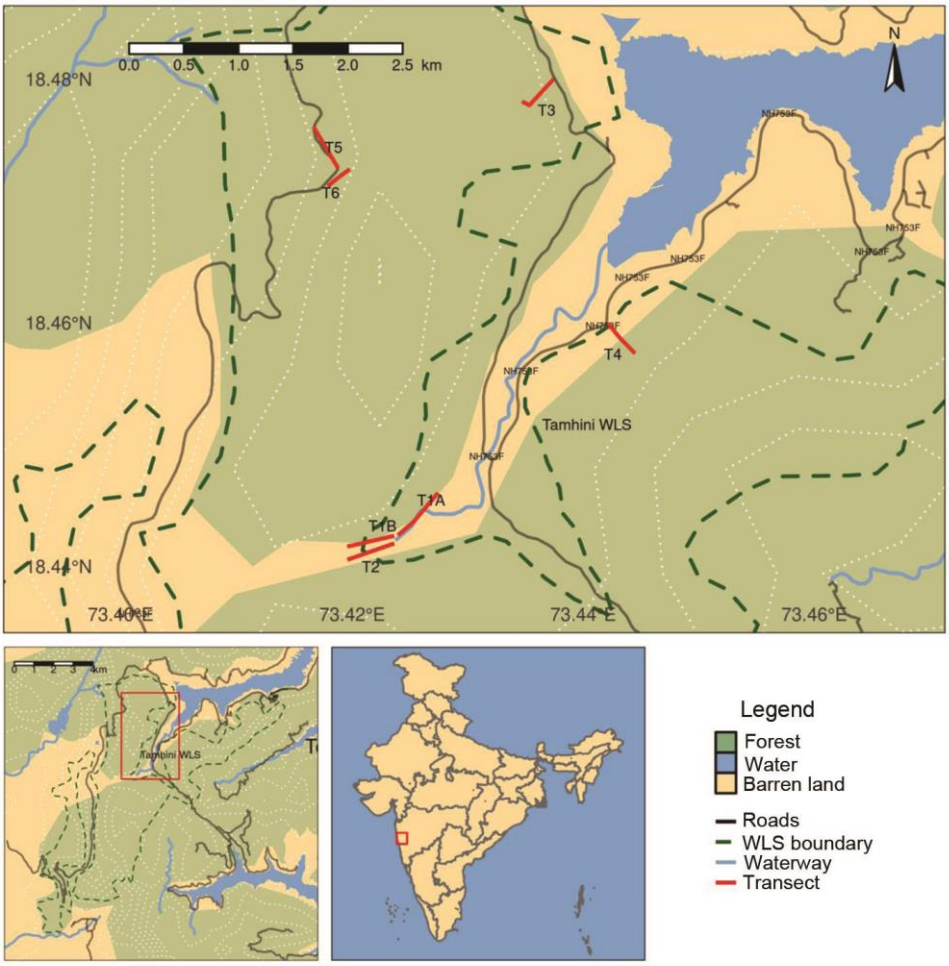

Figure 1. Location of transects (top) laid in the Tamhini Wildlife Sanctuary (WLC; bottom left), situated around 60 km west of Pune in the northern Western Ghats, Maharashtra, India (bottom right). White dotted lines indicate 100 m elevation contours.

has a complex history of protection and management. Despite its protected status, the area is also threatened by encroachment and tourist activities.

We aimed to understand the effects of changing land use and management practices across taxa in Tamhini WLS over two decades. Objectives of the present study were: (a) to compare community shifts (diversity and composition) across indicator taxa at two trophic levels, viz. birds and butterflies, (b) to determine differences in the magnitude of shifts across functional groups within these taxa, and (c) to determine the effect of these shifts on community function.

Materials and methods

Study area

Tamhini WLS (18°27′N, 73°25′E) is situated in the northern Western Ghats around 60 km west of Pune, Maharashtra, India (Figure 1). The area is dominated by hilly terrain and an average elevation of 600 m amsl. A large part of the study area has been modified for human use ranging from farmlands and pastures to resorts and residential complexes[20]. The climate is moderate and tropical most of the year, with heavy to torrential rainfall (5500–6500 mm) during the monsoon season, as is the case with much of the Western Ghats[21]. Mulshi Lake situated in the Sanctuary is a large reservoir fed by the Mula and Neela rivers, which retains water throughout the year, maintaining both favourable temperature and humidity in the area.

Data collection and sampling

We replicated the studies by Padhye *et al.*[22,23] between 1998 and 2001. Seven line transects were laid out throughout the study area identical to the previous studies[22,23]. These represented four habitats, namely riparian, evergreen forest, human habitation and cultivated land, and scrubland and grassland (Figure 1). Transects were sampled every fortnight between April 2016 and April 2017 for a total of 24 visits. Bird and adult butterfly abundances were recorded along each of these transects between 7–11 am and 4–6 pm when the subjects were most active. There was also a chance to encounter crepuscular species[24]. The number of visits and sampling efforts were similar between the present and previous studies[22,23]. Photographs were taken when an additional diagnosis was required. Seasonal changes in land use and vegetation were also recorded incidentally.

Data analysis

We calculated the diversity of both taxa in each site as the effective number of species (D^1)[25] and compared the change in diversity across studies using a linear model with sites as samples. We visualized community composition across studies using non-metric dimensional scaling[26]. We then compared the change in community composition across studies using a permutative analysis of variance test[27,28].

We collected information on host plant species and families of the butterfly species encountered during our survey as well as from a previous study using the HOSTS database of the Natural History Museum, London[29]. We then classified butterfly species into trophic guilds based on host plant habit as grass, herb, liana, shrub, tree specialist or generalist[13,30]. Similarly, we classified birds into guilds based on diet data from the Birds of the World Database[31]. The bird species were classified as carnivores, frugivores, granivores, insectivores and omnivores. We then compared the change in functional diversity across studies using a linear model for each trophic guild in each taxon.

We tested for change in community function by first calculating the habitat specialization index (HSI) for each species of both taxa as

$$\mathrm{HSI} = \frac{\sigma(n_i)}{\bar{n}_i},$$

where n_i is the relative proportion of each species in each habitat. We also computed a trophic specialization index (TSI) for each species as

$$\mathrm{TSI} = \sqrt{\frac{R}{r} - 1},$$

where R is the total number of host plants or prey types used by the r community, and r is the number of host plants or prey types used by a species. We calculated a community specialization index as the mean of the individual species specialization indices at each site[32]. We then compared change in community specialization indices across studies using linear models with sites as samples[33].

The analysis was carried out in *R* version 4.1 (*R* Core Team 2016). The data collected and/or analysed during this study as well as the code for analysis are available at https://github.com/cheesesnakes/tamhini-birds-butterflies.

Results

Species diversity and composition of birds and butterflies

We encountered 105 bird species (n = 2021) and 66 butterfly species (n = 2014) in 2016–17 compared to 70 bird species (n = 1007) and 45 butterfly species (n = 515) during 1998–2001. The species diversity of birds increased significantly compared to 1998–2001 ($D'_{1998–2001} = 17.3 \pm 16.47$, $D'_{2016–17} = 24.88 \pm 5.74$, $\beta = 7.56 \pm 3.38$, $T_{11} = 2.23$, $P = 0.04$, $r^2 = 0.31$). However, the change in butterfly diversity was not significant ($D'_{1998–2001} = 15.87 \pm 3.42$, $D'_{2016–17} = 20.4 \pm 3.24$, $\beta = 4.53 \pm 2.07$, $T_8 = 2.18$, $P = 0.056$, $r^2 = 0.34$) (Figure 2). The species composition of both taxa also changed significantly during the past two decades ($C_{\text{birds}} = 0.55$, $R^2_{\text{birds}} = 0.25$, $p_{\text{birds}} = 0.001$, $C_{\text{butterflies}} = 0.67$, $R^2_{\text{butterflies}} = 0.25$, $p_{\text{butterflies}} = 0.02$) (Figure 3).

Functional diversity of birds and butterflies

The diversity of insectivorous, carnivorous and omnivorous birds increased significantly at Tamhini WLS compared to the previous studies[22,23]. However, the diversity of granivorous and frugivorous birds was not significantly different. It should be noted that the sample size for carnivorous birds was small. Insectivorous birds witnessed the maximum increase in diversity among all bird trophic guilds.

The diversity of grass specialist and generalist butterflies increased significantly. On the other hand, the diversity of herb specialist, shrub specialist and tree specialist species was not significantly different. Generalist butterflies witnessed a maximum increase in diversity. Liana specialists were only encountered in the previous studies and not in the present study (Table 1 and Figure 4)[22,23].

Effect on community function

Neither birds ($\mathrm{CSI}^{\mathrm{T}}_{1998–2001} = 2.58 \pm 0.16$, $\mathrm{CSI}^{\mathrm{T}}_{2016–17} = 2.58 \pm 0.09$, $\beta = -0.05 \pm 0.06$, $T_9 = 0.81$, $P = 0.43$, $r^2 = 0.05$) nor

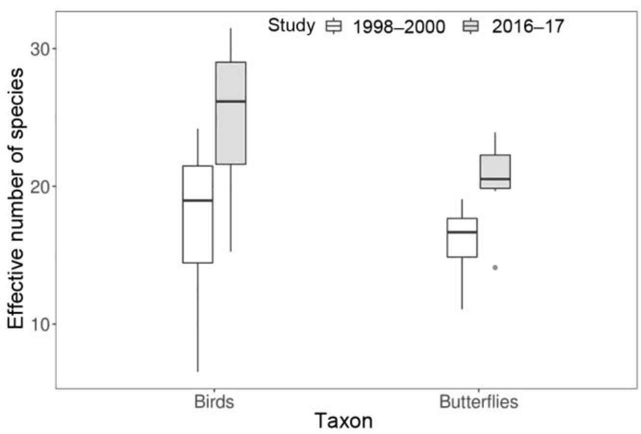

Figure 2. Change in first-order diversity of birds and butterflies in Tamhini WLS between 1998 and 2017.

Table 1. Comparing diversity of trophic guilds in bird and butterfly communities at the Tamhini Wildlife Sanctuary, Maharashtra, India between 1998 and 2017

Taxon	Guild	Study	Estimate (D^1)	SE	T	P	r^2
Birds	Carnivore	1998–2001 (intercept)	3.427	0.048			
		2016–17	2.830	0.085	33.317	1×10^{-10}	0.975
	Frugivore	1998–2001 (intercept)	4.115	0.116			
		2016–17	0.097	0.152	0.637	0.526	0.005
	Grainivore	1998–2001 (intercept)	3.857	0.117			
		2016–17	–0.017	0.185	–0.090	0.929	2×10^{-4}
	Insectivore	1998–2001 (intercept)	8.766	0.680			
		2016–17	4.813	0.863	5.578	3×10^{-7}	0.288
	Omnivore	1998–2001 (intercept)	4.821	0.167			
		2016–17	1.056	0.218	4.842	6×10^{-6}	0.222
Butterflies	Generalist	1998–2001 (intercept)	3.163	0.516			
		2016–17	2.784	0.574	4.851	0.000	0.320
	Grass specialist	1998–2001 (intercept)	1.798	0.273			
		2016–17	0.912	0.292	3.124	0.003	0.204
	Herb specialist	1998–2001 (intercept)	3.581	0.391			
		2016–17	0.511	0.406	1.258	0.214	0.030
	Shrub specialist	1998–2001 (intercept)	4.358	0.441			
		2016–17	–0.178	0.522	–0.341	0.735	0.002
	Tree specialist	1998–2001 (intercept)	5.922	0.413			
		2016–17	0.958	0.493	1.942	0.056	0.053

Summary statics (estimate and standard error) and hypothesis testing values (T statistic, P-value and r^2) are provided in the table.

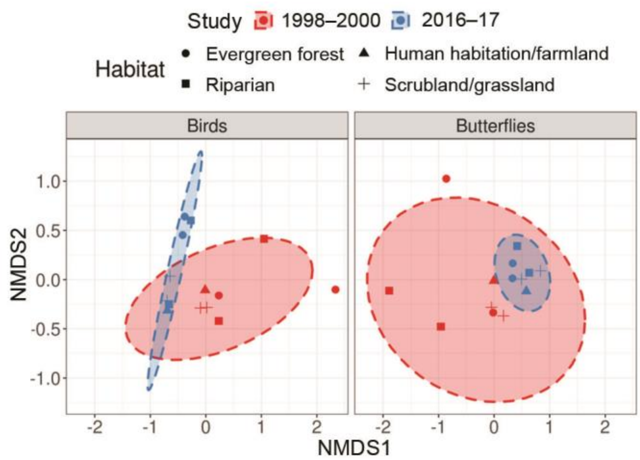

Figure 3. Non-metric dimensional scaling (NMDS) plot depicting change in community composition of birds and butterflies in Tamhini WLS between 1998 and 2017.

butterflies ($CSI^T_{1998–2001} = 5.33 \pm 0.39$, $CSI^T_{2016–17} = 5.06 \pm 0.24$, $\beta = –0.27 \pm 0.17$, $T_9 = 1.57$, $P = 0.14$, $r^2 = 0.17$) showed a significant change in mean trophic niche width. However, butterflies showed a slight trophic niche contraction. Similarly, the degree of community habitat specialization of both bird ($CSI^H_{1998–2001} = 0.54 \pm 0.1$, $CSI^H_{2016–17} = 0.49 \pm 0.02$, $\beta = –0.042 \pm 0.039$, $T_9 = 0.81$, $P = 0.43$, $r^2 = 0.08$) and butterfly ($CSI^H_{1998–2001} = 0.61 \pm 0.09$, $CSI^H_{2016–17} = 0.57 \pm 0.03$, $\beta = –0.041 \pm 0.034$, $T_9 = 1.57$, $P = 0.14$, $r^2 = 0.1$) communities was slightly lower, but not significantly different.

Discussion and conclusion

Tamhini WLS is a biodiversity-rich region, supporting many bird, butterfly, amphibian and reptile species in a relatively small area. Despite its protected status, the WLS is threatened by encroachment[22–34]. The sanctuary also has an interesting history of management interspersed with privately owned land, reserved forest and human habitation. In addition, local people still depend on the remaining forest for firewood and non-timber forest products (pers. obs.).

The comparison of bird and butterfly communities over two decades in the present revealed a significant increase in the diversity of birds and though not significant, an increase in the diversity of butterflies (Figure 2). An increase in diversity does not necessarily indicate that management practices are effective. Different taxa can respond differently to disturbance and these effects vary across spatio-temporal scales[10,33,35]. Both bird and butterfly communities displayed significant turnover when compared across studies (Figure 3). This change in community composition can be attributed to various underlying processes, including changes in land-use patterns, changes in habitat structure, natural cyclic variation and sensitivity of subsets (e.g. functional groups) of the community[5].

When we break down the diversity of these species into functional components, we can observe more fine-scale patterns. Trophic and habitat specialization reduced slightly but not significantly for both taxa. In the case of butterfly communities, we observed a large increase in generalist species diversity compared to more specialist species in the study (Table 1 and Figure 4). Butterflies are sensitive to disturbance at smaller spatial scales, particularly changes to vegetation[15]. Species specializing in specific caterpillar host plants may be disadvantaged in the face of human activities that alter plant communities, such as logging and slash-and-burn agriculture[13], both observed in the study transects. On the other hand, bird communities in Tamhini WLS witnessed a large increase in insectivorous birds and a moderate increase in omnivorous bird species (Table 1 and Figure 4). Habitat modification, such as converting land for agriculture, can result in changes in resource availability and consequent changes in interspecific completion[36]. Thus, species with specific resource requirements may be advantageous in human-modified landscapes[33,37].

The present study is limited in spatial scale and thus the inferences are difficult to generalize beyond the case of Tamhini WLS. In addition, sampling efforts differed among the studies compared. Sampling effort (in terms of the number of individuals sampled) can have a large impact on both alpha and beta diversity, and must be considered when interpreting results (see Supplementary Material). Differences in expertise in identifying the focal taxa may also introduce additional biases. However, the temporal scale of the comparison gave useful insights into how these communities respond to human presence. Future studies may benefit from better spatial replicates and more even sampling

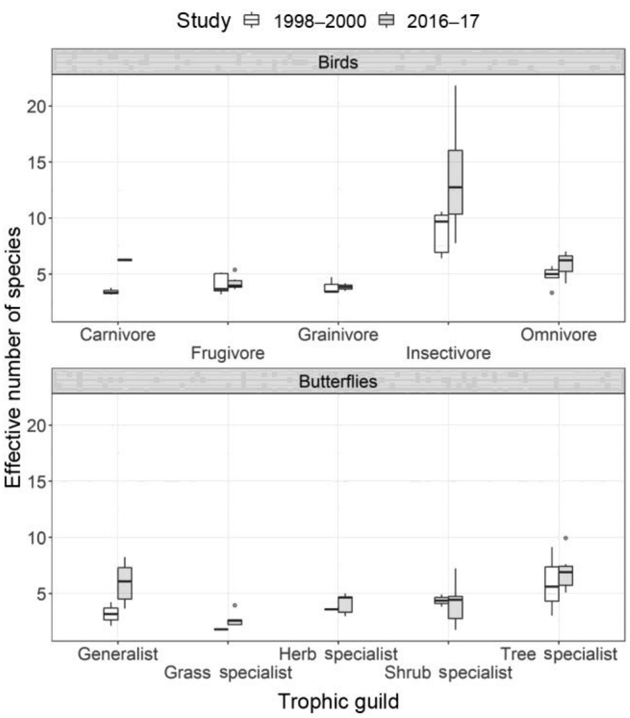

Figure 4. Change in relative proportion of trophic guilds of birds and butterflies in Tamhini WLS between 1998 and 2017. Liana specialist butterflies were encountered only in the present study and not the previous studies[22,23]. In addition, our sample of liana specialists was too small to compute diversity metrics and has thus been excluded from analysis.

efforts to detect effects that we were unable to in the present study.

Despite an apparent increase in diversity at the community level, we observed a shift in functional diversity across both bird and butterfly communities in Tamhini WLS. Such shifts may have implications for community assembly and ecosystem function. Looking beyond species diversity may prove useful for managing biodiverse areas in the Western Ghats, such as Tamhini WLS.

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