Title: A cross taxonomic comparison of bird and butterfly communities of Tamhini Wildlife Sanctuary across two decades.

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Abstract

Human disturbance can alter the structure and function of ecological communities. We studied bird and butterfly communities of Tamhini wildlife sanctuary to understand the effects two decades of changing land use and management. We replicated a previous study conducted between 1998-2001, sampling 7 line transects every fortnight between April 2016 - April 2017. Species diversity increased for both taxa, and community composition was significantly different across studies. Generalist species saw the most increase in diversity while some specialist guilds declined. While our study is limited in spatial scale, we highlight the effects of local changes in land use and management across trophic levels and cascading effects on ecosystem function.

Keywords: Functional Diversity; Landscape Change; Conservation Management; Indicator Species

Introduction

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 hard to come by [3]. In the face of these threats, it is imperative that our management practices are dynamic and that 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 poses a significant challenge, ecological indicators offer an economical solution. Ecological indicators are species that have characteristics (such as sensitivity to pollutants or specific habitat requirements) relevant to monitoring the ecosystem functions of an area [6]. Their use has risen 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 adaptive management of protected areas [9].

47 Monitoring multiple indicator taxa offers a more holistic overview of the effects of disturbance
48 [10]. The efficacy of birds and butterflies as ecological indicators of human disturbance and habitat
49 modification has been well studied (eg. [1,11–13]). In addition, the effects of disturbance on these
50 taxa differ due to differences in their ecology. Birds have complex feeding habits and respond to
51 changes in habitat structure. Butterflies on the other hand respond to local level changes in
52 parameters such as the composition of vegetation [14,15].

53 There are also considerable differences in the monitoring of community parameters. Measuring
54 changes or differences in diversity can be misleading and responses may vary by taxa. For
55 example, Hill and Hammer (2004) found that butterfly diversity may increase in response to site
56 level disturbance, whereas bird diversity reduces with increasing local disturbance [14]. Analyzing
57 the response of components of the community such as functional guilds can reveal specific
58 patterns [13]. For example, insectivorous birds were disproportionately affected due to
59 unsustainable logging [16].

60 The Western Ghats is a biodiversity rich region that is threatened by encroachment through
61 activities such as infrastructure development and agriculture [17]. In addition, many people in the
62 region also depend on forest resources and non-timber forest products. The Western Ghats
63 provide vital ecosystem services to much of western India [18,19]. Tamhini is a recently established
64 wildlife sanctuary in the Northern Western Ghats (National Green Tribunal of India, 2015) that
65 has a complex history of protection and management. Despite its protected status the area is also
66 threatened by encroachment and tourist activities.

67 We aimed to understand the effects of changing land use and management practices across taxa
68 in Tamhini WLS over two decades. In the present study, our objectives were: (a) to compare

69 community shifts (diversity and composition) across indicator taxa at two trophic levels, birds
70 and butterflies, (b) to determine differences in magnitude of shifts across functional groups
71 within these taxa, and (c) to determine the effect of these shifts on community function.

Materials and Methods

Study Area

Tamhini Wildlife Sanctuary (18°27'N, 73°25'E) is situated in the Northern Western Ghats around 60 kms west of Pune, Maharashtra (Figure 1). The area is dominated by hilly terrain and an average elevation of 600m asl. 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 throughout most of the year, with heavy to torrential rains (5500 – 6500 mm) during the monsoons 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 favorable temperatures and humidity in the area.

Data Collection and Sampling

We replicated the studies conducted by Padhye et al. between 1998 and 2001 [22,23]. Seven line transects were laid out throughout the study area (Fig. 1) identical to the previous studies [22,23]. These represented 4 habitats, namely, 1. Riparian, 2. Evergreen Forest, 3. Human Habitation and Cultivated Land and 4. 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 am – 11 am and 4pm – 6pm, when the subjects are most active and there is a chance to encounter even crepuscular species [24]. The number of visits and sampling effort were similar between the current and previous studies. Photographs were taken when 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 effective number of species (D^1) [25]. We 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 change in community composition across studies using a Permutative Analysis of Variance test [27,28].

We collected information on host plant species and families for the butterfly species we encountered during our survey as well as from the 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, or Omnivores. We compared change in functional diversity across studies using 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 $HSI = \frac{\sigma(n_i)}{\bar{n_i}}$, 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 $TSI = \sqrt{\frac{R}{r} - 1}$, where R is the total number of host plants or prey types used by the community and r is the number of host plants or prey types used by a species. We then calculated a community specialization index as the mean of the individual species specialization indices at

each site [32]. We compared change in community specialization indices across studies using linear models with sites as samples [33].

All our analysis was carried out in R version 4.1 (R Core Team 2016). The data collected and/or analyzed during this study as well as the code for analysis is 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 - 2017 compared to 70 bird species (n = 1007) and 45 butterfly species (n = 515) in 1998 – 2001. The species diversity of birds increased significantly compared to 1998 - 2001 ($D^1_{1998\text{-}2001}$ = 17.31 ± 6.47, $D^1_{2016\text{-}2017}$ = 24.88 ± 5.74, β = 7.56 ± 3.38, T_{11} = 2.23, p = 0.04, r^2 = 0.31). However, the change in butterfly diversity was not significant ($D^1_{1998\text{-}2001}$ = 15.87 ± 3.42, $D^1_{2016\text{-}2017}$ = 20.4 ± 3.24, β = 4.53 ± 2.07, T_8 = 2.18, p = 0.056, r^2 = 0.34, Figure 2). The species composition of both taxa also changed significantly over the past two decades (C_{birds} = 0.55, R^2_{birds} = 0.25, p_{birds} = 0.001, $C_{butterflies}$ = 0.67, $R^2_{butterflies}$ = 0.25, $p_{butterflies}$ = 0.02, Figure 3).

Functional diversity of birds and butterflies

The diversity of insectivorous, carnivorous, and omnivorous birds increased significantly at Tamhini WLS when compared to the previous study. However, the diversity of granivorous and frugivorous birds was not significantly different. It should be noted that sample sizes for carnivorous birds was low. Insectivorous birds saw the greatest increase in diversity out of 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 saw the greatest increase in diversity. Liana specialists were only encountered in the previous study and were not encountered in the current study (Table 1, Figure 4).

Effect on community function

Neither birds ($CSI^{T}_{1998\text{-}2001}$ = 2.58 ± 0.16, $CSI^{T}_{2016\text{-}2017}$ = 2.58 ± 0.09, β = -0.05 ± 0.06, T_9 = 0.81, p = 0.43, r^2 = 0.05) nor butterflies ($CSI^{T}_{1998\text{-}2001}$ = 5.33 ± 0.39, $CSI^{T}_{2016\text{-}2017}$ = 5.06 ± 0.24, β = -0.27 ± 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 ($CSI^{H}_{1998\text{-}2001}$ = 0.54 ± 0.1, $CSI^{H}_{2016\text{-}2017}$ = 0.49 ± 0.02, β = -0.042 ± 0.039, T_9 = 0.81, p = 0.43, r^2 = 0.08) and butterfly ($CSI^{H}_{1998\text{-}2001}$ = 0.61 ± 0.09, $CSI^{H}_{2016\text{-}2017}$ = 0.57 ± 0.03, β = -0.041 ± 0.034, T_9 = 1.57, p = 0.14, r^2 = 0.1) communities was slightly lower but not significantly different.

Discussion

Tamhini WLS is a biodiversity rich area, supporting many bird, butterfly, amphibian and reptile species in a relatively small area. Despite its protected status the area is under threat of encroachment [22,23,34]. Tamhini also has an interesting history of management interspersed with privately owned land, reserved forest, and human habitations. In addition, local people still depend on the remaining forests for firewood and non – timber forest products (pers. obs.).

Our comparison of bird and butterfly communities over two decades revealed a significant increase in diversity of birds and though not significant, an increase in the diversity of butterflies as well (Figure 2). An increase in diversity does not necessarily mean 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 a variety of underlying processes including change 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 our study (Table 1, 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 at a disadvantage in the face of human activities that alter plant communities such as logging and slash and burn agriculture [13],

both of which were observed on our transects. On the other hand, bird communities in Tamhini saw a large increase in insectivorous birds in addition to a moderate increase in omnivorous bird species (Table 1, 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 at an advantage in human modified landscapes[33,37].

Our study is limited in spatial scale and thus our inferences are difficult to generalize beyond the case of Tamhini WLS. In addition, sampling effort differed among the studies compared. Sampling effort (in terms of number of individuals sampled) can have a large impact on both alpha and beta diversity and must be kept in mind when interpreting results (see supplementary materials). Differences in expertise in identification of the focal taxa may also introduce additional biases. However, the temporal scale of our comparison reveals useful insights into how these communities respond to human presence. Future studies may benefit from better spatial replicates and more even sampling effort to detect effects that we were not able to in the current 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 the management of biodiverse areas in the Western Ghats such as Tamhini WLS.

Acknowledgments

We'd like to thank the Department of Biodiversity, Abasaheb Garware College, Pune for their help and mentorship. We thank Dr. Kartik Shanker for his comments on the manuscript. We extend our appreciation to Tarun Menon, Anand Pendharkar, Rahul Pungaliya and all others who offered their help in the form of ideas and support. We also thank all those who helped SD in data collection including but not limited to Akshay Marathe, Aseem Shendye, Tarun Menon, Srushti Bhave, Vishal Varma and Pranav Mehsalkar.

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Tables

Table 1: Comparing diversity of trophic guilds in bird and butterfly communities at Tamhini WLS between 1998 and 2017.

Taxa	Guild	Study	Estimate (D^1)	SE	T	p	r^2
Birds	Carnivore	1998 - 2001 (Intercept)	3.427	0.048			
		2016 - 2017	2.830	0.085	33.317	1×10^{-10}	0.975
	Frugivore	1998 - 2001 (Intercept)	4.115	0.116			
		2016 - 2017	0.097	0.152	0.637	0.526	0.005
	Grainivore	1998 - 2001 (Intercept)	3.857	0.117			
		2016 - 2017	-0.017	0.185	-0.090	0.929	2×10^{-4}
	Insectivore	1998 - 2001 (Intercept)	8.766	0.680			
		2016 - 2017	4.813	0.863	5.578	3×10^{-7}	0.288
	Omnivore	1998 - 2001 (Intercept)	4.821	0.167			
		2016 - 2017	1.056	0.218	4.842	6×10^{-6}	0.222
Butterflies	Generalist	1998 - 2001 (Intercept)	3.163	0.516			
		2016 - 2017	2.784	0.574	4.851	0.000	0.320
	Grass Specialist	1998 - 2001 (Intercept)	1.798	0.273			
		2016 - 2017	0.912	0.292	3.124	0.003	0.204
	Herb Specialist	1998 - 2001 (Intercept)	3.581	0.391			
		2016 - 2017	0.511	0.406	1.258	0.214	0.030

	Shrub Specialist	1998 - 2001 (Intercept)	4.358	0.441			
		2016 - 2017	-0.178	0.522	-0.341	0.735	0.002
	Tree Specialist	1998 - 2001 (Intercept)	5.922	0.413			
		2016 - 2017	0.958	0.493	1.942	0.056	0.053

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Figure legends

Figure 1: Location of transects (top) laid in Tamhini Wildlife Sanctuary (bottom left), situated around 60k west of Pune in the Northern Western Ghats (bottom center). White dotted lines indicate 100m elevation contours.

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

Figure 3: NMDS plot depicting change in community composition of bird and butterflies in Tamhini WLS between 1998 and 2017.

Figure 4: Change in relative proportion trophic guilds of birds and butterflies in Tamhini WLS between 1998 and 2017.

Figures

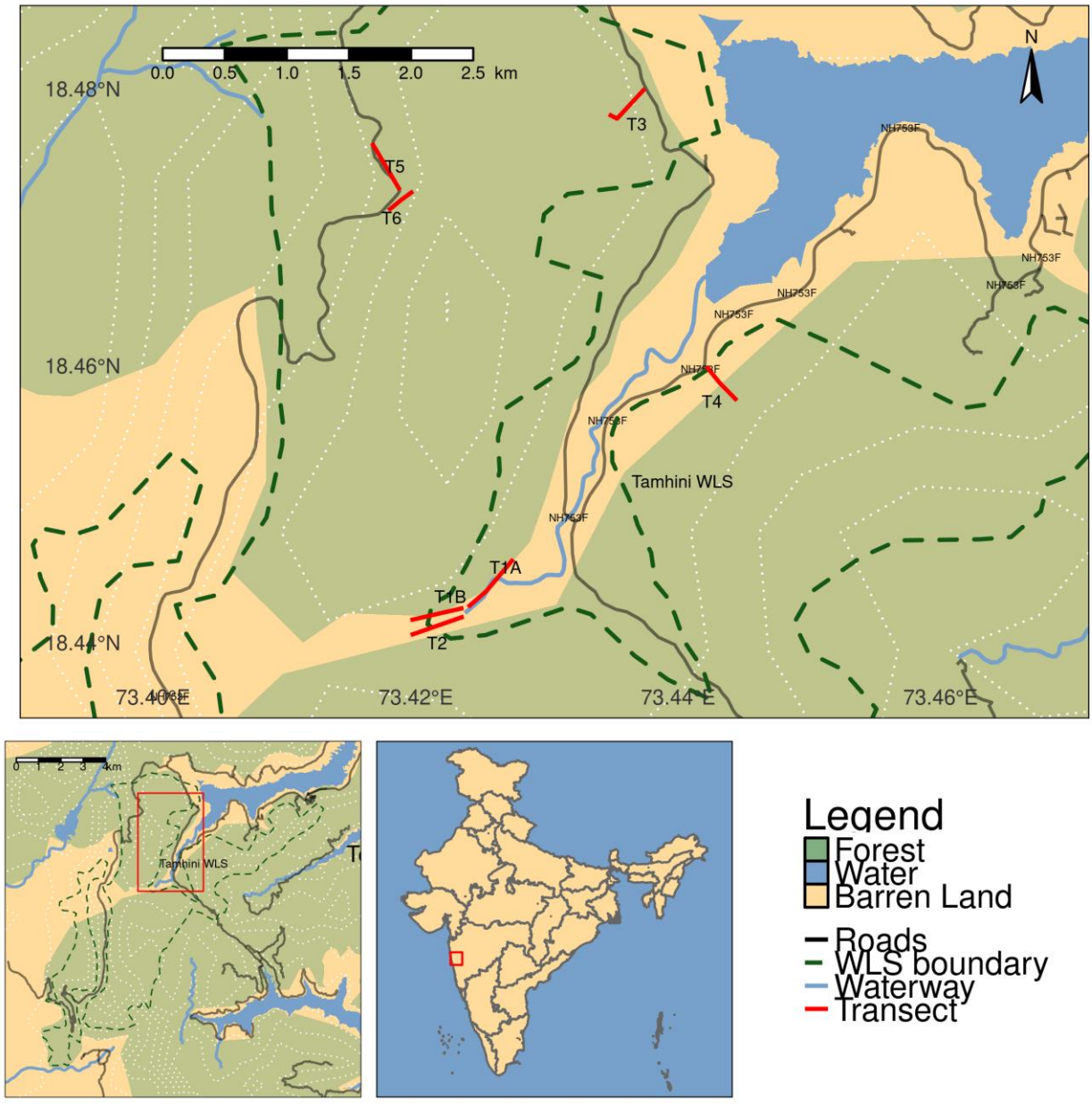


Figure 1: Location of transects (top) laid in Tamhini Wildlife Sanctuary (bottom left), situated around 60k west of Pune in the Northern Western Ghats (bottom center). White dotted lines indicate 100m elevation contours.

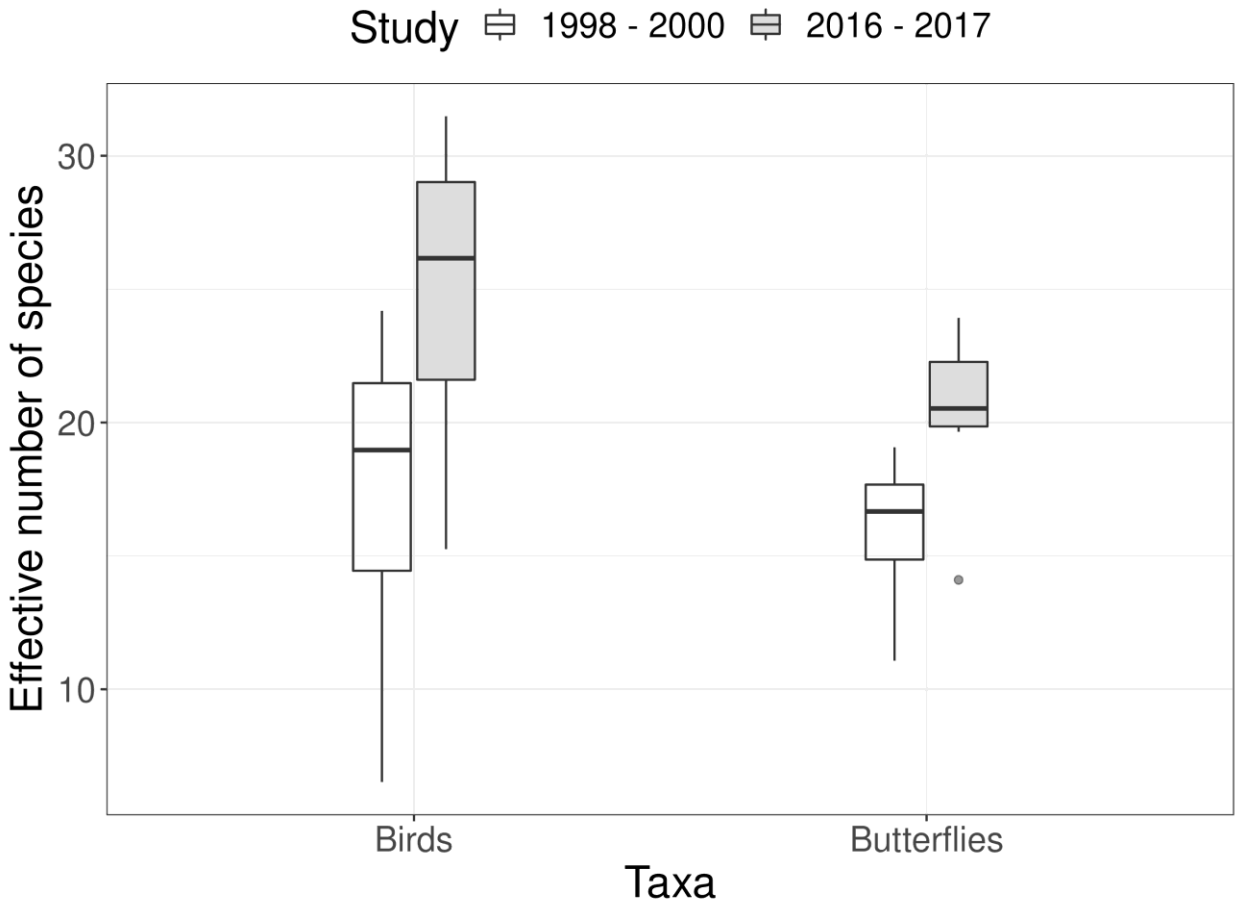
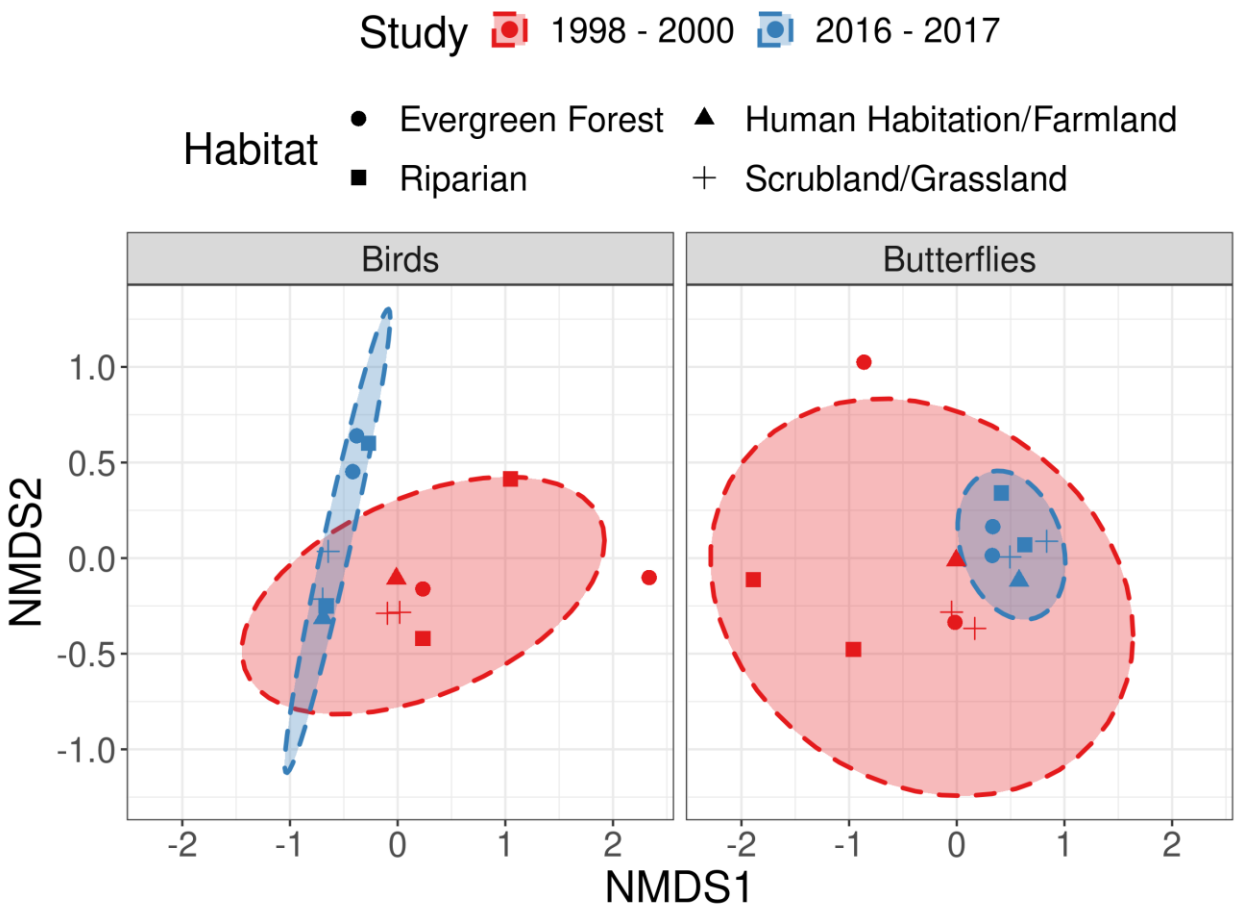


Figure 2: Change in first order diversity of bird and butterflies in Tamhini WLS between 1998 and 2017.



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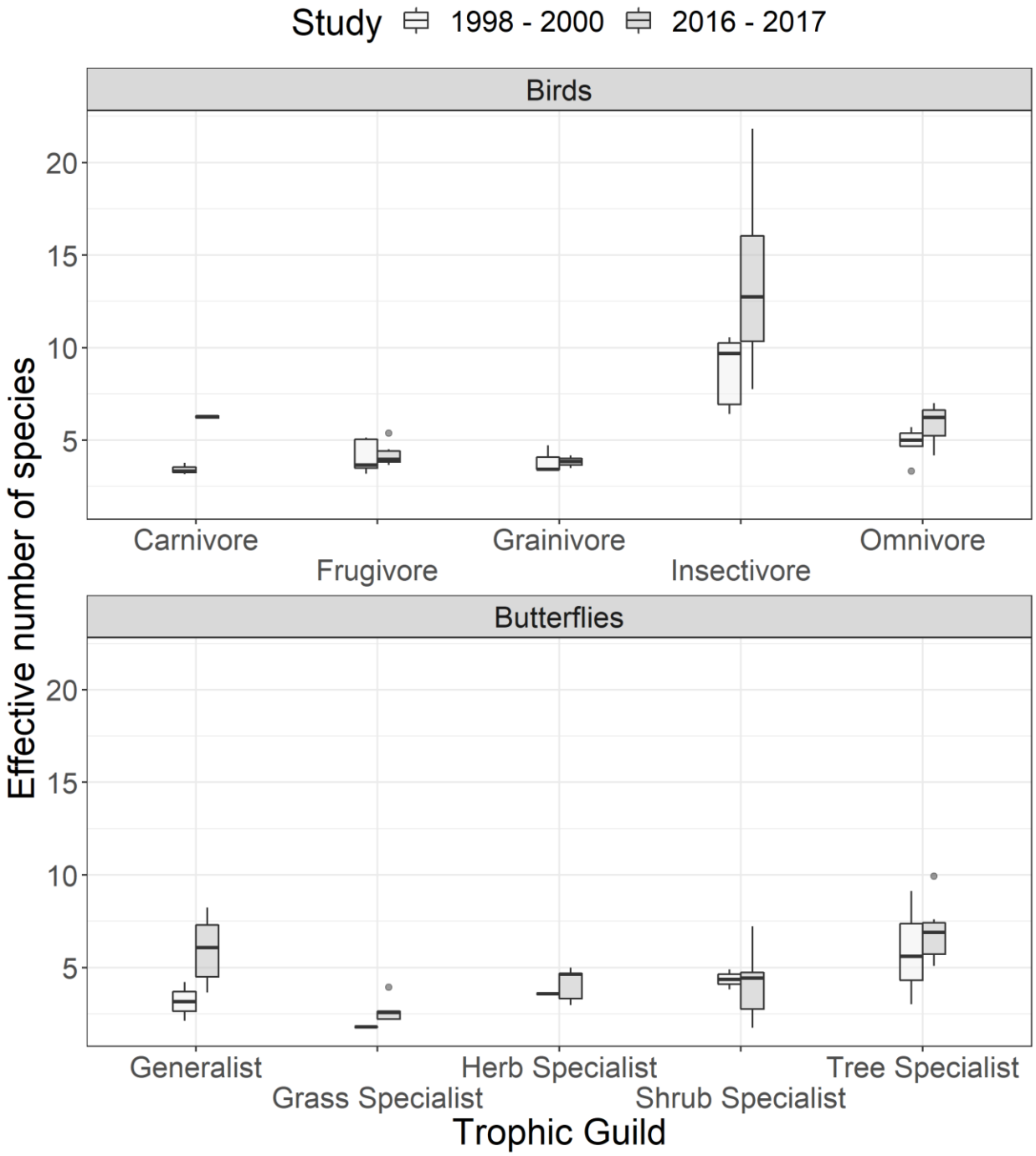
225 Figure 3: NMDS plot depicting change in community composition of bird and butterflies in

226 Tamhini WLS between 1998 and 2017.



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228 Figure 4: Change in relative proportion trophic guilds of birds and butterflies in Tamhini WLS

229 between 1998 and 2017. Liana specialist butterflies were only encountered in the current study

and not the previous study. In addition, our sample of liana specialists was too small to compute diversity metrics and have thus been excluded from the figure and analysis.

Supplementary Materials

Table A: Number of birds and butterflies (individuals) sampled in 1998 – 2000 and 2016 – 2017. (T = Transect)

Study	**Taxa**	**T1A**	**T1B**	**T2**	**T3**	**T4**	**T5**	**T6**
1998 - 2000	Birds	255	165	103	213	236	7	28
1998 - 2000	Butterflies	93	59	12	180	157	10	4
2016 - 2017	Birds	480	393	358	289	165	203	133
2016 - 2017	Butterflies	432	188	207	652	187	224	124

Table B: List of sites sampled with habitat attributes.

Site	Habitat	Start	Start	End	End
T1A	Human Habitation/Farmland	18.446017	73.427433	18.442553	73.423978
T1B	Scrubland/Grassland	18.442493	73.423636	18.441612	73.419593
T2	Riparian	18.440535	73.419611	18.441869	73.42365
T3	Scrubland/Grassland	18.48002	73.437459	18.477847	73.435341
T4	Evergreen Forest	18.459945	73.442139	18.457477	73.444475
T5	Evergreen Forest	18.472681	73.418793	18.476085	73.416667
T6	Riparian	18.471213	73.417911	18.472598	73.419794

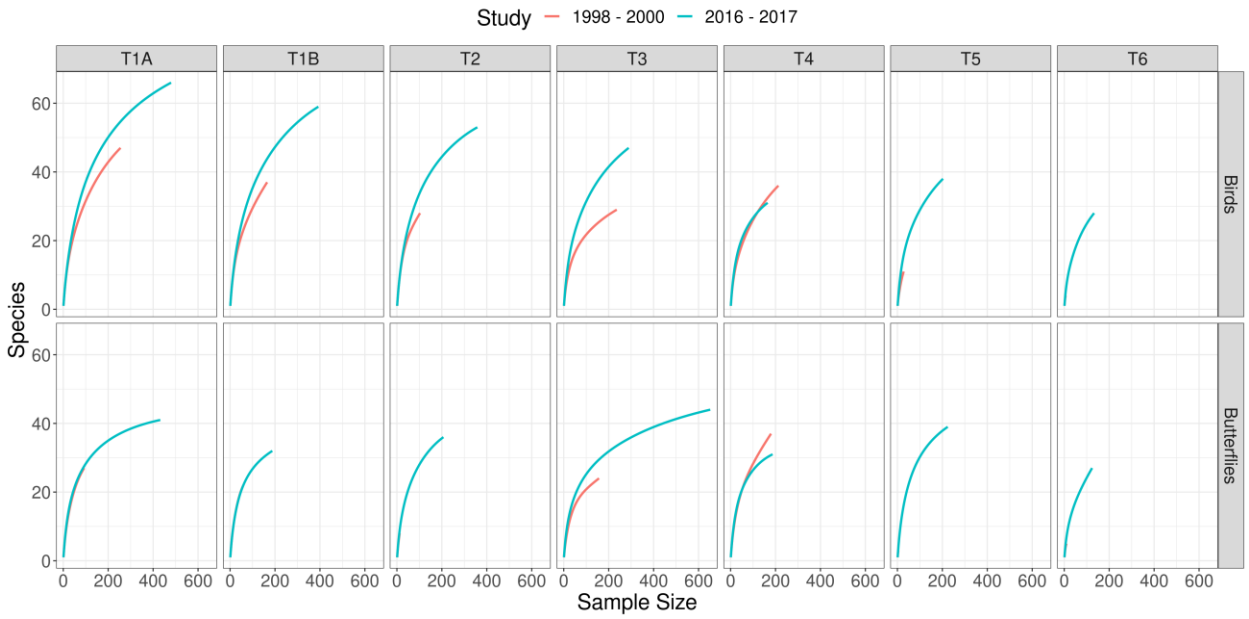

Figure A: Rarefaction curves indicating differences in sampling effort across studies by site.