1 **Title:** A cross taxonomic comparison of bird and butterfly communities of Tamhini Wildlife

2 Sanctuary across two decades.

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15 **Abstract**

16 Human disturbance can alter the structure and function of ecological communities. We studied

17 bird and butterfly communities of Tamhini wildlife sanctuary to understand the effects two

18 decades of changing land use and management. We replicated a previous study conducted

19 between 1998 and 2001, sampling 7 line transects every fortnight between April 2016 and April

20 2017. We analyzed the diversity and structure of functional groups and compared our findings to

21 previous surveys. Species diversity increased for both taxa, however, community composition

22 was significantly different across studies. Changing land may affect multiple trophic levels and

23 alter community assembly and ecosystem function.

24 **Keywords:** Functional Diversity; Landscape Change; Conservation Management; Indicator

25 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 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 ecological 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].

3

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

4

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.

72 **Materials and Methods**

73 *Study Area*

74 Tamhini Wildlife Sanctuary (18°27'N, 73°25'E) is situated in the Northern Western Ghats

75 around 60 kms west of Pune, Maharashtra (Figure 1). The area is dominated by hilly terrain and

76 an average elevation of 600m asl. A large part of the study area has been modified for human use

77 ranging from, farmlands and pastures to resorts and residential complexes [20]. The climate is

78 moderate and tropical throughout most of the year, with heavy to torrential rains (5500 – 6500

79 mm) during the monsoons as is the case with much of the Western Ghats [21]. Mulshi Lake,

80 situated in the sanctuary is a large reservoir fed by the Mula and Neela rivers, which retains

81 water throughout the year, maintaining both favorable temperatures and humidity in the area.

82 *Data Collection and Sampling*

83 We replicated the studies conducted by Padhye et al. between 1998 and 2001 [22,23]. Seven line

84 transects were laid out throughout the study area (Fig. 1) identical to the previous studies [22,23].

85 These represented 4 habitats, namely, 1. Riparian, 2. Evergreen Forest, 3. Human Habitation and

86 Cultivated Land and 4. Scrubland and Grassland (Figure 1). Transects were sampled every

87 fortnight between April 2016 and April 2017, for a total of 24 visits. Bird and adult butterfly

88 abundances were recorded along each of these transects between 7 am – 11 am and 4pm – 6pm,

89 when the subjects are most active and there is a chance to encounter even crepuscular species [24].

90 The number of visits and sampling effort were similar between the current and previous studies.

91 Photographs were taken when additional diagnosis was required. Seasonal changes in land use

92 and vegetation were also recorded incidentally.

93   *Data Analysis*

94   We calculated the diversity of both taxa in each site as effective number of species (D^1) [25]. We

95   compared the change in diversity across studies using a linear model with sites as samples. We

96   visualized community composition across studies using Non-metric dimensional scaling [26]. We

97   then compared change in community composition across studies using a Permutative Analysis of

98   Variance test [27,28].

99   We collected information on host plant species and families for the butterfly species we

100   encountered during our survey as well as from the previous study using the HOSTS database of

101   the Natural History Museum, London [29]. We then classified butterfly species into trophic guilds

102   based on host plant habit as Grass, Herb, Liana, Shrub, Tree Specialist or Generalist [13,30].

103   Similarly, we classified birds into guilds based on diet data from the Birds of the World Database

104   [31]. The bird species were classified as Carnivores, Frugivores, Granivores, Insectivores, or

105   Omnivores. We compared change in functional diversity across studies using linear model for

106   each trophic guild in each taxon.

107   We tested for change in community function by first calculating the habitat specialization index

108   (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

109   species in each habitat. We also computed a trophic specialization index (TSI) for each species

110   as $TSI = \sqrt{\frac{R}{r} - 1}$, where R is the total number of host plants or prey types used by the

111   community and r is the number of host plants or prey types used by a species. We then calculated

112   a community specialization index as the mean of the individual species specialization indices at

7

113   each site [32]. We compared change in community specialization indices across studies using linear

114   models with sites as samples [33].

115   All our analysis was carried out in R version 4.1 (R Core Team 2016). The data collected and/or

116   analyzed   during   this   study   as   well   as   the   code   for   analysis   is   available   at

117   https://github.com/cheesesnakes/tamhini-birds-butterflies.

8

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 ($D^1_{1998-2001}$ = 17.31 ± 6.47, $D^1_{2016-2017}$ = 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 ($D^1_{1998-2001}$ = 15.87 ± 3.42, $D^1_{2016-2017}$ = 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).

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139   *Effect on community function*

140   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,

141   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 = -

142   0.27 ± 0.17, T_9 = 1.57, p = 0.14, r^2 = 0.17) showed a significant change in mean trophic niche

143   width. However, butterflies showed a slight trophic niche contraction. Similarly, the degree of

144   community habitat specialization of both bird ($CSI^H_{1998\text{-}2001}$ = 0.54 ± 0.1, $CSI^H_{2016\text{-}2017}$ = 0.49 ±

145   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,

146    $CSI^H_{2016\text{-}2017}$ = 0.57 ± 0.03, β = -0.041 ± 0.034, T_9 = 1.57, p = 0.14, r^2 = 0.1) communities was

147   slightly lower but not significantly different.

10

Discussion

149   Tamhini WLS is a biodiversity rich area, supporting many bird, butterfly, amphibian and reptile

150   species in a relatively small area. Despite its protected status the area is under threat of

151   encroachment [22,23,34]. Tamhini also has an interesting history of management interspersed with

152   privately owned land, reserved forest, and human habitations. In addition, local people still

153   depend on the remaining forests for firewood and non – timber forest products (pers. obs.).

154   Our comparison of bird and butterfly communities over two decades revealed a significant

155   increase in diversity of birds and though not significant, an increase in the diversity of butterflies

156   as well (Figure 2). An increase in diversity does not necessarily mean that management practices

157   are effective. Different taxa can respond differently to disturbance and these effects vary across

158   spatio-temporal scales [10,33,35]. Both bird and butterfly communities displayed significant turnover

159   when compared across studies (Figure 3). This change in community composition can be

160   attributed to a variety of underlying processes including change in land use patterns, changes in

161   habitat structure, natural cyclic variation, and sensitivity of subsets (e.g., functional groups) of

162   the community [5].

163   When we break down the diversity of these species into functional components, we can observe

164   more fine scale patterns. Trophic and habitat specialization reduced slightly but not significantly

165   for both taxa. In the case of butterfly communities, we observed a large increase in generalist

166   species diversity compared to more specialist species in our study (Table 1, Figure 4). Butterflies

167   are sensitive to disturbance at smaller spatial scales, particularly changes to vegetation [15].

168   Species specializing in specific caterpillar host plants may be at a disadvantage in the face of

169   human activities that alter plant communities such as logging and slash and burn agriculture [13],

11

170   both of which were observed on our transects. On the other hand, bird communities in Tamhini

171   saw a large increase in insectivorous birds in addition to a moderate increase in omnivorous bird

172   species (Table 1, Figure 4). Habitat modification such as converting land for agriculture can

173   result in changes in resource availability and consequent changes in interspecific completion [36].

174   Thus, species with specific resource requirements may be at an advantage in human modified

175   landscapes[33,37].

176   Our study is limited in spatial scale and thus our inferences are difficult to generalize beyond the

177   case of Tamhini WLS. In addition, sampling effort differed among the studies compared.

178   Sampling effort (in terms of number of individuals sampled) can have a large impact on both

179   alpha and beta diversity and must be kept in mind when interpreting results (see supplementary

180   materials). Differences in expertise in identification of the focal taxa may also introduce

181   additional biases. However, the temporal scale of our comparison reveals useful insights into

182   how these communities respond to human presence. Future studies may benefit from better

183   spatial replicates and more even sampling effort to detect effects that we were not able to in the

184   current study.

185   Despite an apparent increase in diversity at the community level, we observed a shift in

186   functional diversity across both bird and butterfly communities in Tamhini WLS. Such shifts

187   may have implications for community assembly and ecosystem function. Looking beyond

188   species diversity may prove useful for the management of biodiverse areas in the Western Ghats

189   such as Tamhini WLS.

12

190 **Acknowledgments**

197

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200 **Tables**

201 Table 1: Comparing diversity of trophic guilds in bird and butterfly communities at Tamhini

202 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

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| | 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
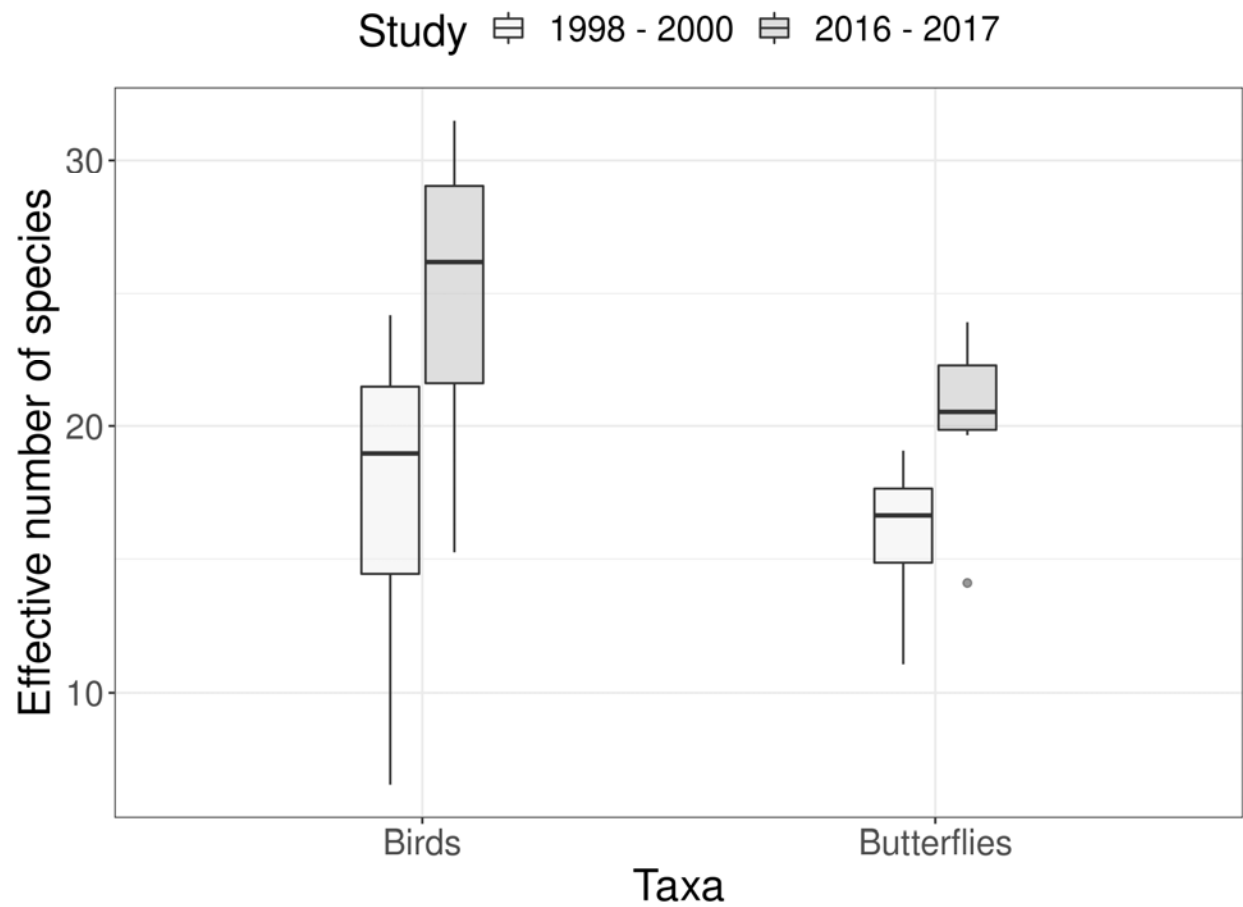between 1998 and 2017.

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214 **Figures**
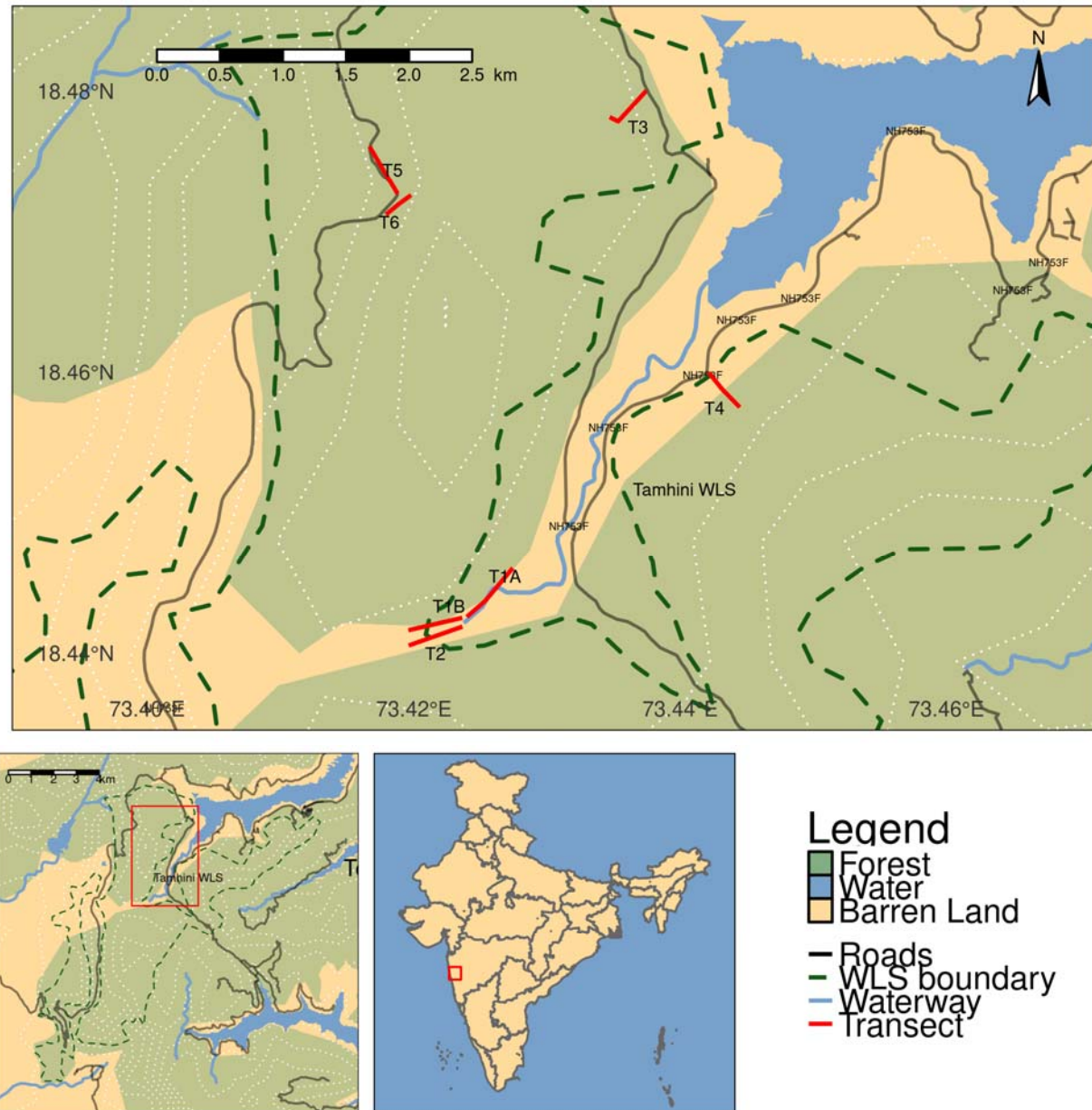
216 Figure 1: Location of transects (top) laid in Tamhini Wildlife Sanctuary (bottom left), situated

217 around 60k west of Pune in the Northern Western Ghats (bottom center). White dotted lines
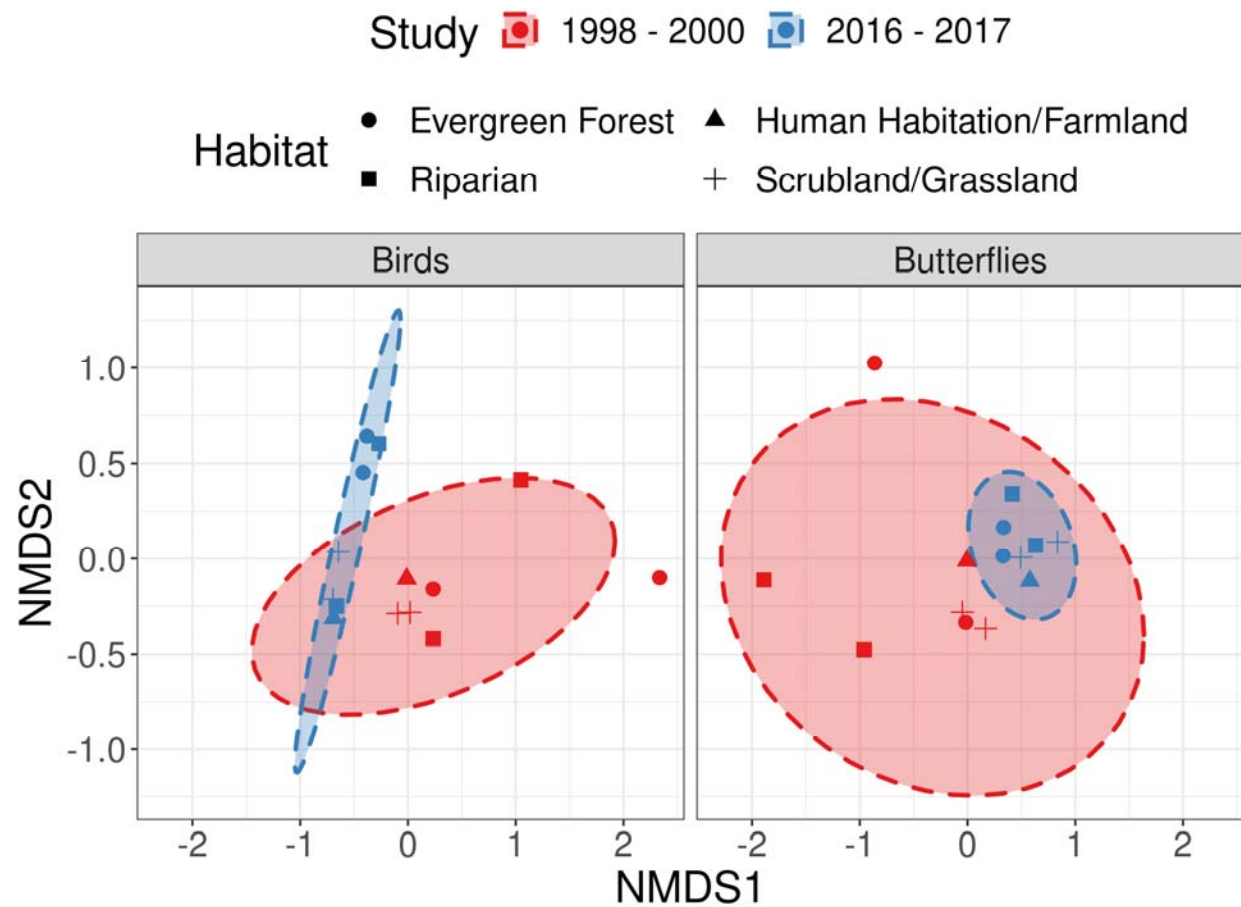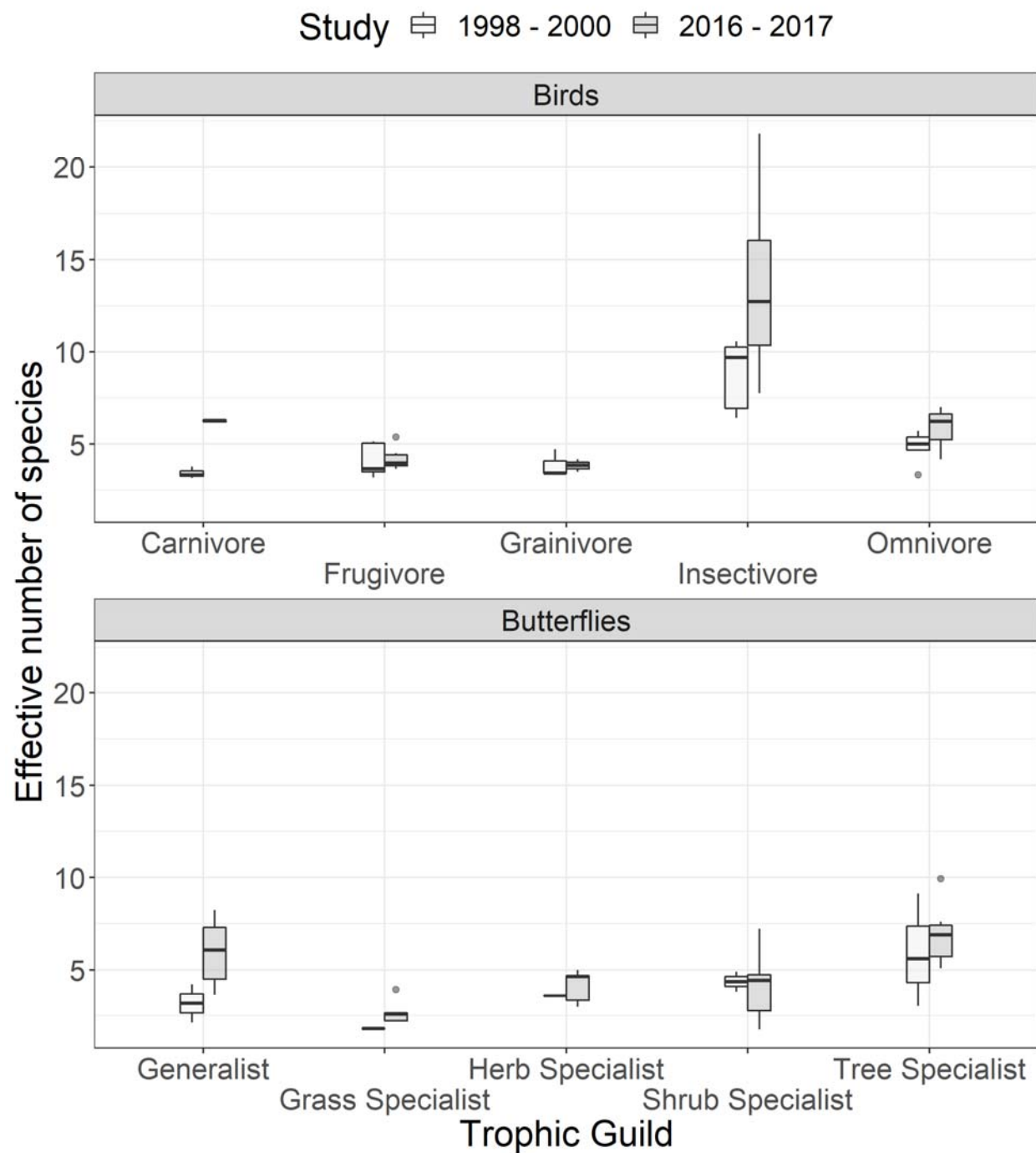
218 indicate 100m elevation contours.

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220
221   Figure 2: Change in first order diversity of bird and butterflies in Tamhini WLS between 1998

222   and 2017.

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

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Figure 4: Change in relative proportion trophic guilds of birds and butterflies in Tamhini WLS between 1998 and 2017. Liana specialist butterflies were only encountered in the current study

230   and not the previous study. In addition, our sample of liana specialists was too small to compute

231   diversity metrics, and have thus been excluded from the figure and analysis.