Abiotic niche predictors of long-term trends in body mass and survival of Eastern Himalayan birds

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Abstract:

Climate change and habitat degradation are two of the greatest threats to tropical biodiversity today. In addition to their independent effects, habitat degradation compounds the impacts of climate change by creating habitats with novel abiotic characteristics (typically hotter, drier and more variable). Tropical species are often microhabitat and microclimate specialists occupying distinct temperature and humidity niches. How species' abiotic niches affect their responses to the joint impacts of climate change and habitat degradation remains poorly understood, especially in terms of changes in phenotype and demographic vital rates. Using an 11-year mark-recapture dataset and temperature-humidity measurements from primary and selectively logged forest from 2000m in the Eastern Himalayas, we investigate how the abiotic (temperature-humidity) niche sizes of populations of species in primary forest and abiotic niche overlaps between populations in primary and logged forest predicted body mass and survival trends over time for populations in each habitat. Our results show that logged forest is hotter and drier than primary forest, and the arthropod community shows dramatic shifts in composition upon selective logging. In understorey insectivores, we find that body masses appear to be declining over time in logged, but not in primary forest. Further, across species, we report a positive relationship between the size of the primary forest niche and body mass trends over time in primary forest but not in logged forest. The degree of dissimilarity between species-specific primary and logged forest niches was strongly and negatively correlated with survival trends in logged forest. Here, we show that temperature-humidity niche shifts in response to anthropogenic habitat modification can impact demographic vital rates crucial for population persistence. This work has the potential to inform prompt, targeted conservation efforts toward species that are the most threatened in a warmer and more degraded world.

Introduction:

Climate change and habitat degradation are the two greatest threats to tropical biodiversity today (Pimm 2008; Pringle et al. 2012). Not only are global temperatures rising rapidly in response to climate change, the anthropogenic modification of tropical forest (e.g., by selective logging and conversion to agriculture) further compounds climate impacts; modified habitats reach far higher temperatures than natural forests

(Jucker et al. 2020) and lose the buffering effects of the forest canopy (De Frenne et al. 2019). There is also a general consensus on the expected effects of climate change and forest modification on the structure and function of ecological communities — large-bodied, *k*-selected species and those at higher trophic levels decline in abundance with selective logging and habitat fragmentation (Petchey et al. 1999; Duffy 2003; Gray et al. 2007; Burivalova et al. 2015; Hamer et al. 2015).

While the impacts of these two factors on biodiversity has received great attention in conservation biology research, their impacts have been mostly considered separately, notwithstanding the fact that species are simultaneously exposed to, and therefore respond to, both climate change and habitat degradation concurrently (Srinivasan and Wilcove 2021). Further, most research on the impacts of climate change and forest loss often examines biodiversity responses in terms of range shifts (Freeman et al. 2018), changes in the population sizes of species (Şekercioğlu et al. 2012), and the structure of ecological communities (Newmark 2006). Little is known about the compounding effects of climate change and habitat modification on demographic vital rates such as survival, and phenotypic characteristics, such as body mass (Cosset et al. 2019; Srinivasan 2019). Such an understanding, however, remains crucial because: (a) vital rates determine the long-term persistence and viability of populations; (b) studying phenotypic changes over time can help us understand the underlying drivers behind shifts in community structure and vital rates; and (c) quantification of an objective, reliable estimate of a species' vulnerability to extinction —using niche parameters—enables effective use of resources to best conserve remnant biodiversity.

All species occupy distinct ecological niches, defined as the sum of the habitat requirements, environmental conditions and behaviours that enable a species to persist at a location (Ruegg et al. 2021; Jirinec et al. 2021). All else being equal, species with large fundamental abiotic niches, quantified as a function of environmental parameters such as temperature and humidity, should be more adaptable to habitat modifications that alter the abiotic environment (Moritz and Agudo 2013). In contrast, niche specialists with narrow temperature-humidity niches are likely to be more sensitive to environmental change (Clavel et al. 2011). Temperature and humidity have especially been shown to determine species, and even individual, responses to habitat change and the resulting alteration in climatic variables (Frishkoff et al. 2016; Bay et al. 2021). For instance, outright habitat loss from conversion to agriculture leads to an average 7.6°C increase in temperature and a reduction in humidity relative to primary forest (Fick and Hijmans 2017). Even relatively minor forest degradation (for instance, through selective logging) raised mean temperatures by 2°C and maximum temperatures by 5.8°C (Srinivasan & Wilcove 2021).

In addition to influencing demographic vital rates, altered thermal environments can also affect phenotype. A morphological change that has been postulated to occur under climate warming is the reduction of body size (Watt et al. 2010). This follows from Bergmann's rule, based on the fact that a higher surface area:volume ratio translates to better heat loss, leading to the expectation that climate change should favour smaller body sizes (Buskirk et al. 2010; Gardner et al. 2011). The evidence, however, shows mixed support for this 'rule' with some species showing reductions in body size, while others showed increased sizes with rising temperatures (Gardner et al. 2011; Teplitsky and Millien 2014). This may be because the adaptability of species to climate change and the determinants of this adaptability are yet to be fully understood. An understanding of the drivers of adaptability of a species to climate change and habitat degradation is, therefore, crucial to forecast the vulnerability of various species present in an ecosystem. Furthermore, the ability of a species to adapt to altered abiotic conditions via reduction in body size is likely to also be linked to long-term survival in modified habitats (Møller and Szép 2002; Rioux Paquette et al. 2014).

We studied year-round resident bird species in the Eastern Himalaya Global Biodiversity Hotspot for an 11-year period, using a mark-recapture methodology. The Eastern Himalayas is among the world's most biodiverse regions (Grenyer et al. 2006; Pandit et al. 2014), and presently faces the twin threats of selective logging and climatic warming. Furthermore, Eastern Himalayan bird species, especially the understorey insectivores, are adapted to narrow thermal ranges and microhabitats, potentially making them extremely vulnerable to anthropogenic change (Jetz et al. 2007; Powell et al. 2015; Srinivasan et al. 2018).

In this study, we asked:

(a) Are there abiotic and biotic differences between logged and primary forest environments?
We expected logged forest to be hotter and drier than primary forest habitats. As a consequence, we also expected shifts in the biotic communities of arthropods in selectively logged forests, due to their thermally-sensitive and ecothermal nature (Renault et al.)**.**

(b) Do species with smaller temperature-humidity niches (i.e., microhabitat specialists) undergo steeper body mass and survival declines over time in response to climate change?
We expected that across species, the size of the temperature-humidity niche in primary forests would be positively correlated with survival because a species with a larger niche (more generalist) can adapt better to changes in its abiotic environment.

(c) Does the degree of niche dissimilarity between primary and logged forest correlate with the body mass and/or survival trends over time in logged forest?
We expected that the more dissimilar the primary and logged forest niche of a species is, the steeper the body mass and survival declines of that species in logged forest. In other words, we expect to see a positive correlation between the degree of overlap between primary and logged forest niches, and species' body mass and survival trends over time.

Methods

Study area and field sampling

We sampled primary and logged montane broadleaf wet evergreen forest at 2000m ASL in Eaglenest Wildlife Sanctuary, West Kameng district, Arunachal Pradesh, India. Six forest patches (three each in primary and logged forest) were selected for sampling based on interviews with persons involved in logging operations. Variation in tree densities on these plots tallied exactly with semi-quantitative estimates of timber extraction (Srinivasan 2013). On average, tree densities in primary forest plots (~200 trees per ha) were more than double those in logged forest (~75 trees per ha). In each plot, a team operated 24-48 mist nets (12m length, 4 shelf, 16mm mesh size; 158 nets in total) from 0500 to 1200h for three consecutive days in the early breeding season (April-May) each year, from 2011-2021. (Sampling was not possible in 2020 because of a nationwide lockdown caused by the COVID-19 pandemic.) Nets were set up systematically within a plot, with neighbouring nets placed ~40m apart. Because sampling was done during the early breeding season, all captured small passerine birds were adults. All captured individual birds were ringed with a uniquely numbered aluminium ring, weighed and then released.

Differences in overall temperature-humidity profiles in primary and logged forest

To measure the temperature and humidity associated with each capture of an individual bird, a single DS 1923 iButton Hygrochron (Maxim Integrated) temperature-humidity logger was placed at the location of each mist net. Temperature-humidity loggers were programmed to record both temperature and relative humidity at 10-minute intervals. Each bird capture was then associated with the closest temperature-humidity reading in time from the mist net of capture. Unlike capture efforts (which span 2011 to 2021), temperature-humidity data associated with bird captures in primary and logged forest was only measured in 2021.

Differences in arthropod community composition between primary and logged forest

Like all ectotherms, arthropods are sensitive to the temperature and humidity changes (Burraco et al. 2020; Renault et al.) and make up the diets of all our study species

(Supriya et al. 2020). Therefore, to better understand biotic changes accompanying selective logging, we studied the arthropod community compositions in primary and logged forest.

We used three arthropod sampling techniques at 25-28 points within each plot to sample the arthropod community in primary and logged forest (total 55 sampling stations in primary forest and 53 sampling stations in logged forest). We accounted for ground-dwelling, flying and understorey foliage arthropods through the use of sticky traps, pitfall traps and branch-beats.

For ground-dwelling arthropods, we placed pitfall traps containing detergent water for 48 hours at each sampling station. For flying arthropods, we used sticky traps, i.e, a cardboard rectangle of 150x200mm dimension covered with an adhesive coating on both sides. These non-toxic sticky traps contained an aromatic substance to attract insects, and were hung approximately 1.5m from the ground for 48 hours at each location. Lastly, we used branch beating for sampling foliage arthropods. For branch beating we stitched a white linen cloth in the shape of a funnel around a metal ring 1m in diameter at the larger end of the funnel and with a container attached to the thinner end of the funnel. At each station, we placed a randomly selected branch within this funnel, beat it ten times with a standard-sized stick and sprayed commercially available insecticide spray. This momentarily paralyzed the arthropods, allowing us to collect them in the container affixed to the narrow end of the funnel.

All collected arthropod samples were photographed with scale using a Nikon P900 camera setup. Each arthropod within the sample was identified to the order level.

Selection of bird species for analysis

We selected species suitable for analyses based on the following criteria:

1) Selected species were understorey insectivores that breed on our sampling plots (migrants were excluded).

2) Selected species possessed sufficient recapture rates to provide robust estimates of species survival in both primary and logged forest.

Temperature-Humidity niche analysis

To estimate the temperature-humidity niches of different species we used the *adeHabitat* package (Calenge 2006) in Program R (Core Team 2022), to model the temperature-humidity niche via a Utilisation Distribution (UD) kernel approach (Calenge 2006; Fig 1). While this method was initially developed to analyse the utilisation of various parts of the home ranges of radio-tracked animals using a Kernel Density Estimate (KDE), we use it to model the use of the temperature-humidity space for each species, in primary and logged forest (Fig 1). Through this approach, for each species, we generated separate temperature-humidity KDEs for primary and logged forest separately, and subsequently calculated the area of the primary forest niche and the

Utilisation Density Overlap Index (UDOI) — a standard measure of UD overlap based on the Hurlbert's index of niche overlap (Hurlbert 1978; Fig 1).

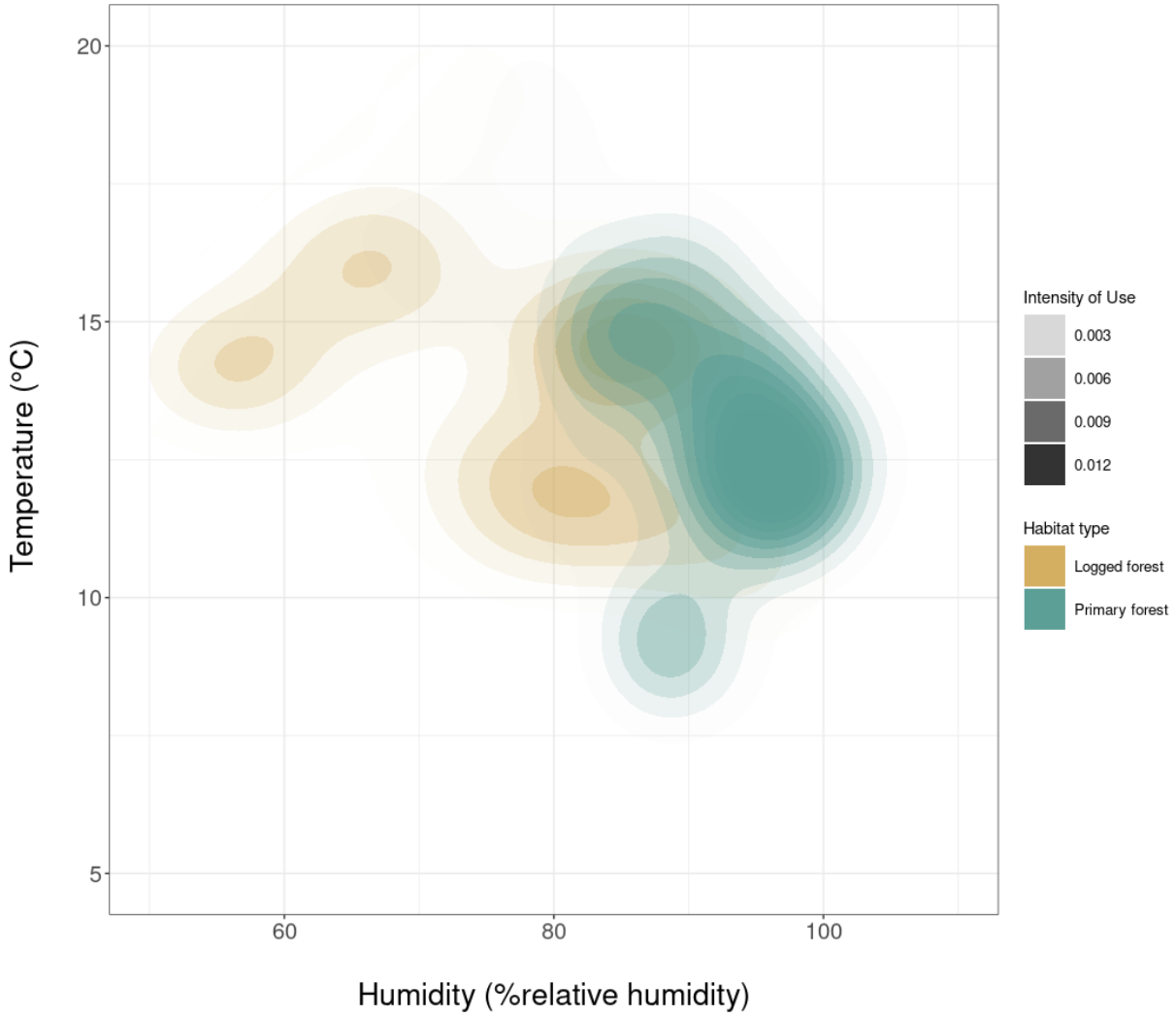

Figure 1: Example of the temperature-humidity niches of Yellow-throated Fulvetta (*Pseudominla cinerea*) in primary and logged forest, visualised as a Utilisation Distribution kernel. The abiotic niche for this species is generally more moist and slightly cooler in primary than in logged forest. The intensity of use of a given region in temperature-humidity space is indicated with a gradient of shading, opaque representing region of most use and transparent representing regions of no use.

Trends in body mass over time

For each species (separately in primary and logged forest), we used linear regressions to examine how the average body mass of birds of each species changed over time in primary and in logged forest. (Example shown in Fig S1). The body masses of all species was standardised to a species-wise z-score to account for the fact that species

which are larger can potentially lose more absolute body mass than species which are inherently small.

Trends in apparent survival over time

We estimated the apparent survival (phi) for each species in each type of habitat using the Cormack-Jolly Seber (CJS) mark-recapture model (Cormack 1964; Jolly 1965; Seber 1965), to estimate adult apparent survival for each species in primary and logged forests separately (Figure S2). Apparent survival is an amalgam of true survivorship and site fidelity (i.e., death and emigration are indistinguishable; Barbour et al. 2013). Therefore, an annual apparent survival estimate of 0.60 indicates a 60% probability of an individual in the population surviving *and* remaining in the same location from one year to the next. For each species, to analyse how apparent survival changed over time, we first created a capture history for each individual bird spanning eleven years. Multiple captures of the same individual within a single year (e.g., on consecutive sampling days) were not considered recaptures (i.e., all captures within a single sampling season were collapsed into a single event in the capture histories). We then pooled capture histories from the three primary forest plots to represent populations sampled in primary forest and pooled capture histories from all logged plots to represent populations sampled in logged forest. We pooled the data to estimate apparent survival in primary and logged forests for each species because plot-level data was insufficient to adequately and reliably estimate survival for each species in each plot.

The CJS model is an open-population model that estimates apparent survival while accounting for imperfect detection (i.e., capture probability < 1). Using the *R2ucare* package (Gimenez et al. 2018) in Program R (Core Team 2013), we first ran tests to ensure that the CJS models fitted the capture history data well (for each species in each habitat). We ran two models each in primary and logged forests separately — one in which recapture probability was constant throughout the study period (across all sampling occasions), and another in which recapture probability was allowed to vary with sampling occasion. In both models, apparent survival was constrained to vary unidirectionally over time (but the slope of survival over time was allowed to be zero). For each species, we chose the best model (between time-variant and time-invariant recapture probabilities) by using the small sample size-corrected Akaike's Information Criterion (AICc).

Linear models

The relationship between the slope of body mass and survival over time and other niche parameters was separately modelled as follows (explanation of terms can be found in Table 1):

slope ~ H + NA + KO + H:NA + N:KO where

1) slope = slope of survival or body mass over time (continuous variable)
2) H = habitat type (categorical variable with two levels; primary and logged)
3) NA = niche area in primary forest (continuous variable)
4) KO = kernel overlap between primary and logged forest niches (continuous variable)

Results

Temperature and humidity in primary and logged forest

Logged forest was hotter than primary forests during the daytime (in the afternoon, maximum temperature in logged forests was on average 1.1°C warmer than primary forest), and had a greater variation in temperature over the 24-hour daily period (Fig 2a). Simultaneously, logged forest was also considerably drier than primary forest, throughout the 24-hour time period (Fig 2b).

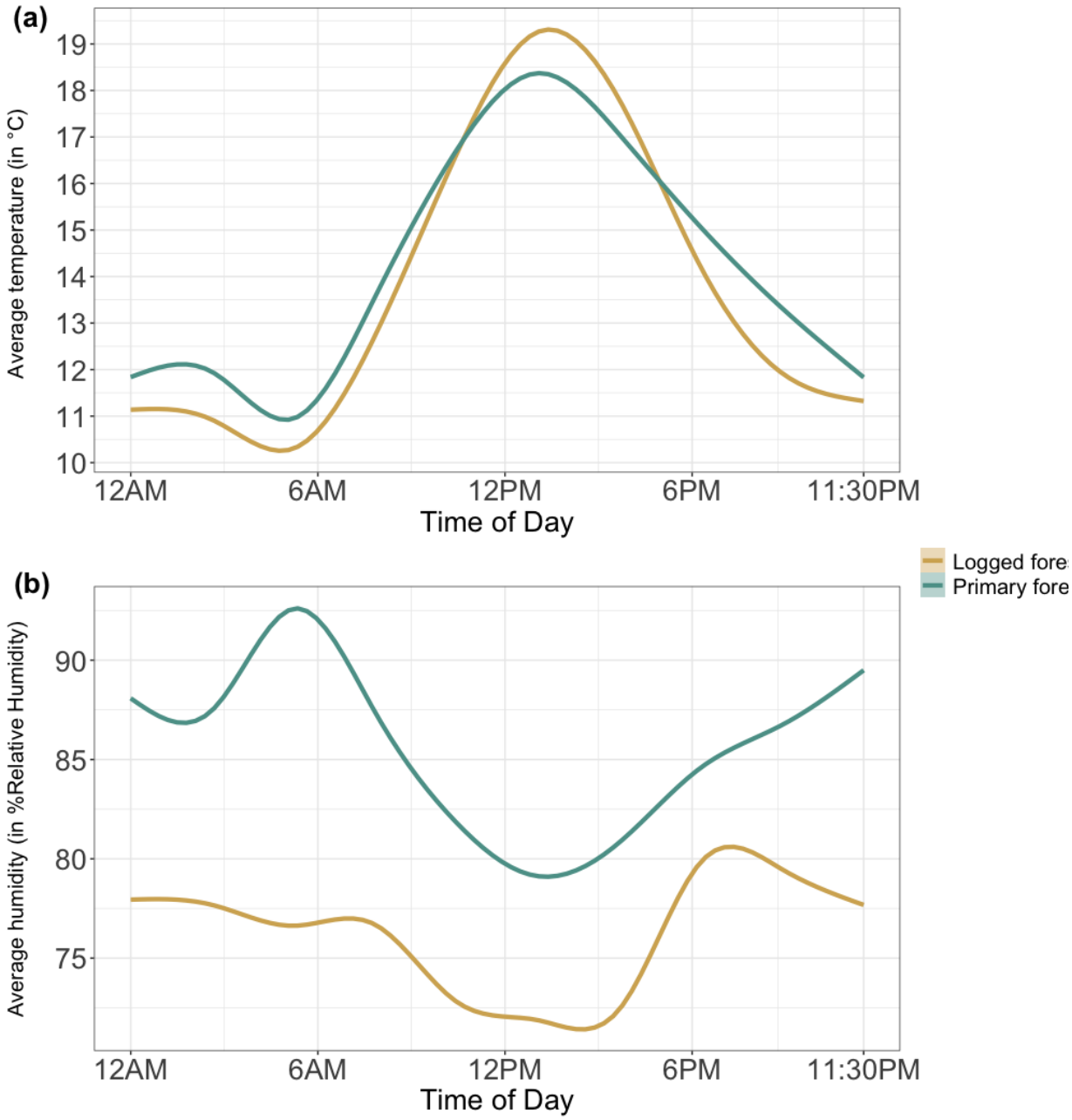

Figure 2: (a) Average temperatures in primary (green) and logged forest over a twenty-four hour period. Logged forest is, on average, considerably hotter than intact forest during the day; (b) average humidity in primary (green) and logged (brown) forest over the 24-hour daily period. Logged forest is consistently and considerably drier than intact forest.

Arthropod Community Composition

Primary and logged forest differed significantly in athropod community composition (NMDS, MoristaHorn index, stress = 0.20; perMANOVA: $F_{1,106} = 24.69$, $p < 0.01$, $R^2 = 0.19$). In general, primary forests harboured more arachnids, lepidopterans and hemipterans while logged forest insect communities had more flies (Fig 3).

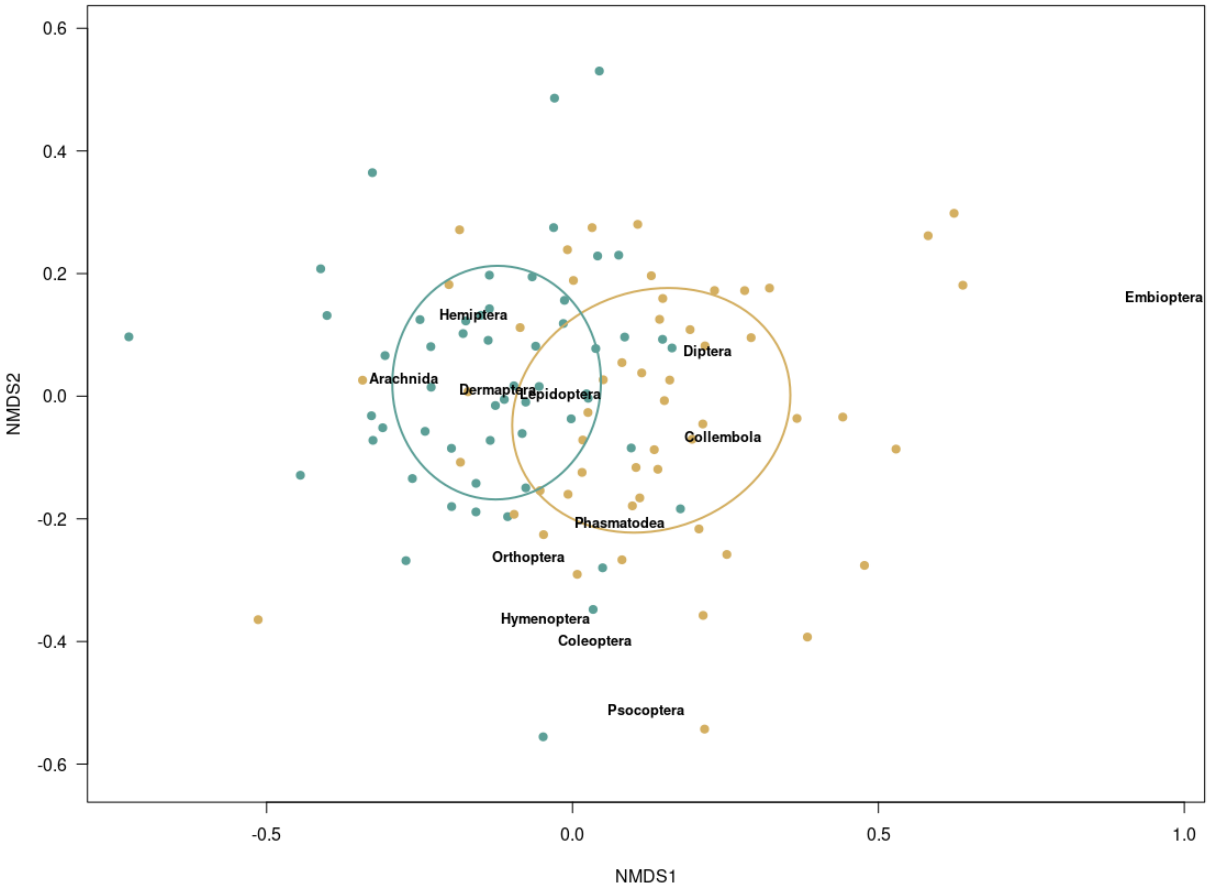

Figure 3: An NMDS visualisation of the arthropod community composition in primary and logged forests at our study site. Primary forest plots had more arachnids, lepidopterans and hemipterans while logged forest insect arthropod communities have a greater proportion of dipterans

Preliminary mist-netting results

During the 11-year study period, we recorded 8,762 captures of 5,971 individuals of 129 species. Based on the two selection criteria (breeding and enough data for capture-recapture analyses) we selected 11 species for further analyses. In total, we recorded 4,743 captures of 2,986 individuals belonging to these 11 species.

Body mass trends

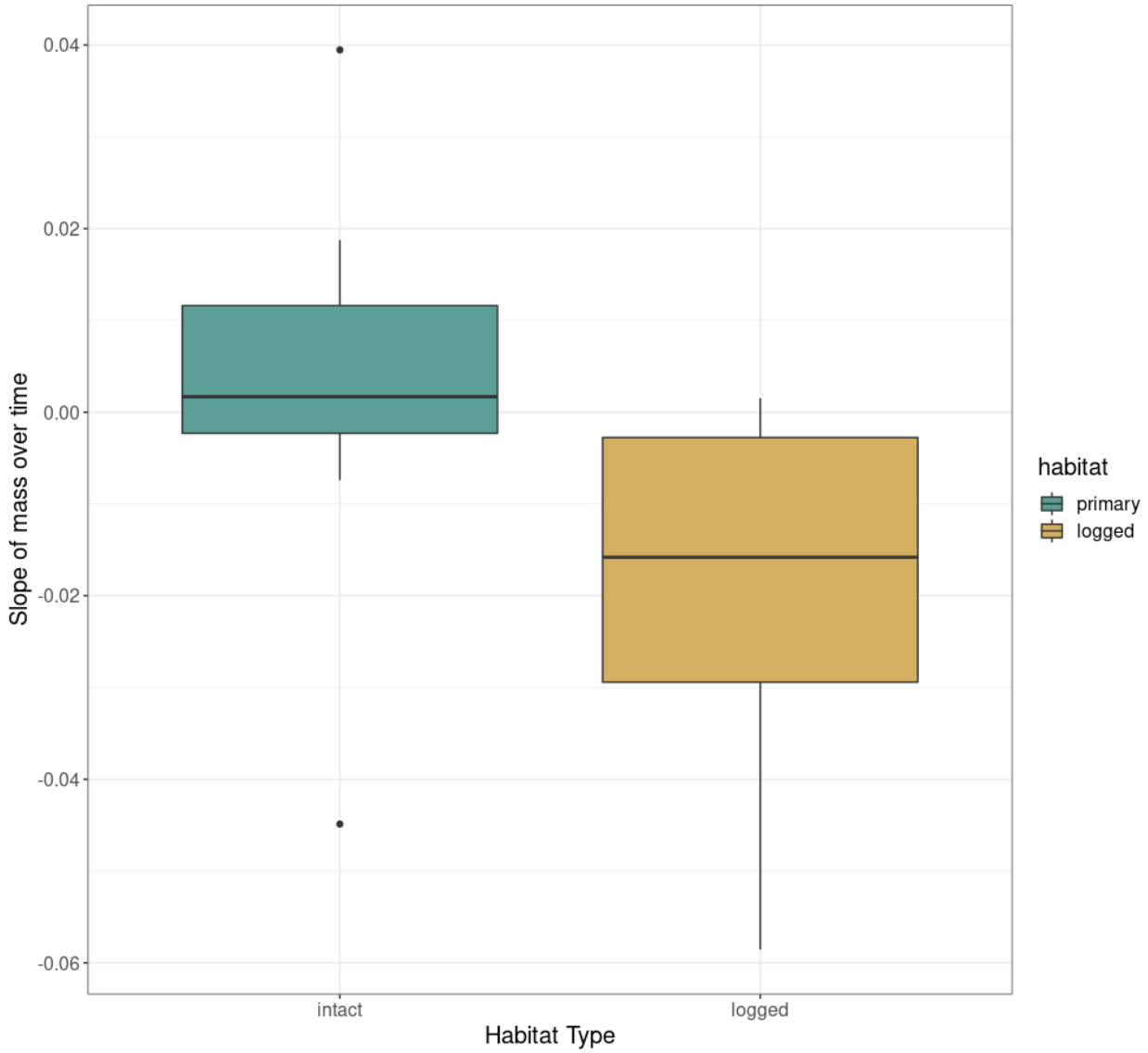

Figure 4: Populations of the same species in primary forest appear to be maintaining body mass over time but appear to be losing body mass over time in logged forest.

Our analysis suggests a significant effect of climate and land-use change on the body mass trends of birds over time (Fig 4; Fig 5, R^2 = 0.56). Habitat type was strongly related to body mass trends, with individuals in logged forest witnessing significant reductions in body weight over time (Slope of body mass over time = -0.02, 95% CI = [-0.04, -0.004]), in comparison to primary forest where body mass was constant (0.002, CI = [-0.01, 0.02]). In primary forest, body mass trends over time showed a positive relationship with niche area ($\beta_{niche.area}$ = 0.25, CI = [0.01, 0.50]), but the degree of niche overlap in primary and logged forest was not strongly related to body mass trends on

logged forest (β_{UDOI} = 0.01, CI = [-0.07, 0.09]). Niche area was not related to body mass trends over time in logged forest ($\beta_{niche.area}$ = -0.14, CI = [-0.47, 0.20]).

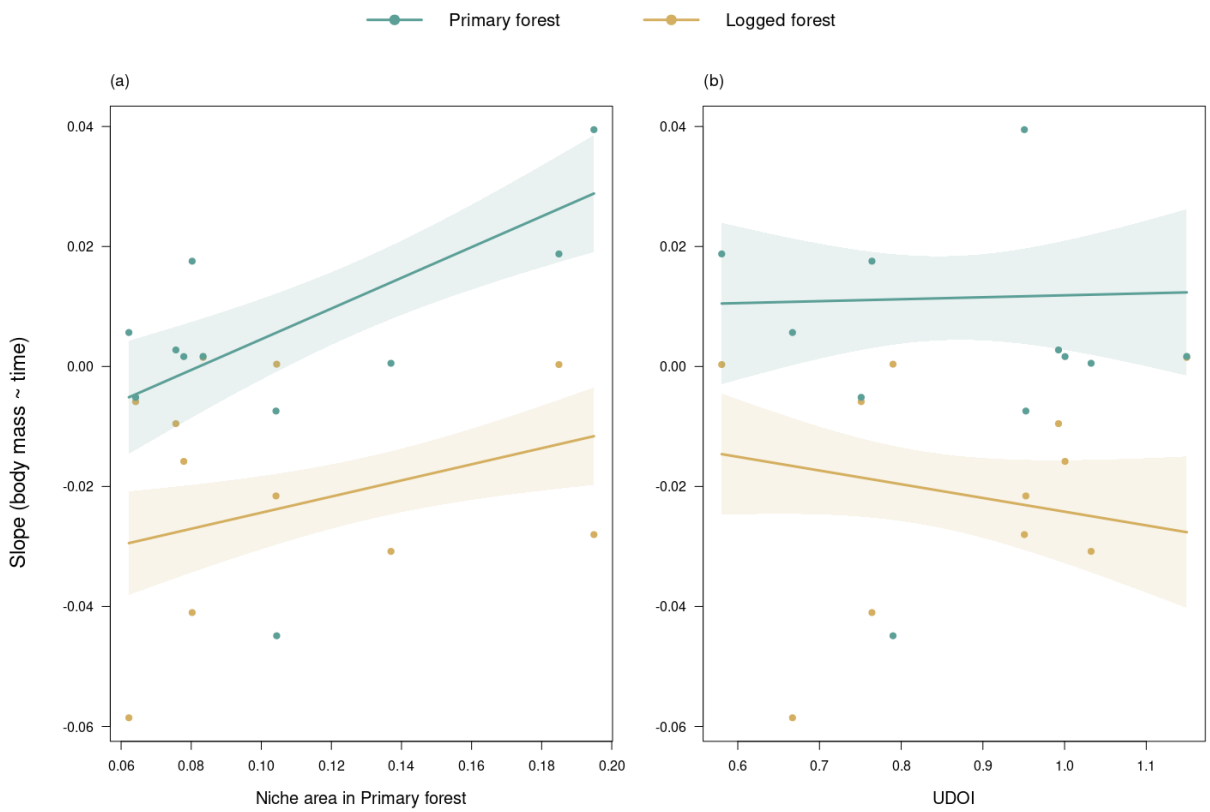

Figure 5: Trends of the slope of average body mass over time of study species in primary and logged forest with changing niche area in primary forests (a), and the UDOI niche overlap index between primary and logged forest niches (b). Shaded polygons indicate the standard error around the fit. Every point represents one of 11 species. Each species has two points on the plot representing its body mass trends in primary (green) and logged (brown). A positive value on the y-axis indicates an increase in body mass over time, while a negative value suggests a decline in body mass over time.

Survival analysis

Individuals that were captured on more than one habitat type (primary or logged) were excluded from further analyses (4.8% of all captured individuals). Models with constant recapture probability performed better for all species, in comparison to one with time-varying capture probability. Survival estimates from the best model are reported in Table S2.

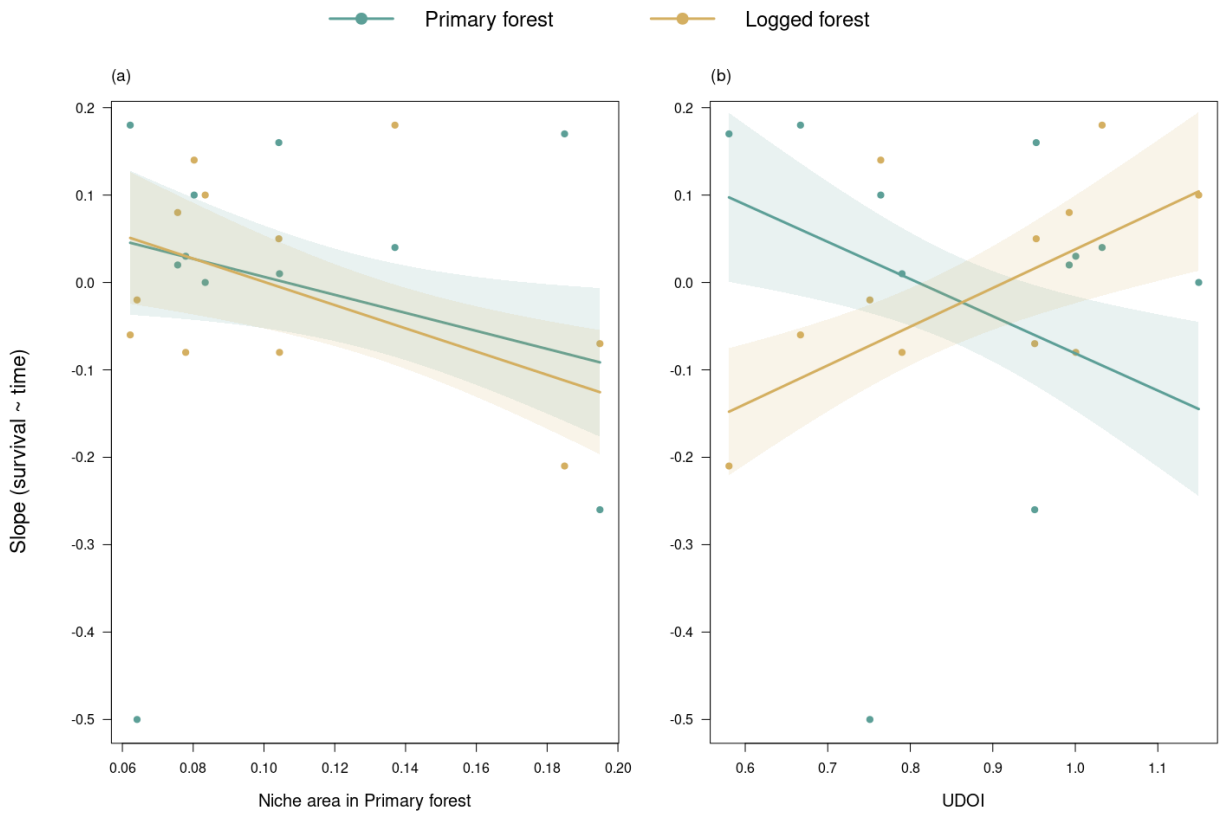

Figure 6: Trends of the slope of survival over time of study species in primary and logged forests with changing niche area in primary forest (a) and the UDOI niche overlap index between primary and logged forest niches (b). With increasing niche dissimilarity between primary and logged forest niches, there is a steeper decline of species' survival in logged forests (b). Shaded polygons represent standard error around the fit.

Overall, the linear regression (R^2 = 0.36) suggested that the niche area in primary forest is not a reliable predictor of survival trends over time in primary ($\beta_{niche.area}$ = -1.13, CI = [-3.07, 0.80]; Fig 6a) or logged forest ($\beta_{niche.area}$ = 0.10, CI = [-1.06, 0.16]; Fig 6a). Instead, niche dissimilarity (i.e., the degree to which a species' temperature-humidity niche changes with logging) is strongly related to survival trends in logged forest ($\beta_{kernel.overlap}$ = 0.82, CI = [0.03, 1.62]; Fig 6b). Species with greater niche dissimilarities in primary and logged forest also had steeper survival declines over time in a logged forest (Fig 6b).

Discussion

We examined differences in the abiotic and biotic environments for 11 species of understory insectivorous birds in primary and selectively logged forest in the Eastern Himalaya. We analysed how the temperature-humidity niche sizes of understorey bird species were related to body mass and survival trends over an 11-year period in primary and logged forest. Primary and logged forest had different temperature-humidity profiles and differed in the composition of arthropod communities. Interestingly, we found a relationship between the size of the temperature-humidity niche in primary forest and body mass over time in primary forests (Fig 5). We also found a strong positive relationship between the degree of niche dissimilarity in primary and logged forest and survival rates over time. In other words, species with very different temperature-humidity niches in primary and logged forest experienced survival declines in logged forest, while those with high degree of niche overlap in primary and logged forest have near-constant survival over time (Fig 6b), even after logging.

Body size is an important and widely-studied life-history trait that greatly influences thermoregulation by individuals/species (James 1970). Heat dissipation theory postulates that tropical animals are limited energetically by the rate at which body heat is lost (Speakman and Król 2010), and purely based on thermodynamic considerations, smaller body sizes should be selected for in progressively warmer conditions (Prokosch et al. 2019). The Eastern Himalaya has a relatively aseasonal climate which selects for thermal niche specialist species (Srinivasan et al. 2018). Not only is the Eastern Himalaya warming at three times the speed as the global average (Shrestha et al. 2012), but forest degradation is concomitantly removing the buffering effects of the primary forest canopy, making logged forests more thermally variable, and significantly hotter and drier than primary forest (De Frenne et al. 2019; Figs 2a, 2b). Our *a priori* expectation was that thermally-sensitive niche specialist species would undergo steeper declines in body mass over time, in keeping with the thermoregulatory capacity hypothesis. In other words, species with smaller temperature niche sizes would undergo steeper declines in body mass over the study period. Indeed, this is what we observe - bird species, on average, are lighter in logged forests (Fig 4) and the slope of the body mass over time graph is negatively correlated with the size of the temperature-humidity niche size in primary forest (Fig 5a).

Several bird species elsewhere are indeed undergoing other morphological changes over time, likely because of climate-driven thermal constraints (Jirinec et al. 2021). Specifically, birds can undergo changes in the morphometry of organs and appendages that serve thermoregulatory (Tattersall et al. 2017) and locomotory functions (Weeks et al. 2020), without drastically changing overall body mass. In the rainforests of the Amazon for example, climate change appears to have selected for progressively longer

wings in comparison to body mass, which suggests that birds are adapting toward relatively longer appendages to offset thermal stress (Jirinec et al. 2021). Therefore, in addition to progressively lighter body mass in logged forests, birds within primary and logged forests would likely exhibit differences in their mass:wing ratio.

In addition to thermal stressors, resource availability also plays a role in determining body size (McNab 2010). Since we were interested in insectivorous understorey birds, we also measured biotic factors determining body sizes such as arthropod composition and abundance (Cox et al. 2019). Arthropod community composition showed a considerable shift with selective logging. This result highlights that a possible confounding variable hitherto unexplored at our study site is the dietary niche breadth of birds (Bond and Lavers 2014; Hansen et al. 2019). Therefore, an assessment of dietary niche space (i.e., its size and shift in response to selective logging) would help us better understand the various mechanisms underlying body mass declines with logging (Edwards et al. 2013; Hamer et al. 2015).

The size of a species' niche determines how it interacts with the larger ecosystem and shapes its individual and population-level responses to ecological disturbances (Voigt et al. 2007; Bellwood et al. 2019). Previous studies have suggested that species with larger niches (i.e., generalists) can inhabit a greater range of environments by drawing from a wider pool of resources. This makes them more resilient to climate change and less likely to face population declines in comparison to species with smaller niches (or, specialists; Swihart et al. 2003; Clavel et al. 2011). Specialist species use a narrow range of resources and/or habitats, and changes in the availability of both can have drastic effects on their populations since they are unable to exploit alternative habitats or resources (Graham et al. 2011).

Studies investigating the effect of niche size on sensitivity to climate change have thus far used occupancy data and theoretical models to estimate niche sizes (Loiselle et al. 2010; Rinnan and Lawler 2019). The direct impact of climatic niche parameters on the long-term survival of species has seldom been tested in the field. Previous studies on tropical rainforest species show that vulnerability is strongly predicted by ecological specialisation (Sekercioglu 2011), and that understory insectivores are in particular peril due to anthropogenic change because of their limited dispersal ability (Moore et al. 2008; Powell et al. 2015) and sensitivity to the opening up of the canopy (Patten and Smith-Patten 2012; Pollock et al. 2015).

We found that the size of a species' temperature-humidity niche in primary forest was not related to long-term survival trends of bird species in logged forests in the Eastern Himalaya. However, the degree of niche dissimilarity between primary and logged

forests was strongly correlated with survival trends over time — the more dissimilar a species' primary and logged forest niches are, the steeper the survival declines in logged forest. A recent paper from the same study system and study species found that the elevational ranges of species (and potential upslope movement; Girish and Srinivasan 2022) explained changes in survival rates of species in primary but not in logged forest (Srinivasan and Wilcove 2021). In logged forest therefore, rather than elevational ranges and range shifts, mismatches in the abiotic niche between primary and logged forest might better explain trends in survival.

Such a relationship can occur in two ways. Firstly, an altered abiotic environment can interact directly with species' physiology, especially on stress response mechanisms. Is likely that birds with more dissimilar temperature-humidity niche spaces (between primary and logged forest) face elevated levels of stress and therefore chronically higher levels of stress hormones over time (Wingfield et al. 2017). Heat-shock proteins (HSPs), which indicate long-term thermal stress, can be used to study this effect (Maak et al. 2003; Pusch et al. 2018). HSPs are also well suited for a mark-recapture methodology because other stress indicator hormones are shorter-lived and the act of capture can lead to biased readings arising from temporary capture-related stress. Apart from HSPs, glucocorticoids (corticosterone) are hormones produced in response to stress in birds and can induce a wide range of metabolic cascades, such as the utilisation of stored nutrients for usage in physiological functions, changes in immunity and the prevention of oxidative damage (Marasco et al. 2017). A meta-analysis of avian response to logging revealed that species also have lowered immunity in logged forests in comparison with old-growth forests (Messina et al. 2018), and were likely to carry higher disease loads. Furthermore, glucocorticoid levels have been shown to have carry-over effects on population dynamics in many bird species (Harms et al. 2015; Hansen et al. 2016; Messina et al. 2020).

A change in abiotic conditions can also have indirect impacts on bird species; for instance, changes in temperature and humidity can impact the abundances and diversity of arthropod prey, which we demonstrate here. While one particular study of altered prey abundances of understory insectivores yielded little support for the prey-limitation hypothesis (Sekercioglu 2011), the same species of birds often forage on arthropods at different trophic levels in primary versus logged forest (Hamer et al. 2015). The method of prey capture has been shown to be a consistent predictor of sensitivity to disturbance; for instance, sallying insectivores —those that capture flying prey while themselves in flight— were more sensitive to logging in African forests (Arcilla et al. 2015).

Our results suggest that the degree of niche dissimilarity is a strong predictor of survival declines of Eastern Himalayan birds in degraded habitats facing climate change. Interestingly, it is not the size of the primary forest niche that determines the rates of survival declines, but rather the shift of the niche with anthropogenic change. By using temperature and humidity loggers, this study demonstrates the applicability of niche estimation and comparison to reliably estimate the vulnerability of species to anthropogenic change. The IUCN Red List, widely used to set species-level conservation priorities, has been criticised for not accounting for climate-related threats to species (Thuiller et al. 2005). More generally, formal assessments of slow-acting threats such as climate change is a necessary but challenging step to kickstarting conservation action. Most often, however, by the time existing criteria such as population or range-size declines are observable at population levels, it may well be too late for effective conservation action (Hannah 2012).

For effective conservation, it is essential that vulnerable species are identified as early as possible to maximise the chances of conservation success (Stanton et al. 2015). To this end, Climatic Niche Factor Analysis (CNFA) has been suggested as a tool to predict the differential vulnerability of various species to extinction (Rinnan and Lawler 2019). However, the real-world applicability of niche modelling approaches to assess risk, especially in terms of demographic rates, is hitherto unexamined.

Our methodology of estimating temperature-humidity niche shifts that correlate with long-term survival declines in Eastern Himalayan bird species is one that potentially has widespread use in conservation management and planning. By providing managers and scientists with an inexpensive quantification method of the relative vulnerabilities of various species found in bird communities, such CNFA methodologies would enable targeted, prompt and judicious use of limited conservation resources for the species which are at the greatest risk of extinction due to global change drivers. Further research is needed to understand the physiological impacts of climate change and forest degradation/loss on tropical bird species. The integration of dietary and climatic requirements of species would also yield a more holistic understanding of the grave threat of anthropogenic change on tropical biodiversity worldwide.

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