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Joint impacts of forest degradation and climate change on Eastern Himalayan birds: insights from 15 years of field research

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Abstract

Climate change and habitat loss/degradation are amongst the greatest global threats to biodiversity today. A rich literature examines empirical field-based research on the impacts of each of these global change drivers on biodiversity separately. However, the interactive effects of climate change and habitat degradation on various levels of biological organisation have rarely been integrated. Here, I use 15 years of field-based data from the Eastern Himalaya of Arunachal Pradesh to investigate how selective logging and climate change impact understorey birds in terms of (a) abiotic and biotic environments, (b) body condition, (c) foraging and social behaviour, (d) long-term population dynamics, and (e) community structure and function. I show that selectively logged forest, having lost the buffering effect of the tree canopy, is significantly hotter, drier and resource-poor compared with primary forest. This is likely associated with the loss of specific thermal-moisture microhabitats that understorey insectivorous birds are highly dependent on. Species that are unable to forage in optimal (*i.e.*, those in primary forest) temperature-humidity microhabitats in logged forest suffer the greatest declines in body mass and survival rates with logging. Multi-species social behaviour (*i.e.*, participating in winter mixed-species bird flocks) and elevational range shifts into higher-elevation primary forest in response to warming temperatures can alleviate the negative impacts of habitat degradation to an extent. In general, climate change and selective logging appear to reinforce each other's impacts to favour small, low-elevation species.

Keywords: Apparent survival, humidity, microhabitat, mixed-species flock, selective logging, temperature.

Introduction

Climate change and the loss and degradation of natural habitats are two of the most pervasive drivers of biodiversity loss and re-assortment across the planet (Mantyka-Pringle *et al.,* 2012,; Guo *et al.,* 2018). These human impacts on species are so widespread and intense that there is a growing consensus to rename the current geological period the "Anthropocene", or the age of humans (Monastersky, 2015). Most of Earth's biodiversity is concentrated in the tropics, where species tend to be thermal specialists (Janzen, 1967; Srinivasan *et al.,* 2018). In the tropics, climate change and habitat loss are likely to interact such that they mutually reinforce each other's impacts on species (*e.g.,* Guo *et al.,* 2018). For instance, forest degradation, leading to canopy loss and structural simplification, can alter the abiotic environment in ways that amplify climate effects, with downstream effects on biodiversity, acting either (a) directly on species' physiologies or morphologies (Jirinec *et al.,* 2021), or (b) through disruptions to trophic and non-trophic interactions *via* changes in resource availability (Planillo *et al.,* 2021). Especially at risk are species dependent on specific microhabitats, because forest canopy loss compromises thermal buffering against climate extremes (De Frenne *et al.,* 2019). Understanding how climate change might exacerbate the impacts of habitat degradation to influence biodiversity across multiple ecological scales will be important not only in predicting the long-term consequences of the now inevitable climate crisis, but also in designing effective interventions allowing species to maximise their resilience to modified environments.

Ecological responses to anthropogenic disturbance are likely to operate hierarchically, and cascade across scales of biological organisation, affecting individuals that are part of species' populations, which in turn are part of ecological assemblages and communities (Smith *et al.,* 2009). Individuals can potentially adapt to anthropogenic disturbance *via* behavioural and physiological plasticity (Charmantier *et al.,* 2008; Buccholz *et al.,* 2019), and through mechanisms such as geographical range shifts to occupy more favourable habitats (Sekercioglu *et al.,* 2008; Freeman *et al.,* 2018). These individual-level responses then scale up to influence demography, through

changes in survival, reproduction, and movement, ultimately determining population size and species' presence (Vellend, 2010). Over time, population-level changes across species lead to shifts in community structure and function (Vellend, 2010). In general, most investigations of anthropogenic impacts on biodiversity focus on particular levels of the individual-population-community hierarchy, perhaps most commonly at the community level (*e.g.,* how species richness changes with habitat fragmentation; Watson *et al.,* 2005; Sekercioglu, 2007). Mechanistic linkages across scales remain scarce, even in well-studied communities and ecosystems (Korfanta *et al.,* 2012; Stouffer, 2020), and especially in hyperdiverse tropical systems.

Mountains (especially tropical mountains) are particularly important for terrestrial biodiversity. Despite occupying only ~25% of the Earth's land surface, mountains harbour ~85% of terrestrial vertebrate species, including a high proportion of endemics, making them veritable powerhouses of diversity (Rahbek *et al.,* 2019). Tropical montane species also tend to be thermal specialists adapted to narrow abiotic niches along particular sections of montane elevational gradients (*e.g.,* mid- or high-elevation specialists; Janzen, 1967), making them susceptible to the negative impacts of habitat degradation and climate change as well as their combined effects. Even within the tropical montane fauna, terrestrial and understorey insectivorous birds are especially vulnerable to the joint impacts of climate change and habitat loss (Powell *et al.,* 2015), because of their extreme dependence on highly specific microclimates (Stratford & Stouffer, 2015).

Here, I review and synthesise ~15 years of published field-based research to examine how selective logging and climate change interact to affect individuals, populations and communities of Eastern Himalayan understorey birds. Long-term monitoring is essential for understanding how biodiversity responds to anthropogenic change (Korfanta *et al.,* 2012; Stouffer, 2020). Focusing on primary and logged forests, I first characterise the abiotic (temperature, humidity) and biotic (arthropod abundance and composition) environments for understorey birds. I then examine various behavioural responses of individuals to selective logging, including changes in foraging behaviour and multi-species sociality. I then report on long-term survival trends in primary and logged forest and how these trends are related to microclimate availability. Concurrently, I present changes in community structure and composition in the light of species' functional traits. Although many crucial gaps inevitably remain, the attempt is to unify, as far as is possible with the available information, anthropogenic impacts on Eastern Himalayan birds at different scales.

Methods

This review integrates methods from a long-term research programme (2011–present) examining the joint effects of selective logging and climate change on understorey birds in Eaglenest Wildlife Sanctuary (EWS), Arunachal Pradesh, India (27°02′–27°15′N, 92°18′–92°35′E) in the Eastern Himalaya, the second most biodiverse region in the world after the Amazon-–Andes gradient (Orme *et al.* 2005). EWS ranges in elevation from ~350 to ~3300m ASL, and hosts tropical rainforests at low elevations, tropical, subtropical and temperate broadleaved forests at progressively higher elevations, and coniferous forests at summits. I established six permanent sampling plots at 2000m ASL (in montane wet temperate forest; Champion & Seth, 1968), three each in primary and in selectively logged forest (Figure 1). The total area sampled in each of these two habitats was 9ha.

To sample birds, I primarily used mist- nets (12m long, 2.4m high, 16mm mesh size, four shelves). In each plot, I placed 24-28 nets in a grid with neighbouring nets ~40m apart (Srinivasan *et al.,* 2015). Nets were operated from 0500 to 1200hrs for three consecutive days in the early breeding season (April-May) in each year from 2011 to 2025 (except 2020, when the nationwide COVID lockdown made sampling impossible), for a total of 18 netting days every year. I weighed and ringed all captured birds with numbered aluminium rings and released them immediately (Srinivasan *et al.,* 2015). In some years, I added individual-specific unique combinations of colour rings for behavioural observations.

For demographic analyses, I used 15 years of mark–recapture data (from mist netting and bird ringing) to estimate apparent survival trends (Φ) using the standard Cormack–Jolly–Seber (CJS) model (Cormack, 1964; Jolly, 1965; Seber, 1965) in Program MARK (called through RMark in program R; Laake & Rexstad, 2008; R Core Team, 2025); modelling details are in Srinivasan *et al.* (2015), Srinivasan & Wilcove (2021) and Bharadwaj *et al.* (2025a).

I conducted environmental and resource measurements concurrently with bird monitoring using iButton Hygrochron (DS1923-F5#) dataloggers placed 1.5 m above ground to record temperature and relative humidity associated with each bird capture (Bharadwaj *et al.,* 2025a). I placed one Hygrochron at each mist net, programmed to record temperature and humidity at 10-minute intervals. For each bird captured, the temporally closest record of temperature and humidity was used to construct the temperature-humidity niche of a species in primary and logged forest. I sampled arthropods using a combination of (a) branch beating for foliage invertebrates, (b) sticky traps for aerial invertebrates and (c) pitfall traps for terrestrial arthropods (Aggarwal *et al.,* 2023). I preserved specimens in ethanol and identified these to the level of the Order.

For behavioural studies on foraging and sociality, I used direct observations of foraging rates and associations between colour-band ringed individuals, respectively (sampling and analytical details in Aggarwal *et al.,* 2023; Bharadwaj *et al.,* 2025b). I located individual birds in primary and logged forest plots using sight and sound, after which I recorded start and end times of the observation, time spent in foraging or other behaviours, number of foraging attempts and nature of substrate from which food was obtained (Aggarwal *et al.,* 2023).

Results and Discussion

Forest degradation and climate change, both separately and in interaction with each other, appear to have important impacts on understorey birds at individual, population and community levels. Do note that the sections below have been arranged in order from environmental to individual to population/community impacts (with potential mechanistic relationships across these levels), and not in the chronological order in which these studies were carried out.

For trees with diameter at breast height (DBH) greater than or equal to 10cm, logged forest (tree density = 76 to 109 trees ha−1) had significantly fewer trees than primary forest (168 to 192 trees ha−1; Srinivasan, 2023; Srinivasan *et al.,* 2025). The opening up of the canopy in response to logging resulted in logged forest being, on average, 2°C hotter than primary forest at mid-day, at ~18°C versus ~16°C in primary forest; this effect does not persist during the night, when logged forest is actually slightly cooler than primary forest (Aggarwal *et al.,* 2023; Chanda *et al.,* 2023; Figure 2a). Maximum temperatures (above the 95% quantile of measurements) in logged forest were 5.8°C higher than in primary forest (Aggarwal *et al.,* 2023), a staggering increase in mid-day ambient temperature. At this study site, therefore, not only climate change is causing overall increases in temperature in both primary and logged forest, but logging also exacerbates the impacts of climate change, compounding environmental warming. Whether the observed increase in mean and maximum temperatures imposes physiological constraints on birds inhabiting logged forest at this study site is yet unknown – species might adapt to degradation *via* behavioural and/or morphological change. Further, increases

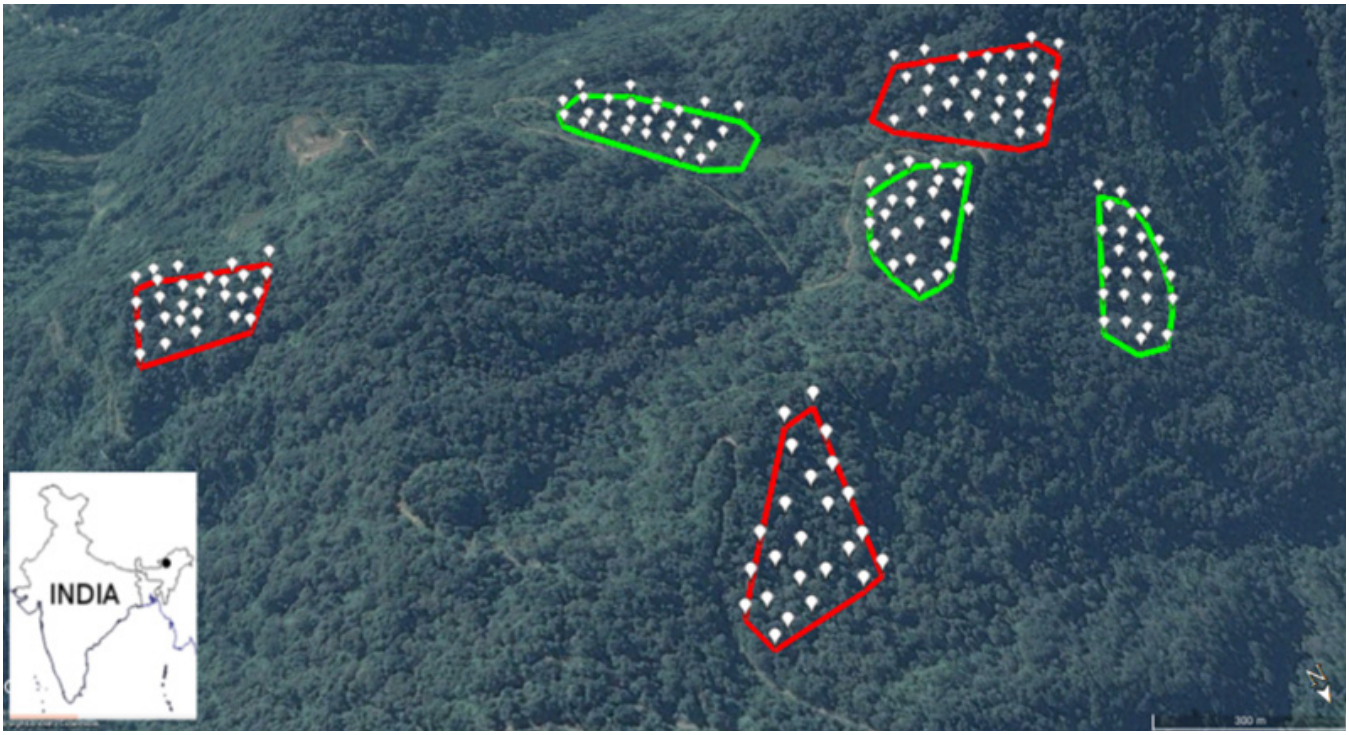


Figure 1: Map showing primary forest sampling plots (outlined in green) and logged forest sampling plots (outlined in red) at 2000m ASL. Each white marker shows the location of a mist net. The inset shows the study site in Eaglenest Wildlife Sanctuary, Arunachal Pradesh, India.

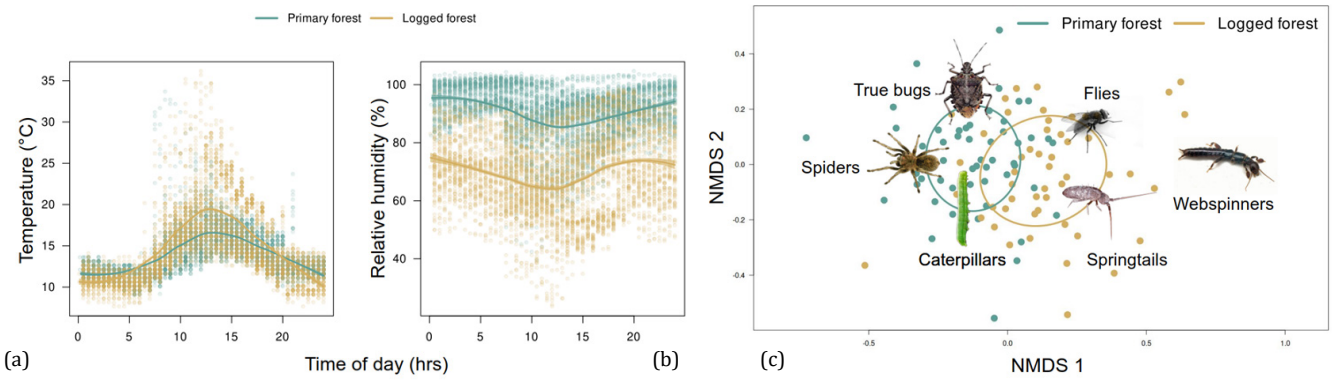


Figure 2: Changes in (a) temperature and (b) humidity and arthropod community composition with selective logging. Panel (c) depicts arthropod community differences between primary and logged forest using a Non-metric Multidimensional Scaling analysis. Redrawn from Aggarwal *et al.* (2023). All images CC BY 3.0.

in maximum temperature (*e.g.,* number of days experienced above a certain threshold) rather than mean temperature might be more influential in determining stress to species and species responses (Román-Palacios & Wiens, 2020). Similar synergistic interactions have been documented across tropical forests in Amazonia, Southeast Asia, and Africa, where degraded habitats amplify exposure of forest organisms to climatic extremes and reduce ecological resilience (Senior *et al.,* 2017; De Frenne *et al.,* 2019). More work is needed to understand how species' morphologies or time-activity budgets might be changing as a result of warming (*e.g.,* Buchholz *et al.,* 2019; Jirinec *et al.,* 2021). Logged forest is, however, consistently 20% less humid than primary forest (Aggarwal *et al.,* 2023). It is likely that this loss of the canopy buffering effect (Senior *et al.,* 2017; De Frenne *et al.,* 2019) in logged forest has some direct physiological consequences for birds, as well as indirect impacts through altered arthropod prey abundance and composition, especially because arthropods are extremely vulnerable to overheating and desiccation (Ghosh-Harihar, 2013). Arthropod communities do show significant compositional shifts, with foliage-dwelling Lepidoptera, Coleoptera, Hemiptera and Araneae—the primary orders consumed by invertivorous birds (Aggarwal *et al.,* 2023; Figure 2b)—declining steeply in abundance with logging, with a concomitant increase in aerial Dipteran abundance (Aggarwal *et al.,* 2023; Figure 2b). Comparable shifts in arthropod abundance and community composition following forest degradation have also been reported from Neotropical and Southeast Asian forests, with declines in foliage arthropods frequently cascading to higher trophic levels such as insectivorous birds (Ewers *et al.,* 2015; Planillo *et al.,* 2021).

Changes in the abiotic and biotic environment(s) for understorey birds lead to potentially opposite predictions for foraging behaviour. Higher temperatures might inhibit foraging because of costs associated with thermal stress, and lower resource abundance might require birds to invest more time in foraging for scarcer food. In fact, birds spend about 10% more time foraging in logged forest, indicating that, at the current magnitude of environmental change in response to logging, resource declines might be more important in influencing foraging behaviour than

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ambient temperatures per se (Aggarwal *et al.,* 2023). Consistent with declines in the abundances of foliage-dwelling arthropods and increases in the abundance of flies in logged forest, foliage-gleaning birds had higher foraging success (prey capture rates) in primary forest, while the opposite was true for sallying species that capture flying insects on the wing (Aggarwal *et al.,* 2023). Increased foraging effort in logged forest mirrors behavioural responses documented in tropical insectivorous birds elsewhere, where declining prey availability forces birds to allocate more time to food acquisition despite elevated thermal stress (Hamer *et al.,* 2015; Powell *et al.,* 2015). Similar guild-specific responses to altered prey communities have also been observed in Amazonian and African forests, with aerial salliers sometimes benefiting from increases in flying insects in disturbed habitats while foliage gleaners decline (Arcilla *et al.,* 2015; Stratford & Stouffer, 2015).

In parallel, research on (winter) multi-species social behaviour indicates other mechanisms through which birds might adapt to altered prey availability through plasticity in social foraging. Mixed-species flocks (MSFs) are cohesive associations of multiple, mostly insectivorous, bird species that feed and move together (Sridhar *et al.,* 2012). Within MSFs, species exchange benefits such as reduced predation risk and enhanced access to resources (Sridhar *et al.,* 2009). MSFs do persist in selectively logged forests with the same species composing them, but with altered interspecific associations and species-specific relative abundance compared with MSFs in primary forest (Borah *et al.,* 2018). Species' importance in flock structuring and the strength of associations between species pairs change with logging (Borah *et al.,* 2018). This could be because of the changes in the relative abundances of flocking species in response to logging or because of changes in the propensity to flock in an altered environment (Sridhar & Sanker 2008). The persistence of mixed-species flocks in logged forest is consistent with studies across the tropics showing that flocking behaviour can buffer species against increased predation risk and reduced resource availability in disturbed habitats (Sridhar *et al.,* 2009; Mokross *et al.,* 2014). More broadly, behavioural plasticity and cooperative information-sharing are increasingly recognised as important mechanisms enabling species to persist in rapidly changing environments, particularly in structurally altered tropical forests (Buchholz *et al.,* 2019; Goodale *et al.,* 2020).

Therefore, changes in the structure and composition of MSFs with logging might actually be beneficial rather than maladaptive. One explanation for such a pattern might be that logging-induced reduction in prey availability might increase the importance of associating with species that enhance resource access for other species in MSFs, leading to changes in association networks. Such plasticity in social behaviour might allow MSF participants to at least partially overcome resource constraints in logged forest (Borah *et al.,* 2018). Indeed, analysis of survival rates of MSF participants versus solitary foragers indicates that MSF participants are able to maintain survival rates even in logged forest, while solitary foragers that never join MSFs show 30% declines in survival (Srinivasan, 2019; Figure 3). This result might also arise from the fact that large species decline in logged forest and could be much less likely to participate in MSFs, thereby introducing a bias in the data. However, on examining the species that were included in the comparison (ranging in size from ~5g to ~71g), the three largest species (Streak-breasted Scimitar-Babbler *Pomatorhinus ruficollis* Hodgson; ~32g, Rusty-fronted Barwing *Actinodura egertoni* Gould; ~36g and Chestnut-crowned Laughingthrush *Trochalopteron erythrocephalum* Vigors; ~71g) in fact participated in MSFs (Srinivasan, 2019).

I further constructed multi-species inter-individual social networks within MSFs (by observing associations between uniquely colour-ringed individuals of different species). These networks revealed two distinct flock types. The first was led by the Rusty-fronted Barwing (*Actinodura egertoni*; Figure 4); in these MSFs the same individuals of the territorial Rusty-fronted Barwing associated consistently with the same individuals of White-breasted Parrotbill (*Psittiparus ruficeps*) and Black-crowned Scimitar-Babbler (*Pomatorhinus ferruginosus*) over days and weeks (Bharadwaj *et al.,* 2025b). The second MSF type was led by the Yellow-throated Fulvetta (*Schoeniparus cinereus* Blyth) and included as flock participants Rufous-capped Babblers (*Cyanoderma ruficeps* Blyth), Golden Babblers (*Cyanoderma chrysaeum* Blyth) and Grey-cheeked Warblers (*Phylloscopus poliogenys* Blyth). Unlike in the Rusty-fronted Barwing groups, however, individual membership in the Yellow-throated Fulvetta MSFs seemed more unstructured, with different individuals of participant species assorting with each other in MSFs across days and weeks (Bharadwaj *et al.,* 2025b). The contrast between highly structured Rusty-fronted Barwing and relatively unstructured Yellow-throated Fulvetta MSFs suggests that the mechanisms of MSF formation and the benefits exchanged between individuals within MSFs might vary across species. Rusty-fronted Barwing MSFs were more common in logged rather than in primary forest, likely because logging leads to an increase in the density of bamboo in the understorey and midstorey, a preferred foraging substrate for the constituent species (Ali & Ripley, 1972). The relative importance of escaping predation versus overcoming resource scarcity in logged forest might differ between species, resulting in consistent inter-individual associations in one MSF type but not in the other (Bharadwaj *et al.,* 2025b).

Declines in prey abundance in selectively logged forest can have implications not only for non-breeding multi-species social behaviour, but also for the structure of breeding bird communities. In most ecological communities, mass-abundance scaling is a near-universal property, where within a trophic level, local abundance (or density) is negatively correlated with body mass. In primary forest, the classic inverse scaling of abundance with body size might reflect the often-hypothesised "energy equivalence" across species, which posits that all species, regardless of body size, use the same absolute amount of energy (Carbone *et al.,* 2007). In other words, many individuals of a small species access the same amount of energy from the environment as do fewer individuals of a large species. In logged forest, however, this mass-abundance scaling is altered in the understorey passerine bird community, with large species declining in abundance and small species "compensating" with abundance increases (Srinivasan, 2013), altering the way in which energy is partitioned between species. In logged forest, the understorey bird community is numerically dominated by small insectivores at the expense of large species; the latter tend to be vulnerable to almost all forms of global change (Ausprey *et al.,* 2023). This size-dependent persistence in logged forest indicates that logging (and the consequent reduction in prey availability) acts as a filter, selectively retaining small species while excluding larger ones, a finding reinforced by the results of Chand *et al.* (2023). Smaller species have lower absolute energy requirements (per individual) and might also be able to dissipate body heat better (Jirinec *et al.,* 2021), making them potentially better adapted to resource-poor and warmer logged forest. The disproportionate loss of large-bodied species in logged forest parallels a global pattern whereby large tropical vertebrates are particularly sensitive to anthropogenic disturbance and climatic stress (Dirzo *et al.,* 2014; Ausprey *et al.,* 2023). Similar shifts towards communities dominated by smaller-bodied species have been reported from degraded forests in the Amazon and Southeast Asia, potentially reflecting energetic constraints and the greater thermal tolerance of small-bodied taxa (Newbold *et al.,* 2013; Jirinec *et al.,* 2021).

Differences in species traits such as body mass, social behaviour—and in mountains—elevational range can mediate changes in community structure and composition (*i.e.*, the relative abundances of species in a community) *via* demographic vital rates such as survival. All montane species have distinct elevational ranges, with well-defined lower (warm-edge) and upper (cold-edge) elevational range limits, defined at least in part by species-specific thermal tolerances (Sheldon & Tewksbury, 2014); for instance, high elevation species are better adapted to colder temperatures and greater seasonality than their low-elevation counterparts, which tend to be warm-

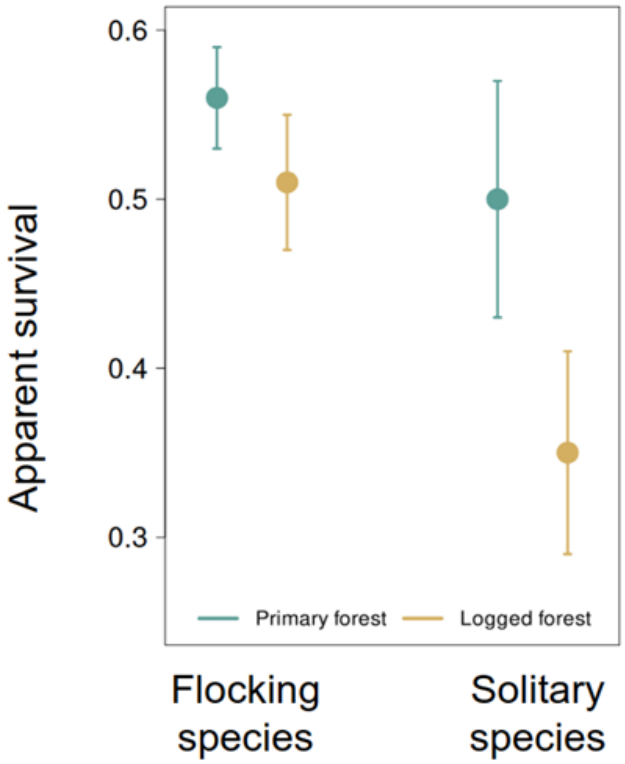


Figure 3: Species that participate in mixed-species flocks show no evidence of decline in survival rates with selective logging. On the other hand, solitary foragers, on average, decline in survival by 30% in logged forest (redrawn from Srinivasan, 2019). Error bars represent standard errors.



Figure 4: A Rusty-fronted Barwing (*Actinodura egertoni*) ringed with a unique combination of colour rings (yellow-red), enabling individual identification via direct observations. The Rusty-fronted Barwing leads mixed-species bird flocks that also contain White-breasted Parrotbill (*Psittiparus ruficeps*) and Black-crowned Scimitar Babbler (*Pomatorhinus ferruginosus*). Photograph: Aman Biswakarma.

adapted (Londoño *et al.,* 2017). An analysis of citizen-science (eBird) data from EWS shows that many species in the Eastern Himalaya are shifting their breeding elevational ranges upslope, presumably tracking climate-induced temperature change (Girish & Srinivasan, 2022), as has been shown in other tropical mountain ranges (Freeman *et al.,* 2018). As species shift their ranges upwards, they might encounter either primary forest or logged forest at higher elevations. Whether populations shifting upslope colonise primary forest or significantly hotter, drier and resource-poor logged forest at higher elevations might

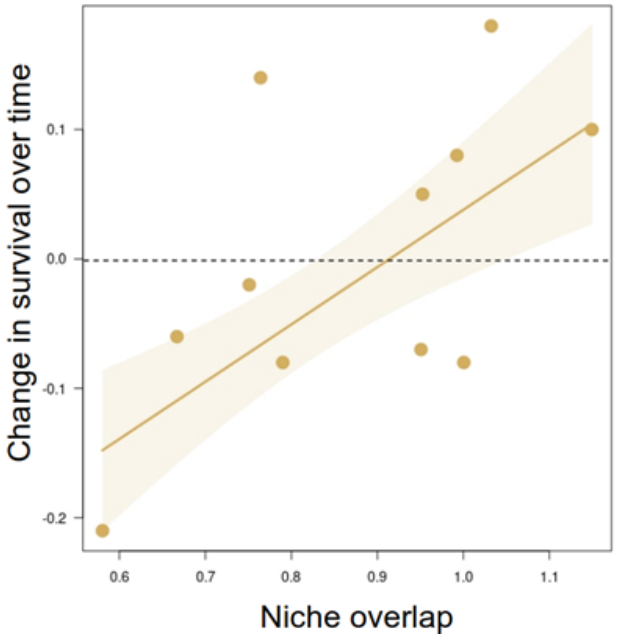


Figure 5: Species with low overlaps in temperature-humidity niches between primary and logged forest also show steep survival declines in logged forest. Those with high niche overlaps tend to have more stable survival rates. Data from Bharadwaj *et al.* (2025a).

have profound implications for survival. Upslope range shifts in response to warming temperatures have now been documented across most major tropical mountain systems, including the Andes, African mountains, and Southeast Asian highlands (Chen *et al.,* 2011; Freeman *et al.,* 2018). However, the ability of montane species to track suitable climates depends critically on the availability of intact habitat along elevational gradients, making continued forest degradation a major constraint on climate adaptation globally (Sekercioglu *et al.,* 2008; Guo *et al.,* 2018).

Long-term demographic monitoring in mid-elevation species-rich forests (see Figure 1) shows a clear correlation between species-specific elevational ranges and long-term survival trends (Srinivasan & Wilcove, 2021). To examine this across species, I examined how the survival trend (slope of survival with time) was related to the difference in the midpoint of the species' elevational range from 2000m ASL (the elevation of the study site). Populations of low-elevation species moving upslope towards 2000m ALS into primary forest showed increases in survival rates over time (Srinivasan & Wilcove, 2021). In contrast, higher-elevation species moving upslope away from 2000m ASL showed long-term survival declines, emphasising the importance of retaining primary forest across entire elevational gradients to allow species to move and adapt in response to warming (Srinivasan & Wilcove, 2021). However, such a correlation between survival trends and elevational ranges was not present for populations of the same species moving upslope into or away from logged forest (Srinivasan & Wilcove, 2021). This was surprising, because I expected that relationships between elevational range and survival declines (or at least, failure to maintain survival rates) would be much more stark in logged forest in which abiotic and biotic environments for understorey birds are significantly altered (Figure 2). To understand why survival trends in logged forest did not conform to expectations, I turned to how microhabitat availability might differ in primary and logged forest, and how this might influence the body condition and survival rates of understorey insectivorous bird species.

To do so, I separately characterised the temperature-humidity niches of species in primary and logged forest, and quantified species-specific overlaps in temperature-humidity niches

between primary and logged forest (Bharadwaj *et al.,* 2025a). I found a strong correlation between the degree of niche overlap between habitats and body mass and survival declines in logged forest (Bharadwaj *et al.,* 2025a; Figure 5). Species that had low temperature-humidity niche overlaps between primary and logged forest showed the greatest declines in body mass and survival rates over time (Bharadwaj *et al.,* 2025a). Low niche overlaps between undisturbed and disturbed habitats might arise either because (a) particular microhabitats are simply not available in hotter and drier logged forest, or (b) species were unable to alter their foraging microhabitats or foraging times in logged forest towards cooler and wetter conditions (Bharadwaj *et al.,* 2025a). In contrast, species that maintained similar thermal–moisture conditions across both habitats had stable body masses and survival rates. The relationship between microclimatic niche overlap and demographic stability supports a growing body of work demonstrating that fine-scale thermal and moisture refugia are critical determinants of persistence in tropical ectotherms and endotherms alike (Scheffers *et al.,* 2014; De Frenne *et al.,* 2019). Increasingly, studies suggest that species unable to track suitable microclimates within degraded landscapes experience reduced body condition, lower survival, and elevated extinction risk under ongoing climate change (Zellweger *et al.,* 2020; Jirinec *et al.,* 2021).

Therefore, species unable to behaviourally or physiologically overcome logging-induced microclimatic change presumably suffered energetic deficits that manifested as declines in body condition and likely therefore reduced survival, highlighting the synergistic and compounding effects of climate warming and habitat degradation. Some limitations of this approach might be that the species-specific climatic niches were calculated only from data at the field site and do not necessarily represent the total physiological niche breadth of the species across its entire range. Further, climate generalists would have lower niche overlaps simply because they can persist in both primary and logged forest, and preferred microclimates are not available after logging. On the other hand, microclimate specialists might only occupy those parts of logged forest that still have preferred microclimates, thereby exhibiting high temperature-humidity niche overlaps.

Here, I integrate information on the abiotic (temperature and humidity microhabitats) and biotic (prey availability) environments for Eastern Himalayan understorey birds to attempt to understand how changes to these factors as a result of selective logging might influence species' behaviour (foraging, multi-species sociality), body condition (mass) and demography (apparent survival). Overlaid on these impacts are long-term climate-driven changes in the environment, elevational range shifts, and interactions with habitat degradation to influence species' body condition and demography. Selective logging and climate change act in concert to modify both the physical and biological environment; canopy loss reduces thermal buffering of microhabitats, potentially leading to increased energetic costs; social and behavioural responses can ameliorate, but might not entirely eliminate, these pressures. Species persistence is determined by the capacity to maintain ecological niches thermal, trophic, or social across environmental gradients. Small, behaviourally flexible species capable of exploiting specific microhabitats or forming cohesive mixed-species groups fare better than large, specialised species dependent on stable microclimates.

Taken together, these findings reinforce an emerging global consensus that biodiversity responses to climate change cannot be understood independently of land-use change, especially in tropical ecosystems where species occupy narrow thermal niches (Mantyka-Pringle *et al.,* 2012; Guo *et al.,* 2018). The results also support broader calls for conservation strategies that simultaneously preserve habitat structure, microclimatic refugia, and elevational connectivity in order to maximise resilience of tropical biotas under accelerating global change (De Frenne *et al.,* 2019; Rahbek *et al.,* 2019).

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CONFLICT OF INTEREST

The author declares no competing interests.

DATA AVAILABILITY

This is a review article synthesising 15 years of research. Data for individual papers can be accessed from the DOIs cited in each paper.

AUTHOR CONTRIBUTIONS

The author conceptualised or co-conceptualised the research from the study area cited in the manuscript, collected or co-collected the data from the study area, analysed or co-analysed the data and wrote this manuscript.

ETHICS STATEMENT

Permission to handle wild birds was provided by the Office of the Principal Chief Conservator of Forests, Arunachal Pradesh Forest Department, vide scientific research permit number CWL/Gen/998/2023/Pt-IX/4190-93.

ORIGINALITY STATEMENT

This is a synthesis of original research work.

USE OF GENERATIVE AI STATEMENT

No generative AI tools were used in any form in the preparation of this manuscript.

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