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Warming threat compounds habitat degradation impacts on a tropical butterfly community in Vietnam

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ABSTRACT

Species are threatened globally by multiple and often synergistic environmental changes including habitat loss, fragmentation and climate change. However, how these changes act in concert is poorly understood, especially in the tropics where the vast majority of biodiversity resides. Here, using a unique dataset covering 10 years of butterfly surveys (2003–2013) at Tam Dao National Park in northern Vietnam, we examined the combined impacts of habitat degradation (following intensive infrastructure development in 2005) and the possible threat of warming (extrapolating upon the relationship between natural climatic variation and community indices) for tropical butterfly communities. We found that both habitat degradation and warmer temperatures led to fewer narrow-range and forest-associated species comprising the sampled communities. Under projected climate change scenarios, the impact of warming was comparable to habitat degradation with respect to community change, and degraded forest communities were projected to shift towards cosmopolitan and non-forest species even more. The tropics have been heavily deforested world-wide and also suffer from heavy impacts of degradation and fragmentation, especially road construction. Warming will compound habitat degradation impacts such that the conservation of tropical biodiversity will require addressing these multiple global changes simultaneously.

1. Introduction

Climate change is anticipated to have large and significant impacts on biodiversity world-wide (Pacifici et al., 2015; Urban, 2015). However, most research on the subject has taken place outside the tropics (Parmesan, 2006; Pacifici et al., 2015). Thus despite being home to the majority of global biodiversity, considerable uncertainty persists as to the possible impacts of climate change in the tropics (Bonebrake, 2013). Recent physiological and gradient based models have highlighted possible high vulnerabilities of tropical species to climate change, particularly for ectotherms (Deutsch et al., 2008; Bonebrake and Deutsch, 2012; Corlett, 2012; Araújo et al., 2013; Sunday et al., 2014). Many studies have documented upslope and poleward shifts of species distributions, particularly throughout North America and Europe (Chen et al., 2011; Breed et al., 2013). Yet, empirical evidence for any climate change impacts in the tropics is scant, though a few recent studies have demonstrated strong upward shifts in the elevation of tropical montane species (Chen et al., 2009; Freeman and Freeman, 2014).

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There are innumerable conservation threats to tropical forests aside from climate change, especially habitat loss and degradation, which threaten biodiversity hotspots in tropical regions (Brodie et al., 2012; Laurance et al., 2014a). One of the biggest threats to tropical biodiversity is forest loss and disturbance, especially via agricultural expansion (Gibson et al., 2011; Laurance et al., 2014a). Road building is a major driver of this forest loss and is expected to dramatically increase in extent this century (Laurance et al., 2014b). Roads themselves have large impacts on tropical species and encourage exotic species invasion, increase edge effects, cause vehicle-related mortality and create sources for chemical and nutrient pollution (Laurance et al., 2009).

Multiple additive and interacting threats are projected to have especially strong, non-additive and detrimental impacts on species diversity (Hof et al., 2011; Parmesan et al., 2013). For example, habitat fragmentation has had the most impact in areas of high temperature and precipitation change over the past century (Mantyka-Pringle et al., 2012). Additionally, climate change impacts are projected to be compounded in biomes with low habitat intactness (Eigenbrod et al., 2015). Climate change could also worsen land-use change impacts on bird and mammal species by 20%–40% globally (Mantyka-Pringle et al., 2015). However, how the combined effects of climate change and habitat degradation will affect biodiversity generally, especially in the tropics, remains uncertain. A lack of long-term data in tropical biodiversity-rich communities (Bonebrake et al., 2010; Corlett, 2011) has limited our capacity to understand these critical conservation threats.

Here we take advantage of a unique long-term monitoring programme to examine how a large-scale habitat degradation event and variation in environmental temperatures altered butterfly communities. In the late 1980s and early 1990s, a series of studies conducted on the butterfly fauna of Tam Dao National Park in northern Vietnam showed that many species were confined to forest habitats and that forest habitats tended to harbour a greater proportion of locally distributed, non-cosmopolitan species than open and disturbed habitats (Spitzer et al., 1993, 1997). Elsewhere in the park, butterfly communities were surveyed from 2003 to 2013 along six 700 m transects across forest and open habitats (Vu and Yuan, 2003; Vu et al., 2015). In 2005, development and road construction around the town of Tam Dao disrupted much of the habitat within these transects (Fig. 1). This provided an opportunity to examine the impacts of habitat degradation by comparing butterfly communities pre and post disturbance. Specifically we evaluated the impacts on butterfly communities using the forest association and distribution (locally distributed vs. regionally or globally widespread) species characterizations provided by Spitzer et al. (1993). The results presented here provide an examination of possible cumulative impacts of warming and habitat degradation on a species rich and biodiverse tropical butterfly community.

2. Methods

2.1. Study site and sampling

Butterfly surveys took place in Tam Dao National Park (21.3°N, 105.4°E) (Fig. 1). Six transects of 700 m were set up in multiple habitats which can be classified into forest (three transects: bamboo forest, open road in forest, and secondary forest) and open habitats (three rural transects). The forest sites are a mixture of primary and secondary forest with a history of disturbance (e.g. logging, though protected since 1977 and designated a National Park in 1996) while the rural sites represent a mixture of small croplands and residential properties (Fig. 2; Vu and Yuan, 2003; Vu, 2009). All transects were sampled between 2003 (but the bamboo forest sampling began in 2005) and 2013 though no surveys were conducted 2009–2011. Detailed descriptions of transects are available in Vu (2009) and Vu et al. (2015). Transects were surveyed during the wet season from May to November. However, sampling effort was focused in June (early wet season) and October (late wet season), and all sampled years conducted surveys in each of these months (but in 2004 only a July survey was conducted) with varied effort across years for May, Aug, Sept and Nov (Table A1). Over the course of the study period we conducted 574 surveys across the six transects.

One of the authors (LVV) conducted most of the surveys himself over the 10-year period though trained research assistants have also taken part in surveys. Each survey consists of a walking transect where all individuals within 10 m of the surveyor are identified and recorded across the 700 m transect. Most species could be identified on the wing but netting and photography were necessary for some species (e.g. some Lycaenidae and Hesperiidae). Further details on the survey approach are available in Vu et al. (2015).

2.2. Observed changes in community composition

Major development in Tam Dao occurred in 2005 when roads were built and paths paved directly upon or close to the established transects (Vu et al., 2015). Development was not even across all transects—but in general, rural transects experienced paving while forest transects had extensive path widening into roads (Fig. 2). This provided a unique opportunity to compare butterfly communities before the development event (in 2003 and 2004) and after (2005–2013). For the community analysis we pooled survey data for each year and transect and used non-metric multidimensional scaling (NMDS) to ordinate and examine similarities and differences between forest and open habitat communities. However, we kept the bamboo forest distinct given its unique community properties as highlighted in Vu et al. (2015). Using the NMDS we also examined pre and post road building communities. Butterflies not identified to species level were excluded from analysis. The NMDS plot was based on Bray–Curtis similarities.