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How individual links affect network stability in a large-scale, heterogeneous metacommunity

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Abstract. Elucidating how dispersal and landscape connectivity influence metacommunity stability will shed light on natural processes structuring ecosystems and help prioritize conservation actions in an increasingly fragmented world. Much of the theoretical and mathematical development of the metacommunity concept has been based on simplified experimental systems or simulated data. We still have limited understanding of how variation in the habitat matrix and species-specific differences in dispersal ability contribute to metacommunity dynamics in heterogeneous landscapes. We model a metacommunity of rainforest mammals in Borneo, a tropical biodiversity hotspot, where protected areas are increasingly isolated by ongoing habitat disturbance and loss. We employ a combination of hierarchical models of local abundance, circuit-theory-based dispersal analysis, and metapopulation models. Our goal was to understand which landscape links were the most important to metapopulation persistence and metacommunity stability. Links were particularly important if they were short and connected two large patches. This was partly because only the very shortest links could be traversed by poorly dispersing species, including small herbivores such as chevrotains (*Tragulus* spp.) and porcupines. Links that join large patches into a "super-patch" may also promote island–mainland rather than Levins-type metapopulation dynamics for good dispersers, particularly large carnivores such as clouded leopards (*Neofelis diardi*) and sun bears (*Helarctos malayanus*), reducing metapopulation extinction risk and thereby enhancing metacommunity stability. Link importance to metacommunity stability was highly correlated between heterogeneous and homogeneous landscapes. But link importance to metapopulation capacity varied strongly across species, and the correlation between heterogeneous and homogeneous landscape matrix scenarios was low for poorly dispersing taxa. This suggests that the environmental conditions in the area between habitat patches, the landscape matrix, is important for assessing certain individual species but less so for understanding the stability of the entire metacommunity.

Key words: biodiversity hotspot; Borneo; camera trap; circuitscape; connectivity; dispersal; fragmentation; habitat corridors; metapopulation capacity; network; protected areas.

Introduction

The metacommunity concept encapsulates many of the recent advances in ecology related to the interplay of diversity across spatial scales. For example, metacommunity ecology has demonstrated important ways in which dispersal among numerous patches affects both local and regional diversity, as well as the stability of the entire network (Leibold et al. 2004, Holyoak et al. 2005, Logue et al. 2011). The vast majority of quantitative examinations of metacommunities employ modeling of simulated data (e.g., Aiken and Navarrete 2014), experimental mesocosms (e.g., Cadotte 2006, Howeth and Leibold 2010, 2013), or small-scale natural communities such as rock pools (e.g., Vanschoenwinkel et al. 2013, Simonis and Ellis 2014) or bryophyte patches (e.g., Astrom and Part 2013). A greater understanding of larger-scale metacommunity systems in nature remains a critical need (Logue et al. 2011, Vanschoenwinkel et al. 2013, Simonis and Ellis 2014).

Our ability to apply metacommunity concepts to many larger-scale, particularly terrestrial, systems is limited by at least two important knowledge gaps. First, we need a much better understanding of whether and how species-specific differences in dispersal affect the structure of metacommunities (Logue et al. 2011, De Bie et al. 2012). Such differences can arise from the organisms varying in physiological traits related to dispersal (Van De Meutter et al. 2007, De Bie et al. 2012, Vanschoenwinkel et al.

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