Biological Conservation 221 (2018) 257–260

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Perspective

Using landscape fragmentation thresholds to determine ecological process targets in systematic conservation plans

Philip G. Desmet*

Institute for Coastal and Marine Research, Department of Zoology, Nelson Mandela University, PO Box 77000, Port Elizabeth 6031, South Africa

ARTICLE INFO

Keywords:
Systematic conservation planning
Ecological processes
Biodiversity target
Conservation goal
Fragmentation threshold
Percolation

ABSTRACT

Systematic conservation planning requires that quantitative targets be set for both biodiversity pattern and processes. While the challenge of setting quantitative representation targets has been well addressed in the literature, guidelines for conceptualising and setting process targets are lacking. Process targets can be defined as the minimum amount of natural habitat that must remain to ensure the long-term survival of the majority of species. While a representation target may represent the majority of species in a landscape, this target often falls far short of conserving processes necessary for the persistence of these species. This paper explores the potential for landscape ecology research to provide useful insights into developing process targets by relating critical thresholds in habitat amount to the probability of population persistence. It is proposed that these thresholds provide a basis for developing generic top-down ecological process targets in conservation planning. The percolation threshold, theoretically defined at 59%, is increasingly used to inform research into ecological state-shifts and ecosystem resilience. This threshold may provide a basis for developing top-down process targets in instances where comprehensive bottom-up spatial data on individual ecological processes is unavailable. In the context of ongoing global habitat loss, this approach provides a pragmatic, but also potentially biologically meaningful, way of incorporating defensible and quantitative ecological process targets or biodiversity persistence goals into conservation plans.

1. Introduction

Habitat loss is the primary driver of biodiversity loss on the planet today (Baillie et al., 2004). In this context of ongoing habitat loss, immediate conservation choices have to be made regarding how much and which areas need to be set aside in order to conserve representative and persistent examples of the planet's biodiversity. Such choices should be based on sound scientific evidence and reasoning, but data to support this is often unavailable. Thus, a careful balance is needed between scientific certainty and pragmatic decision-making based on sound ecological logic. The well-established concept of Systematic Conservation Planning has been used for many years to assist in making a range of conservation decisions in a spatially explicit manner (Pressey et al., 2007). Conservation planning is "the process of locating, configuring, implementing and maintaining areas that are managed to promote the persistence of biodiversity and other natural values" (Pressey et al., 2007). Systematic conservation planning is based on two underlying principles: 1) the principle of representation aims to conserve a sufficient sample of the full variety of biodiversity, while 2) the principle of persistence aims to conserve the necessary ecological and evolutionary processes that allow biodiversity to persist over time (Margules and Pressey, 2000). In order to achieve these goals, systematic conservation planning requires that quantitative targets be set for both biodiversity pattern (representation) and ecological processes (persistence).

Despite acknowledged limitations of quantitative conservation targets (Carwardine et al., 2009; Pressey et al., 2003), they remain common practice for conservation in general (Aichi biodiversity targets; CBD, 2010) and systematic conservation planning in particular (Carwardine et al., 2009). Representation targets for species and ecosystems have generally been well-researched (Pressey et al., 2007) and standard methods for determining these targets are becoming established (Rondinini and Chiozza, 2010; e.g. Desmet and Cowling, 2004). However, these representation targets will be ineffective in the long-term unless the ecological processes that maintain these patterns are also conserved. Unfortunately, methods for setting quantitative targets for ecological process are still unresolved. Conserving ecological processes means not only conserving the area where a species currently occurs, but also sufficient of its habitat so that it will continue to survive, now and into the future. From a conservation planning

* 84 Clearwater Road, Lynnwood Glen, Pretoria 0081, South Africa.
E-mail address: drphil@ecosolgis.com.

https://doi.org/10.1016/j.biocon.2018.03.025
Received 15 May 2017; Received in revised form 26 January 2018; Accepted 20 March 2018

perspective, this involves determining the minimum amount and configuration of area required to conserve these ecological processes.

The most widely used approach to incorporating ecological processes into systematic conservation plans is to map and set targets for individual elements of ecological processes (such as corridors, ecotones, climate refugia, migration routes etc.) (e.g. Pressey et al., 2003). However, this comprehensive, 'bottom-up' approach requires not only that the relevant ecological processes can be identified and understood, but also that empirical data be available on the spatial components of these processes (Pressey et al., 2007). The reality in most regions of the world is that this type of data is non-existent. Given the time scales and budgets under which conservation planning operates, it is unlikely that the required research will be achieved soon. This lack of data fundamentally limits the incorporation of individual process elements into systematic conservation plans.

This paper presents an alternative approach for incorporating ecological processes into conservation planning. It is proposed that, based on current ecological understanding, it is possible to use a generalised 'top-down' target for a whole landscape that will define the minimum amount of natural habitat required to secure a suite of ecological processes. This paper explores the potential for landscape ecology to provide useful insights into developing ecological process targets by relating the amount and structure of remaining habitat to critical thresholds in the probability of population persistence.

2. Ecological processes and landscape ecology

Ecological processes include both biological (e.g. survival, reproduction, dispersal and interaction) and abiotic (e.g. climate, geomorphological, pedological and hydrological) processes. Landscape ecology is a field of study that focuses on the interactions between spatial pattern and ecological processes (Mayer et al., 2016; Turner, 2005). It investigates how the spatial configuration of a landscape influences the populations and community dynamics of organisms (Collinge, 2001; Turner, 2005). Since habitat loss through land transformation is one of the primary threats to biodiversity globally, and a significant cause of fragmentation (Haddad et al., 2015), research into landscape ecology is highly relevant to spatial conservation planning. Conservation efforts aimed at conserving ecological and evolutionary processes require biologists to integrate understanding of landscape change, such as habitat loss and fragmentation, with responses of individual populations and species to these broad-scale modifications (Collinge, 2001). As noted by Mayer et al. (2016), the findings of landscape ecology have important implications for conservation policy and can be significant informants to conservation management decisions, especially under extensive land-use change, urbanisation and climate change.

Habitat fragmentation is defined as a loss of habitat that results in reduced patch size and increasing distance between patches (Andrén, 1994; Fahrig, 2003; Haddad et al., 2015). The largest-scale cause of habitat destruction and fragmentation is the expansion and intensification of human land-use (Millennium Ecosystem Assessment, 2005). The impacts of habitat loss on biodiversity are generally negative, but can vary widely according to the species sensitivity, their life history, mobility, spatial requirements, vulnerability to habitat edges, the character of the matrix, or, the spatial configuration of the preferred habitat (Collinge, 2001; Fahrig, 2003; Huggett, 2005; Pardini et al., 2010; Swift and Hannon, 2010; Villard and Metzger, 2014). A general trend, however, is a decline in population sizes and loss of species from the system as habitat is lost (Fahrig, 2013; Parker and Mac Nally, 2002). This is a result of a decrease in the amount of habitat available to organisms and a gradual break down in ecological processes.

3. Fragmentation and critical thresholds

Most fragmentation studies agree that the overall amount of remaining habitat accounts for almost all of the variation in observed population size in fragmented landscapes (Fahrig, 2013; Flather and Bevers, 2002; Villard and Metzger, 2014). The relationship between habitat loss and species persistence is generally negative, with a higher rate of species persistence where the amount of habitat remains high, and a lower rate of persistence where a large amount of habitat has been lost (Fahrig, 2013; Villard and Metzger, 2014). However, it has long been posited that this relationship is non-linear and that at some point, a threshold/s is reached below which the slope of the relationship becomes steeper and where the population crashes in response to a very small change in the amount of habitat (Huggett, 2005; Swift and Hannon, 2010, Villard and Metzger, 2014). Two broad thresholds are recognised in the literature, defined according to different causal factors (Swift and Hannon, 2010) (Fig. 1). Various terms have been used for these thresholds, so for the purposes of this paper they are defined as follows:

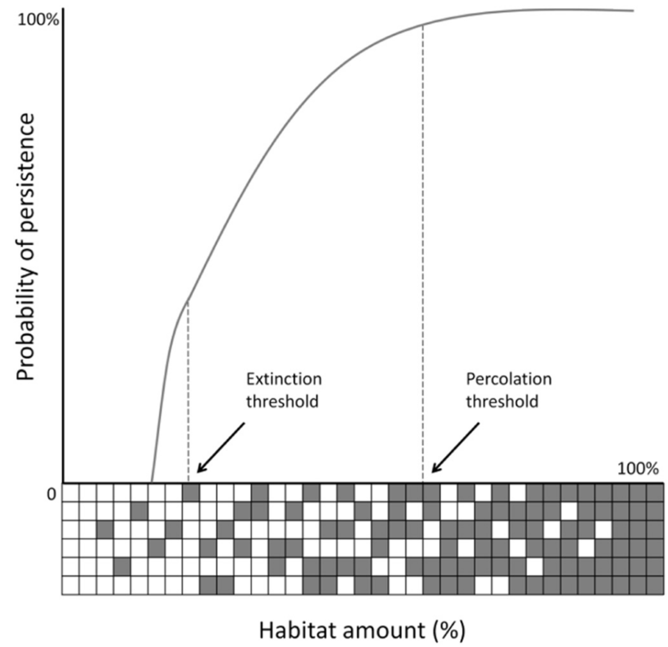

Fig. 1. A conceptual framework illustrating the potential extinction and fragmentation thresholds in relation to habitat loss.

The extinction threshold is the minimum amount of habitat required for a population of a particular species to survive in the landscape (Fahrig, 2002). This threshold emerged from meta-population theory and is the threshold below which a population is likely to go extinct. The extinction threshold is a result of change in intrinsic population demographic properties in response to habitat amount and structure. Below a certain low critical threshold of habitat amount, isolated populations of species are unable to persist. Reasons proposed for this threshold are related to Allee effects, such as inbreeding depression, increased vulnerability to stochasticity and disrupted social processes (Swift and Hannon, 2010). It is at this threshold that the ratio of mortality exceeds the rate of reproduction (or immigration), resulting in local extinctions (Fahrig, 2002). Andrén (1994) suggested that this threshold occurred at between 10 and 30% of original habitat remaining, a point at which habitat patches become smaller and more distant from each other. This has been widely tested empirically and although there remains uncertainty, there is some support for a threshold within this range (Swift and Hannon, 2010). This threshold has become known in the literature as the 20%-rule, the mean habitat amount at which the threshold is predicted to occur (Hanski, 2015).

The percolation threshold is related to habitat amount, configuration, condition and permeability. The identification of this threshold emerged from percolation theory and the resultant neutral landscape