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Research paper

To model the landscape as a network: A practitioner's perspective

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HIGHLIGHTS

- Landscape science increasingly applies graph theory to study landscape connectivity.
- We survey opinions on applying a network-analysis software in planning practice.
- Practitioners today lack analysis tools to communicate the importance of connectivity.
- Practitioners view network analysis as a potent tool in ecological communication.

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ABSTRACT

Recent years have shown a rapid increase in the number of published studies that advocate network analysis (graph theory) to ecologically manage landscapes that suffer from fragmentation and loss of connectivity. This paper studies the reasons, benefits and difficulties of using network analysis to manage landscape fragmentation in the practice of land-use planning. The results are based on interviews with thirteen municipal ecologists and environmental planners in Stockholm, Sweden, who had been introduced to a GIS-tool for network-based connectivity analysis. Our results indicate that fragmentation is not considered enough in municipal planning and demonstrate that none of the interviewed practitioners used systematic methods to assess landscape connectivity. The practitioners anticipate that network-level and patch-level connectivity measures and maps would help them to communicate the meaning and implications of connectivity to other actors in the planning process, and to better assess the importance of certain habitats affected by detailed plans. The main difficulties of implementing network-based connectivity analyses reported by the respondents related to the choice of focal species and the lack of model input in terms of landscape data and dispersal distances. The main strengths were expressed by the practitioners as graphical, quantitative and credible results; the ability to compare planning alternatives and to find critical sites in a more objective manner than today; and to relate local planning and ecology to the regional structure of the landscape. Many respondents stressed the role of fragmentation assessments in the endeavor to overcome current spatial mismatches of ecological and administrative scales.

1. Introduction

The field of landscape ecology has in the past two decades rapidly increased its awareness of the importance of connectivity for biodiversity conservation (Crooks & Sanjayan, 2006). Landscape connectivity is commonly defined as the degree to which the landscape facilitates or impedes the movement of species among resource patches (Taylor, Fahrig, Henein, & Merriam, 1993). A species will likely disappear from a landscape if its dispersal rates between habitat fragments are too low (Hanski, 1998). This poses a challenge on the planning of landscapes with high land-use intensity such as urban regions. As a result, the management of landscape connectivity has become a key measure to counteract negative impacts on biodiversity by habitat loss and fragmentation (Heller & Zavaleta, 2009), and landscape ecologists are recommending that connectivity assessments are included in activities such as land-use planning, conservation planning, environmental assessments and monitoring programs (Leitão & Ahern, 2002).

To support such assessments, several research papers have developed and validated quantitative connectivity metrics. (e.g., Calabrese & Fagan, 2004; Kindlmann & Burel, 2008). In particular, network analysis has been proposed to be user-friendly and to provide robust estimates of a species' sensitivity to land-use

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changes, given its low data requirements compared to other models (Bodin & Norberg, 2007; Bunn, Urban, & Keitt, 2000; Laita, Kotiaho, & Mönkkönen, 2011; Minor & Urban, 2008; Pascual-Hortal & Saura, 2006; Rayfield, Fortin, & Fall, 2011). Network analysis builds on a graph-based representation of habitat networks that offers a well-developed mathematical framework, which can be applied to quantify the impacts of management decisions on connectivity (see Section 1.1 and Urban, Minor, Treml, & Schick, 2009). There are several recent reviews on network analysis of landscape connectivity (Baranyi, Saura, Podani, & Jordán, 2011; Dale & Fortin, 2010; Galpern, Manseau, & Fall, 2011), and over 60 different network-based connectivity measures to choose from (Rayfield et al., 2011). Furthermore, Opdam, Steingrover, & Rooij (2006) argued that ecological network tools should be used in multi-actor planning processes to systematically provide planning alternatives that can be understood by different actors and to help them to focus on ecologically important spatial scales.

Given the large amount of research and suggestions for conservation and planning practice, there is a need for empirical investigation of the actual use, barriers and potential of network-based connectivity analysis in the perspective of practitioners. The purpose of this paper is to survey the opinions of municipal ecologists and environmental planners regarding landscape connectivity in land-use planning. In addition, we report their views and expectations on network analysis as a tool for analyzing and communicating landscape connectivity.

1.1. The network approach to analyze landscape connectivity

Many research methods in landscape ecology represent habitat for a focal species, or group of species, as patches in a surrounding matrix (cf. Forman, 1995). In network analysis, patches serve as network nodes that are inter-connected by links that indicate the potential for organism to move between patches, for example during dispersal (Fig. 1). Nodes are connected by links only when the distance between patches is below the maximum dispersal distance for the organism. Most applications of network analysis have used geographic distance (Galpern et al., 2011), whereas others have applied traversal cost thresholds based on the landscape permeability that a species experiences when dispersing through different types of land cover (e.g., Bunn et al., 2000). Links are not interpreted as structural features of the landscape such as corridors, but rather as connections between patches as a dispersing organism might experience them (Galpern et al., 2011). The resulting network models can be used to evaluate a species' functional

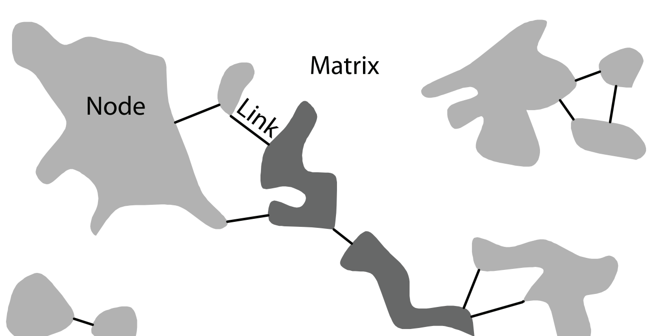

Fig. 1. A habitat network represented by nodes and links. Dark gray represents high betweenness centrality, i.e., that a patch is a necessary stepping-stone for organisms dispersing between other patches. Groups of connected nodes are called components, which imply that an organism inhabiting a node within the component can disperse to other nodes in the same component, although the probability may decrease if several intermediate nodes need to be traversed (cf. Pascual-Hortal & Saura, 2006).

response to the creation or removal of patches, or to compare different habitat networks (Bergsten, Bodin, & Ecke, 2013). It is a model of potential connectivity (sensu Calabrese & Fagan, 2004) because it does not represent actual observations of dispersal events. However, additional information about a species' biology and empirical observations can be used to validate or calibrate existing network models (Fall, Fortin, Manseau, & O'Brien, 2007; Minor & Urban, 2008).

1.2. Planning in Stockholm County

Stockholm County has a population of 2 million people distributed along an urban gradient in 26 municipalities. Like in urban regions elsewhere, municipal planners and policy makers in Stockholm County face the challenges posed by the competing demands on land. A major challenge is to protect biodiversity and ecological functions while simultaneously permitting further socioeconomic development. Swedish municipalities are obliged to establish municipal-scale land-use plans, which are strategic visions of the overall land and water use in the entire municipality (hereafter referred to as comprehensive plans). On a smaller scale they create detailed plans that cover a part of a city district. Detailed plans are legally binding and grant a building permit to the landowner (Nyström, 2003).

There is also a regional development plan developed by the council of Stockholm County, which uses the terms "green structure" and "green wedges" to communicate the regional importance of continuous large green areas (displayed in Fig. 2; Stockholm County Council, 2010). Most of the local administrations in the county have adopted this understanding of green wedges, and have the explicit ambition to protect the social and ecological values of the green wedges, when these extend over the municipal domain. However, smaller local habitats are either aggregated or excluded in the large green wedges.

Swedish county councils have very limited influence on the actual land-use planning. The full responsibility is on the municipal level, as a result of a nationally driven decentralization policy. Therefore, no actor is formally responsible to identify and manage ecological connections over municipal borders, which creates a large potential in the noncompulsory collaboration of adjacent municipalities. The decentralized planning also requires each municipality to have the capacity to monitor and manage its biodiversity. For this purpose, land-use planners are supported with ecological knowledge from ecologists and environmental planners within the municipal administration; these experts constitute the respondent group targeted by this study.

2. Methods

2.1. Case study: the respondents and the network tool

The background of this interview study is the development of a GIS-based network-analysis tool involving officials from 24 municipalities, a few regional authorities and two academic researchers in Stockholm County. During one year around 35 officials participated in up to four workshops, in which they met the researchers who designed the tool and learned the methodology of network-based connectivity analysis. Also, participants shared how they address connectivity issues as municipal officials, and their thoughts were considered by the researchers when designing the network tool. Among the topics discussed were: how the concepts of "connectivity" and "green structure" are defined and applied in planning practice and landscape theory, respectively; possibilities to apply the network tool to specific planning situations, in particular related to loss or creation of habitat; and the need for data habitat and species data.