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Contribution of connectivity metrics to the assessment of biodiversity – Some methodological considerations to improve landscape planning

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ABSTRACT

Land use change and the resulting physical and functional disconnection of ecological networks are some of the driving forces of biodiversity loss. Landscape planning and environmental assessments are essential instruments for addressing such problems. Methods for quantifying and predicting the impacts of fragmentation on biodiversity are needed, as are methods for deriving objectives and measures in the landscape planning process. While a number of different methodologies regarding network analysis and graph theory provide tools and methods for analyzing ecological networks, graph theory is a tool that may be helpful for reducing negative ecological impacts and finding appropriate solutions in the landscape planning process. These methods can be used as evaluation tools in the planning process, to analyze and visualize different possible scenarios for the participation process, or to define areas that are most important for measures to preserve or enhance biodiversity. Using the example of three target species in Saxony, the use of the Probability of Connectivity Index (PC) as a functional connectivity index for potential connectivity analysis is examined. Implementation and requirements for the planning process are described.

1. Introduction

Land use change and the resulting physical and functional disconnection of ecological networks are some of the driving forces of biodiversity loss (Zetterberg et al., 2010; Bundesamt für Naturschutz, 2004; Spangenberg, 2007; Reck et al., 2010). There are a number of different methodologies (see Fig. 1), including network analysis and graph theory, which are tools and methods for analyzing ecological networks (Pietsch and Krämer, 2009; Urban et al., 2009; Zetterberg et al., 2010; Rubio et al., 2015). Three different types of connectivity analysis can be classified according to data requirements and detail: structural, potential and actual connectivity (see Fig. 1) (Calabrese and Fagan, 2004).

Graph theory can be used with very few data requirements, thus making it easy to use and less sensitive than other methods to changes in scale (Urban et al., 2009; Bunn et al., 2000; Calabrese and Fagan, 2004; Urban and Keitt, 2001; Saura and Pascual-Hortal, 2007a; Pascual-Hortal and Saura, 2006a). It is a model for functional connectivity and can be used to analyze potential connectivity (Galpern et al., 2011). This means graph predictions have not been tested with observations of animal movements even though empirical information about species movement or dispersal can be used for analysis. Several graph-theoretic metrics related to classical network analysis problems such as the Probability of Connectivity (PC) or the Integral Index of Connectivity (IIC) have been developed, tested, and ecologically interpreted (Pascual-Hortal and Saura, 2006b; Wolfrum, 2006; Pietsch and Krämer, 2009; Gurrutxaga et al., 2011; Blazquez-Cabrera et al., 2014; Rubio et al., 2015).

In graph theory, a graph is represented by nodes (e.g., habitats) and links (dispersal). A link connects node 1 and node 2 (see Fig. 2) (Tittmann, 2003; Urban and Keitt, 2001; Saura and Pascual-Hortal, 2007a; Wolfrum, 2006). If the distance between two nodes is inside the dispersal or movement of a target species there is a functional connection or link (Pietsch and Krämer, 2009; Zetterberg et al., 2010; Galbert et al., 2011).

Graph theory models can be described as binary or probability models (Pascual-Hortal and Saura, 2006a; Saura and Pascual-Hortal, 2007a; Bunn et al., 2000; Urban and Keitt, 2001). Binary models enable an analysis of whether or not a link exists, while probability models allow an analysis of the existing situation (the presence or absence of links), in addition to evaluating each specific patch (habitat) (Minor and Urban, 2007; Zetterberg et al., 2010; Rubio et al., 2015). The distance between nodes can be represented as an edge-to-edge interpatch distance, as Euclidian distance, or as a least-cost path (Tischendorf and Fahrig, 2000; Ray et al., 2002; Adriaensen et al., 2003; Nikolakaki, 2004; Theobald, 2006; Zetterberg et al., 2010).

That means graph theory models can be used in landscape planning and environmental assessments to deliver basic information and sup-

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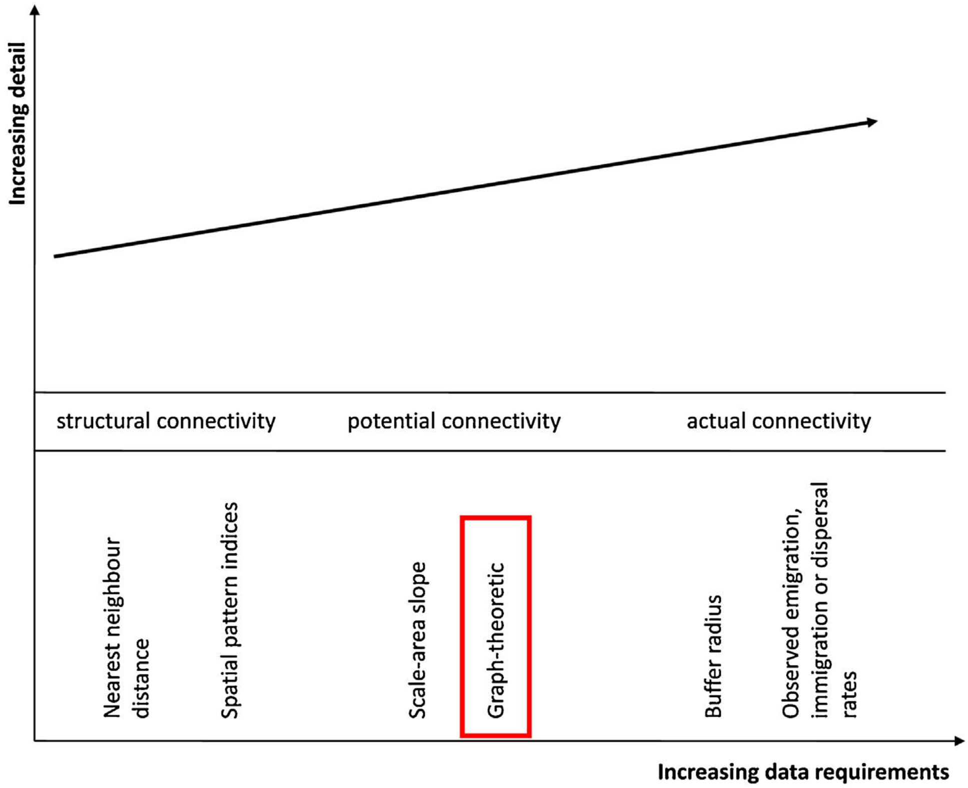

Fig. 1. Different types of quantitative connectivity analysis (graph-theoretic highlighted) (adapted from Calabrese and Fagan, 2004; Wolfrum, 2006).

port the assessment process.

Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA) are relevant tools for the assessment of impacts on biodiversity (Gontier et al., 2006; Gontier et al., 2010; Kim et al., 2013; Noble and Nwanekezie, 2017). While EIA is used at a project level, SEA is applied to plans, programs and policies (Gontier 2007; Pietsch, 2012). SEA was conceptualized as an instrument for assessment processes that can help formulate and implement strategies and play a role in decision-making (Noble and Nwanekezie, 2017). In particular, SEA emphasizes that possible alternative solutions should be considered to establish a transparent and balanced relationship between relevant needs and social interests in planning and decision-making (Jiricka and Pröbstl, 2008). Although the assessment of potential impacts on biodiversity, fauna, and flora are elements of these tools, there are problems with translating it into practice (Gontier et al., 2006). Though variations exist in these tools, the fundamental components of EIA and SEA are:

- Screening
- Scoping
- Assessment and evaluation of impacts and development of alternatives
- Reporting
- Review

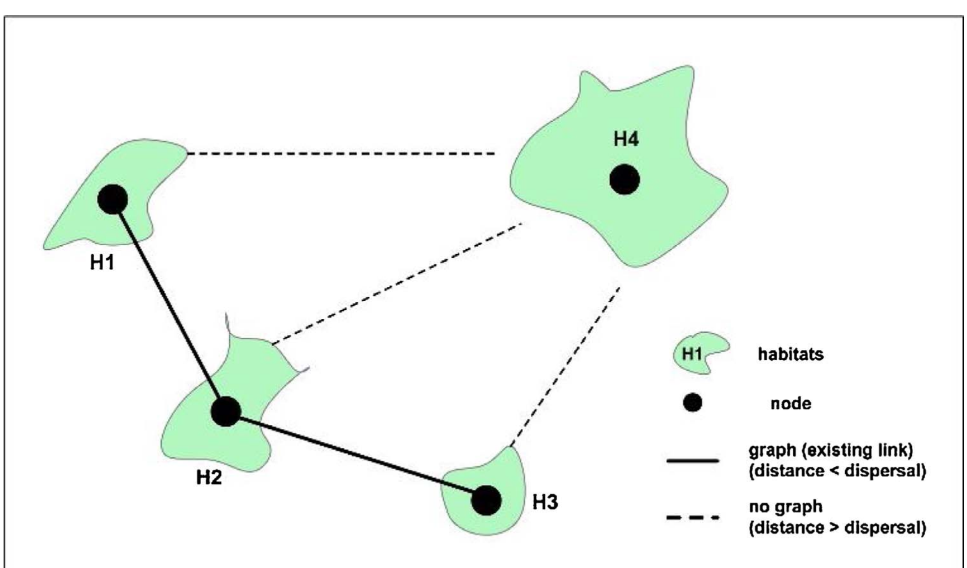

Fig. 2. Scheme of nodes and landscape graph representing habitats and links (Pietsch and Krämer, 2009).