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Topological and Conceptual Complex Network Models for Environmental Planning

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Abstract

The growing importance of environmental planning has encouraged researchers to apply complex network analysis on topological models of environmental networks. Relevant features of current green infrastructure can be derived with common and ad hoc techniques, but results tend to expose only a limited view, whether by geographical areas or by species. In this paper, the possibility to extend complex network analysis to conceptual models with a higher degree of abstraction is explored.

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1. Introduction

Environmental planning for landscape development is growing to be a very important topic, as the preservation of wildlife even in an increasingly urbanized society has become a priority for many countries. In the European Union, policies concerning the environment and the protection of biodiversity have converged into the definition of a wide environmental network denominated "Natura 2000", consisting of nature protection areas designated by the EU and at national level. To understand the implications of the creation of an environmental network, it is sensible to study these networks using complex network analysis (CNA). Applications of these techniques have been successful in a varied amount of fields[1], including power grids and social networks, often uncovering properties of real networks that were previously thought to be properly modeled with random graphs[2]. CNA is beginning to be applied on topological models of environmental networks, but in many applications, graph models need not be tightly coupled with an underlying geographical structure; rather, graph models can be derived for conceptual entities. Particularly striking is the case for bioinformatics, with biological meanings being found for many mathematical indices[3].

In this paper, current applications of CNA on environmental networks are reviewed, and possibilities are explored to expand its use to increase the understanding of their features, working at different degrees of abstraction. First, in Section 2, the concept of environmental network is introduced, and its implementations are discussed, providing a

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view of administrative details as well. Section 3 describes the activity of data collection on current nature protection areas that make up the Natura 2000 network. In Section 4, a framework for the analysis of data is established. In Section 5, a case study is discussed, involving reports filed for protection areas in Italy, and more specifically in Sardinia. Lastly, in Section 6, conclusions are drawn and opportunities for future work are outlined.

2. Natura 2000 Basics

Current society is characterized by an increasing degree of urbanization, as most human activities are now focused on cities, as opposed to rural areas. Human activities require contiguous infrastructure for connections between cities, for transportation of people and goods, and for the continued provision of many communication services (telephone, Internet, etc.). As increasing amounts of land, including coasts, become part of urbanized systems, the environmental balance is at a peril of being destroyed, with the elimination of habitats from land and sea. Concern for the protection of the environment, particularly endangered species, has given rise to the creation of nature protection areas.

However, since the contiguity of land for human activities has been held as a priority, these areas have long existed only in the form of isolated regions, resulting in a fragmentation of habitats. This is a major limitation, as it has been shown that factors such as an insufficient size of preservation areas, or an excessive distance between areas, can hamper their effectiveness[4]. In addition to this, even when the size of areas is sufficient for the survival of species to be preserved, biodiversity can be negatively affected, due to the frequent cases of inbreeding.

2.1. Elements of an environmental network

To address the fragmentation problem, in more recent years, the concept of isolated protection areas has been replaced with a reticular model[5], in which sites are connected with one another by elements of "green infrastructure", or other steps are taken to enable a conglomerate of sites to act as a network, in which each site, rather than being setup only to protect very specific categories of wildlife, has a role in contributing to larger preservation goals.

Where network behavior can not emerge from conservation areas by themselves, a commonly implemented way to provide a connection between nature protection areas is the creation of a 'habitat corridor' (also known as 'wildlife corridor' or 'green corridor'), defined as a linear strip of habitat connecting two or more larger patches of habitat, surrounded by a dissimilar matrix[6]. Corridors are intended to act as a path for the migration of some animal species, whether ordinarily or in the event of catastrophes hitting one of the larger areas; furthermore, corridors can provide a stable habitat for plants, insects and other smaller animals.

A habitat corridor ought to be tailored to the needs of the species intended to use it[7]. In different cases, it may be more sensible to form either a contiguous strip of land, or a set of disconnected patches (referred to as 'stepping stones'), arranged to form a line. The usefulness of corridors as a way to improve the conservation of species has often been put into question[8], and there is still no widespread consensus regarding the long-term effects of habitat corridors. However, it has been shown in a number of studies that their implementation has had a good effect for the biodiversity of some categories of species at least in the short-term[9].

In the European Union, nature and biodiversity policies have converged in the establishment of a network of nature protection areas, denominated "Natura 2000". Sites are designated as follows:

- Special Protection Areas (SPA), which are designated by member states according to the EU Birds Directive (2009/147/EC);
- Special Areas of Conservation (SAC), designated by member states according to the EU Habitats Directive (92/43/EEC).

A Special Area of Conservation is generally designated in a two-step process: first, a site is proposed by a member state to become a Site of Community Importance (SCI); once it has been approved as such by the EU, the member state can designate it as a SAC. It is possible for the boundaries of SPAs to overlap with those of SACs and SCIs, and a site can be designated to be a SPA as well as a SAC or SCI at the same time. Natura 2000 sites may include areas dedicated to human activities, as well as privately owned land. In these cases, the site should not be treated as a strictly enforced reserve where human activity is forbidden, but rather as an area where the EU seeks a sustainable