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A framework for systematic conservation planning and management of Mediterranean landscapes

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ABSTRACT

Active and dynamic management of biodiversity is of utmost importance in the face of increasing human pressures on nature. Current approaches for site selection of protected areas often assume that both conservation features and management actions are fixed in space and time. However, this approach should be revised to allow for spatio-temporal shifts of biodiversity features, threats and management options. Our aim here was to demonstrate a novel approach for systematic conservation planning at a fine scale that incorporates dynamic ecological processes (e.g., succession), biodiversity targets and management costs. We used the new 'Marxan with Zones' decision support tool to spatially redistribute the major structural types of vegetation within a privately-owned nature park in Israel and facilitate the achievement of multiple conservation targets for minimum cost. The park is located in the Mediterranean climate region of the eastern Mediterranean Basin, one of Earth's richest biodiversity hotspots. This small park alone (4.5 km^2) holds 660 species of native plants and six structural types of vegetation. The region has been subject to manifold human pressures such as grazing, clearing and fire for millennia and is currently threatened by a range of modern human-related activities (e.g., invasive alien species). By spatially redistributing the six structural vegetation types under three scenarios, representing different conservation objectives (no change, equal distribution – evenness of structural types, preference to early succession stages) within three budget frameworks, we identified a set of near-optimal conservation strategies that can be enacted over time. The current spatial distribution of structural types and the cost of changing one structural type into another via management actions had a major impact on the spatial prioritization outcomes and management recommendations. Notably, an advanced successional stage (dense Mediterranean garrigue) tended to dominate a large portion of the landscape when the available budgets were low because it is a relatively inexpensive structural type to maintain. The approach presented here can be further applied to spatially prioritize conservation goals in the face of shifting environments and climates, allowing dynamic conservation planning at multiple spatial scales.

1. Introduction

Systematic conservation planning tools and approaches are increasingly used by both government and non-government organizations (NGOs) around the world (Groves et al., 2002; Pressey et al., 2007; Moilanen et al., 2009). However, there is still an important gap between conservation science and conservation practice (e.g., Arlettaz et al., 2010; Gibbons et al., 2011). By guiding practitioners and policy makers to identify management objectives that incorporate biological, social and economic factors within one decision making framework, systematic conservation planning

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can help to both clarify goals and plan strategically (Joseph et al., 2009; Watson et al., 2011a). Spatial decision support tools (e.g., Marxan, developed by Ball and Possingham, 2000; Possingham et al., 2000; Zonation, developed by Moilanen, 2007) are now frequently used to guide management actions and locations that simultaneously meet conservation targets while minimizing social and economic costs (Wilson et al., 2006; Carwardine et al., 2008; Kark et al., 2009). Their use is increasing accountability and transparency in the planning process and leading to more economically efficient conservation actions (Knight et al., 2006; Pressey and Bottrill, 2009; Joseph et al., 2011; Marignani and Blasi, 2012).

One major limitation to current systematic conservation planning is the assumption that biotic and abiotic conditions are static in space and in time. Increasing attention is now being given to include dynamic changes and shifts of species and ecosystems into conservation planning in the face of ongoing (and often increasing) land use and rapid, climate change (Meir et al., 2004; Pressey et al., 2007; Drechsler et al., 2009; Heller and Zavaleta, 2009; Possingham et al., 2009; Watson et al., 2009). While in forest management planning dynamic optimization models with habitat conservation objectives have been in use since the 1990s (e.g., Bevers et al., 1997; Hof et al., 2002; Öhman et al., 2011), these models were mostly solved with linear integer programming methods, which have not been used in reserve site selection models (such as Marxan, developed by Ball and Possingham, 2000).

A range of conservation actions have been proposed as outcomes of the planning process, including the relocation of species (McDonald-Madden et al., 2010), protecting altitudinal gradients (Watson et al., 2011b), designing protected areas, and creating large scale corridors that allow shifts in species ranges due to environmental changes (Hannah et al., 2007). However, these actions are usually at regional and global scales (e.g., Ricketts et al., 2005; Drechsler et al., 2009; Hoffmann et al., 2010; Lourival et al., 2011), and there is less work demonstrating the use of a dynamic approach in systematic conservation planning and prioritization of actions at the local scale (but see Toth et al., 2011). At regional scales various types of spatial components are identified as surrogates for key ecological processes (e.g., riverine corridors, upland-lowland gradients, macroclimatic gradients; Rouget et al., 2003). At more local scales participatory or incentive-based instruments are often applied and optimization approaches are rarely used. In addition, processes such as changing human land uses and natural successional dynamics in space or in time need to taken into account in dynamic conservation planning (Pressey et al., 2007). The bias towards conservation planning at regional and global scales unfortunate as many conservation decisions occur at the local level (a reserve or park) and local conservation efforts can benefit from effective strategic planning processes (Hockings et al., 2000; Possingham et al., 2006; Boyd et al., 2008).

The Mediterranean Basin, one of Earth's richest biodiversity hotspots (Myers et al., 2000), has been subject to multiple human pressures such as grazing, clearing and fire for millennia (Naveh and Dan, 1973) and is currently threatened by a range of human activities (Kark et al., 2009). Very few systematic conservation plans have been developed for the Mediterranean Basin, which is partly due to its complexity and diversity, ranging over many different countries, cultures and conservation agendas (Kark et al., 2009), and partly due to the huge population and economic pressures in this region. Most of the region is human dominated with multiple land uses and relatively little room for allocation of new single-use reserves and land purchase for conservation. Thus, the conventional conservation planning approach has not been widely applied in this region. Furthermore, the long history of human disturbances in the area has led to diverse landscape mosaics and high biodiversity (Naveh and Whittaker, 1980; Perevolotsky and Seligman, 1998; Bar Massada et al., 2009). The traditional agro-pastoral disturbance regime based on clearing and grazing has been abandoned in many places in the Mediterranean Basin during the last few decades due to socio-economic changes (Perevolotsky and Seligman, 1998). Nowadays, conservation management in these regions is complicated also because the end target or the reference state for conservation is subjective and hard to define (Perevolotsky, 2005). The concept of pristine ecosystem or undisturbed climax as the desired state of the ecosystem to set as the conservation goal has little meaning in this region, and the role of professional planning defining active management schemes becomes very important.

The aim of our study was to develop and apply a new approach of conservation planning for successional landscapes at the local scale. We used a novel spatially-explicit decision support tool, Marxan with Zones (Watts et al., 2009), to relocate and redistribute the major vegetation features within a privately-owned nature park in Israel to allow for maximum achievement of multiple targets with minimum cost. In many Mediterranean ecosystems, including the Eastern Mediterranean, it has been shown that the succession process is one of the most important dynamic ecological processes shaping the ecosystem structure (Drechsler et al., 2009). One of the final stages of the succession process in Mediterranean landscapes leads to an increase in the cover of the woody vegetation (Bar Massada et al., 2009; Koniak and Noy-Meir, 2009). This in return leads to decline in overall plant richness, and potentially increases fire risk to human infrastructures (Naveh and Whittaker, 1980; Perevolotsky and Seligman, 1998; Levin and Heimowitz, 2012). Reducing threats to biodiversity is costly and needs to be done continuously. Therefore, a challenge for Mediterranean conservation managers is to decide whether, where and how to effectively intervene in the natural succession process and its dynamics. We illustrate an approach to solving the management challenge of meeting conservation targets over 30 years while minimizing costs. We believe this represents one of the first attempts to utilize a spatially explicit systematic conservation planning approach to identify management priorities at the local scale while at the same time considering the underlying dynamics of the system (McBride et al., 2010; Wilson et al., 2011).

2. Methods

2.1. Study area

The study was conducted in Ramat Hanadiv, a privately owned nature park established by the descendants of the Baron Edmond Benjamin de Rothschild, and operated for the benefit of the general public by the Rothschild Foundation (Yad Hanadiv). The site covers approximately 4.5 km^2 on a plateau at the southern tip of the Carmel mountain range in NW Israel (Fig. 1). In comparison, the average area of nature reserves in Israel is about 6.7 km^2, and the median area of nature reserves in Israel is less than 1 km^2. The most common shrubs in the park are *Phillyrea latifolia*, *Pistacia lentiscus*, *Calycotome villosa* and the dwarf shrub *Sarcopoterium spinosum* (Koniak and Noy-Meir, 2009). There are also conifer groves in the park planted in the 1970s, mostly the species *Pinus brutia*, *Pinus pinea* and *Cupressus sempervirens* (Osem et al., 2011). The park is perhaps the most researched and managed open space in Israel (e.g., Hadar et al., 1999; Koniak and Noy-Meir, 2009; Osem et al., 2011), with over 25 years of intensive research and dozens of fine spatial resolution data layers that were specifically surveyed and mapped within this park.

The nature park managers seek to conserve and nurture diverse habitats to support high species richness and biodiversity (660 plant species; Liat Hadar, personal communication). In order to achieve these goals, various management operations have been