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Can agro-ecosystems efficiently complement protected area networks?

David Troupin [a,*], Yohay Carmel [b]

[a] Faculty of Architecture and Town Planning, Technion – Israel Institute of Technology, Haifa 32000, Israel
[b] Faculty of Civil and Environmental Engineering, Technion – Israel Institute of Technology, Haifa 32000, Israel

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ABSTRACT

Threats to biodiversity are often enhanced in human-dominated and densely-populated regions. The prospects for establishing new protected areas are generally more limited in such regions, due to competition with other land-uses. Improving the conservation value of agricultural lands has been proposed as a complementary strategy. Our goal was to compare alternatives for expanding an existing protected area system. We used the conservation planning software Marxan to select candidate sites for addition to an existing protected area system, based on the following three strategies: (1) focusing on remaining natural habitats; (2) prioritizing agricultural lands for wildlife-friendly farming and agri-environmental measures that can improve conservation value; and (3) a strategy combining the former two. We used area as a surrogate for cost with the aim of minimizing the total area needed to meet our conservation objectives. We evaluated the sites found via each strategy with respect to their landscape structure and the coverage they provided to the target species' habitats. We focused on breeding bird species in Israel's Mediterranean region, a challenging and relevant case study due to the area's high level of urbanization, population density, and its heterogeneous landscape. We found that the existing protected areas provided adequate coverage to only 23% of the target species, clearly demonstrating the need for action. Of the three strategies, expanding the existing protected area system based on the combined strategy was the most beneficial since it provided greater coverage to the target species' habitats, and resulted in a larger, more compact, and less patchy conservation area network. In addition to protected area planning, our approach can be used to target agricultural lands for agri-environmental schemes, particularly in human-dominated and densely-populated regions.

1. Introduction

In Israel's Mediterranean region, the human population density and growth rate, as well as urbanization levels, are higher than those found in countries with a similar economic profile (Orenstein and Hamburg, 2010; Population Reference Bureau, 2012). As is characteristic of human-dominated landscapes, specifically in the Mediterranean (Blondel et al., 2010), the region is primarily agricultural and the landscape is a mosaic of agricultural land, natural and semi-natural habitats, and built-up land. Major changes have occurred in Israel in recent decades: urban sprawl and development (Orenstein and Hamburg, 2010), agricultural intensification (Yom-Tov, 2012), and a decline in wetlands and riparian ecosystems (Levin et al., 2009; Yom-Tov, 2012). Consequently Israel's Mediterranean region constitutes a challenging case study for conservation planning. It is also globally relevant, given both the large extent of densely-populated and human-dominated regions worldwide, and the human population growth and expansion of urbanization (Angel et al., 2011; Williams, 2012) and agriculture (Dobrovolski et al., 2011) predicted for the developing world.

Threats to biodiversity are often enhanced in human-dominated and densely-populated regions, as edge effects and isolation of natural habitats are often more severe and the natural/semi-natural patches and protected areas (PAs) are smaller (Di Giulio et al., 2009). Human population density has been found to be positively related to extinction rates (Cardillo et al., 2008) and to environmental threats such as deforestation (Sodhi et al., 2010) and invasive species abundance (Pysek et al., 2010). Competition between multiple land-uses and conflicts between human needs and biodiversity tend to be stronger in densely-populated regions (Langevelde et al., 2000; Deelstra et al., 2001). Whether there is a positive relationship between human density and biodiversity conflicts is debatable (Luck et al., 2004; Gaston, 2005). Nevertheless, it is widely accepted that in densely-populated regions the prospects for PA expansion or establishment are often limited, due to local constraints (e.g., social, financial, cultural and land-use).

Abbreviations: PAs, protected areas; LC, land cover; PU, planning unit.

* Corresponding author. Tel.: +972 54 7910799.
E-mail addresses: davidtroupin@gmail.com (D. Troupin), yohay@technion.ac.il (Y. Carmel).

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Yom-Tov et al. (2012) reviewed the past century's population trends of breeding birds in Israel. In Israel's Mediterranean region nearly half of the species experienced declines, and this was attributed to high human population density and habitat alteration, more specifically, the intensification of agriculture and agriculture-related land-uses, such as aquaculture, water reservoir construction, wetland drainage, cultivated area expansion, and afforestation. A decline in the number of threatened and common bird species, due to agricultural intensification and natural habitat depletion have been reported widely also in other regions (Donald et al., 2006; Maiorano et al., 2006; Johnson et al., 2011).

The worldwide expansion of agriculture has resulted in concern over its environmental consequences (Green et al., 2005; Dobrovolski et al., 2011) and led to a debate among conservation scientists and practitioners regarding the best approach for minimizing its negative impact and maximizing conservation. This cost-benefit problem in agricultural landscapes is related to the land sparing–sharing debate (Fischer et al., 2008; Phalan et al., 2011a,b; Balmford et al., 2012). On the one hand, land sparing favors separating land for nature conservation from land for agricultural production, and intensive use of the latter in order to maximize agricultural yield (Balmford et al., 2005; Fischer et al., 2008). Overall, this approach conforms to the traditional focus of nature conservation on natural and wilderness habitats (Sutherland, 2002; Mittermeier et al., 2003). On the other hand, land sharing is based on the idea that biodiversity conservation and agricultural production can co-occur, or even create synergies, through the implementation of wildlife-friendly farming methods (Balmford et al., 2012; Lin and Fuller, 2013). This approach is supported by the idea that conservation should focus also on agro-ecosystems (Tscharntke et al., 2005; Maiorano et al., 2006; Vandermeer and Perfecto, 2007; Norris, 2008) and that agro-ecosystems can persistently mimic essential functional attributes of "natural ecosystems" or even create novel ecosystems that are relevant for native biodiversity (Hobbs et al., 2006). In line with this approach, methods of sustainable and wildlife-friendly agriculture have been implemented throughout the world, e.g., through agri-environmental schemes (Harvey et al., 2008; Vepsäläinen et al., 2010; Tomich et al., 2011).

There is evidence that agriculture, particularly extensive and traditional practices, can support biodiversity and provide important, or even essential, habitats for a substantial number of species (Tscharntke et al., 2005; Vandermeer and Perfecto, 2007; Norris, 2008; Johnson et al., 2011). However, the effectiveness of agri-environmental schemes in promoting biodiversity conservation is debatable (Kleijn and Sutherland, 2003; Kleijn et al., 2006; Filippi-Codaccioni et al., 2010) and has been found to depend among other things on the species and taxa in question (Kleijn et al., 2006; Billeter et al., 2008; Phalan et al., 2011a,b) and on the targeting of such measures (Davies et al., 2009; Moreno et al., 2010).

Systematic conservation planning (Margules and Pressey, 2000) can be utilized to inform and spatially prioritize such agri-environmental efforts. Recently, Arponen et al. (2013) demonstrated that conservation management could be improved by the spatial reallocation of agri-environmental schemes in Finland. Similarly, Davies et al. (2009) found that aquatic biodiversity could be better protected if agri-environmental resources were reallocated. Nevertheless, within the field of conservation planning, agriculture is still commonly regarded as a threat (e.g., Jarvis et al., 2010; Visconti et al., 2010; Vimal et al., 2012), and the use of spatial prioritization tools to designate areas for low-impact agricultural practices has been very limited.

Central questions in conservation planning are how to prioritize areas for protection and where to allocate resources and efforts. The land sharing–sparing debate described above represents a highly relevant question of whether to invest in additional PAs and conservation efforts on remaining natural habitats or to increase the conservation value of agricultural lands in human-dominated regions. Comparing and evaluating the conservation benefits of each option is especially pertinent, since the expansion of PAs is not always possible.

In this case study, we compared three main conservation planning strategies: (1) expanding the PA system by focusing on the protection of remaining natural habitats (in line with land sparing); (2) complementing the PA system by improving the conservation value of agricultural habitats (in line with land sharing); and (3) a combination of the two approaches. Focusing on the breeding birds of Israel's Mediterranean region, we evaluated the coverage provided by the existing PAs by means of a gap analysis (Scott et al., 1993). We then used a site selection algorithm to identify conservation priority areas under each strategy. We used area as a surrogate for cost with the aim of minimizing the area needed to meet our conservation objectives. We then evaluated and compared the sites selected in each option with respect to their landscape structure and the habitat coverage they provide to the target species.

2. Methods

2.1. Study area

Israel's Mediterranean region (Fig. 1a) is characterized by a high level of biodiversity relative to its size, a diversity of habitats and a rich avifauna (Dolev and Perevolotsky, 2004; although see Roll et al., 2009). Due to its geographic location, the region is part of several important bird migration routes and serves as a junction for species from several biogeographic regions (Shirihai, 1996; Dolev and Perevolotsky, 2004). We excluded the Tel Aviv municipal district and the Golan Heights from the analysis, since land cover data for these regions were incomplete.

2.2. Land cover and protected areas

We produced a land cover (LC) map by integrating data from several sources (Table 1 and Fig. 1b). We approximated the distribution of riparian vegetation and cliffs (both important habitats for many bird species) by overlaying the LC map with a 50 m buffer around the running streams and cliffs layers, respectively. The resulting map included thirteen LC classes (Table 2). We refer to classes 1–8 and 9–10 as natural and agricultural LC, respectively. PAs included nature reserves and national parks, as well as forests, managed by the Israel Nature and Parks Authority and the Jewish National Fund's Forest Authority, respectively. These organizations provided us with maps of the areas under their management. All layers were provided as vector layers and converted into raster format at a resolution of 50 m.

2.3. Target species

We focus our analyses on breeding bird species ($N = 87$, see Appendix), excluding 23 species which are strongly associated with human settlement areas. We used breeding distribution maps from a bird atlas (Shirihai, 1996) that indicate the population density of each species (high, low, sporadic, localized and historical) at a spatial resolution of $7.5' \times 7.5'$ lat/long (corresponding to 11.8×13.8 km). We excluded historical records and used the remaining classes as indicative of each species' presence. For 19 species, we used distribution range maps from the Red Book of Vertebrates (Dolev and Perevolotsky, 2004).

We then used information on species-habitat associations for each species to obtain maps of potential suitable habitat within