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Is conservation right to go big? Protected area size and conservation return-on-investment

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ABSTRACT

Policy guidelines for creating new protected areas commonly recommend larger protected areas be favored. We examine whether these recommendations are justified, providing the first evaluation of this question to use return-on-investment (ROI) methods that account for how protected area size influences multiple ecological benefits and the economic costs of protection. We examine areas acquired to protect forested ecosystems in the eastern US that are rich in endemic species. ROI analyses often alter recommendations about protected area size from those obtained when considering only ecological benefits or only economic costs. Large protected areas offer a greater ecological return per dollar invested if the goal of protecting sites is to reduce forest fragmentation on the wider landscape, whereas smaller sites offer a higher ROI when prioritizing sites offering protection to more species. A portfolio of site sizes may need to be included in protected area networks when multiple objectives motivate conservation.

1. Introduction

Protected areas play a critical role in efforts to conserve biodiversity and to secure and enhance ecosystem services (Le Saout et al., 2013; Watson et al., 2014). Recognizing this, nations around the world have committed to expanding the coverage of their protected area networks under Target 11 of the Aichi agreement (Convention on Biological Diversity, 2011). Protected areas vary in all manner of characteristics (Barnes et al., 2017; Chape et al., 2008) and countries must ensure that newly established protected areas will be ecologically effective (Convention on Biological Diversity, 2011; Watson et al., 2016); this includes ensuring that protection is targeted to locations where it is most needed and that protected areas are suitably sized and adequately funded. However, financial support for the establishment of new protected areas is limited (McCarthy et al., 2012) and the cost of protecting sites varies widely (Armsworth, 2014; Balmford et al., 2003). As such, any new protected areas need to be chosen in a way that is cost effective as well as being ecologically effective. Conservation organizations increasingly rely on return-on-investment (ROI) analyses to balance these demands (Groves and Game, 2016). ROI approaches seek to identify candidate sites for protection that offer the greatest return, when measured in terms of the ecological goals motivating conservation, for every dollar spent on protection.

Policies governing the establishment of protected areas often include guidance on preferred protected area size. For example, IUCN are developing guidance to help nations deliver on the effectiveness dimension of Aichi Target 11 (United Nations Environment Programme - World Conservation Monitoring Centre and International Union for Conservation of Nature, 2016). The draft guidelines discuss the importance of ensuring protected areas are adequately sized. Similar

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statements regarding the desirability of ensuring protected areas are big enough can often be found in national conservation policy documents (Canadian Council on Ecological Areas, 2008; Lawton et al., 2010) and policies governing establishment of protected areas by NGOs and other actors (Groves, 2003). In making such recommendations, policy-makers are responding to the fact that most protected areas are still very small; over half of the world's protected areas are < 100 ha in size (Deguignet et al., 2014). The push towards favoring larger protected areas (Dudley et al., 2014) has driven innovations in conservation finance (Clark, 2007; Lennox et al., 2017) and parallels a broader movement in conservation to consolidate programs and favor larger projects (Levitt, 2013). But is this emphasis on larger protected areas supported by ROI-based planning?

Understanding how the size of protected areas influences the ecological benefits being provided was one of the founding questions around which the discipline of conservation biology coalesced (Diamond, 1975; Schwartz, 1999; Simberloff and Abele, 1982; Whittaker et al., 2005). As well as driving current protected area policies, this question continues to spur ecological research, whether focused on biodiversity benefits (Albers et al., 2016; Bartonova et al., 2016; Duran et al., 2016; Hunter Jr. et al., 2017; Watts et al., 2016) or ecosystem services (Mitchell et al., 2015).

The cost of protecting sites also depends on their size. A common claim is that protected area costs show economies of scale with site size, such that adding a hectare to a large protected area increases costs by less than adding a hectare to a small protected area (Armsworth et al., 2011; Ausden, 2007; Balmford et al., 2003; Kim et al., 2014). Yet, to date, studies claiming to find economies of scale in protected area costs either ignore, or give very limited consideration to, how effectively protected sites deliver desired ecological benefits.

Here we attempt to unify these two bodies of research. Specifically, we provide the first comprehensive evaluation of how the ROI offered when protecting different sites is affected by their size. The ROI offered from protecting a site is defined as the ecological benefit from protecting it divided by the economic cost of securing that protection (Murdoch et al., 2007). Importantly, we show that recommendations one would arrive at regarding protected area size when studying either ecological benefits or economic costs in isolation are often reversed when considering benefits and costs together.

When establishing a protected area, a conservation organization is commonly trying to advance multiple goals (Groves and Game, 2016). There are also alternative ways that progress towards each goal can be quantified. Because ecological processes scale in different ways with protected area size, recommendations regarding how ROI is influenced by area may depend on how ecological benefits are quantified. As such, we test how our results regarding ROI and protected area size vary across a range of ecological benefit metrics.

2. Materials and methods

2.1. Case study

We focus on areas protected by The Nature Conservancy (TNC) to protect forested ecosystems in the central and southern Appalachian Mountains in the eastern US (Fig. 1) TNC is a large, private, not-for-profit organization that operates in the US as a land trust and is active in acquiring or helping to acquire and manage land for conservation (Armsworth et al., 2012; Birchard, 2005; Brewer, 2003). The central and southern Appalachian Mountains supports one of the largest concentrations of endemic species with small geographic ranges in the US that are not already well-covered by protected areas (Jenkins et al., 2015). In addition, the region will play a critical role in future efforts to conserve species under climate change (Lawler et al., 2013). We examined 96 parcels purchased for protection between 2000 and 2009. Parcels ranged in size from less than half a hectare to nearly 1700 ha (quartiles = [8.7, 27.9, 104.1] ha).

Focusing on a single broad ecosystem type (forests in the eastern US), allows us to use a consistent set of ecological benefit metrics across all of the study protected areas (see below). In addition, by focusing on sites protected by one conservation organization, we are able to ensure that a consistent process determined how sites were identified for protection. We are also able to take advantage of consistent reporting about the protection of different sites, including what motivated their protection and what they cost to protect. The trade-off that comes with benefiting from tightly aligned data from working with a single organization is that the scope for generalizing inferences from the study is necessarily more limited. These concerns may be mediated in part, because in the US TNC operates a land protection business model similar to that employed by a number of other conservation organizations (Brewer, 2003). Moreover, working with TNC still allows some variation in conservation practice, because TNC is structured into semi-autonomous state chapters, ten of which feature in our study. State chapters differ in their history and conservation focus to some degree, while still being subject to consistent overall reporting and governance processes (Fishburn et al., 2013).

2.2. Identifying economies of scale

For our ROI measure, we focus on the ecological benefits protecting a site offers divided by the economic costs of securing that protection. We examine whether ROI increases or decreases with the size of the protected area after controlling for the effect of potentially confounding factors, such as elevation or population density nearby. Larger protected areas offer a more cost effective choice for conservation if the slope coefficient in the relevant regression equation is positive and significant, meaning that ecological benefits from protecting larger protected areas accrue faster than increases in the costs of protection as area is increased.

2.3. Ecological benefit metrics

To help identify ecological benefit metrics relevant to decisions over which parcels to protect, we examined TNC's ecoregional plans for the study area, e.g., The Nature Conservancy and Southern Appalachian Forest Coalition (2000). TNC's acquisition of these sites was guided by a collaborative ecoregional planning process (Groves, 2003). As part of this process, a broad set of conservation targets were identified, including species from many different taxonomic groups as well as community types, and their persistence needs evaluated. From this set of targets, TNC developed a portfolio of particular priority areas for conservation action. As well as these regional planning documents, we also examined internal TNC documents detailing why each individual parcel was acquired and we consulted with individual TNC staff involved in the relevant land deals. Based on this background, we identified a set of ecological benefit metrics relevant to TNC's goals for forested ecosystems spanning both coarse-filter and fine-filter conservation metrics (Schwartz, 1999). Values for our benefit metrics vary widely among the protected areas (Table 1) and show a range of patterns of association with one other; some ecological benefit metrics are strongly positively correlated with one another, others weakly correlated and some negatively correlated (Armsworth et al., 2017). The unitization of the metrics differed in that some applied per parcel and some per unit area. We reflected this difference in the calculation of ROI either by dividing by cost per parcel or cost per hectare as appropriate.

2.3.1. On-site metrics

To estimate ecological benefits of protection, we conducted field surveys on 23 of the protected parcels in May–September 2013. Surveyed parcels were chosen to span the entire spatial domain and range of variation we observed (Fig. 1), although sites with an area of < 20 ha were excluded because they could not accommodate our