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Systematic review

Effectiveness of terrestrial protected areas in reducing habitat loss and population declines

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ABSTRACT

Protected Areas (PAs) are a critical tool for maintaining habitat integrity and species diversity, and now cover more than 12.7% of the planet's land surface area. However, there is considerable debate on the extent to which PAs deliver conservation outcomes in terms of habitat and species protection. A systematic review approach is applied to investigate the evidence from peer reviewed and grey literature on the effectiveness of PAs focusing on two outcomes: (a) habitat cover and (b) species populations. We only include studies that causally link conservation inputs to outcomes against appropriate counterfactuals. From 2599 publications we found 76 studies from 51 papers that evaluated impacts on habitat cover, and 42 studies from 35 papers on species populations. Three conclusions emerged: first, there is good evidence that PAs have conserved forest habitat; second, evidence remains inconclusive that PAs have been effective at maintaining species populations, although more positive than negative results are reported in the literature; third, causal connections between management inputs and conservation outcomes in PAs are rarely evaluated in the literature. Overall, available evidence suggests that PAs deliver positive outcomes, but there remains a limited evidence base, and weak understanding of the conditions under which PAs succeed or fail to deliver conservation outcomes.

1. Introduction

Protected Areas (PAs) have long been regarded as an important tool for maintaining habitat integrity and species diversity (Brooks et al., 2004; Butchart et al., 2010; Coad et al., 2008; Rodrigues et al., 2004), covering more than 12.7% of the planet's land surface (Bertzky et al., 2012). However, there is considerable debate on the extent to which PAs deliver conservation outcomes in terms of habitat and species protection (Brooks et al., 2006; Ferraro and Simpson, 2002; Meir et al., 2004). It has been suggested that many of the world's PAs exist only as 'paper parks' (Dudley and Stolton, 1999), lacking effective management capacity, and unlikely to deliver effective conservation (Joppa et al., 2008).

PAs are often treated as a single conservation strategy. However, in reality they are established for a variety of reasons, with very different objectives and criteria for success. PAs have been set up for the conservation of ecosystems and their constituent species (Dudley, 2008), protection of specific threatened species (Liu et al., 2001), ecosystem services (Campos and Nepstad, 2006), or for cultural and social reasons (Coad et al., 2008). Understanding the conditions under which PAs deliver conservation benefits for habitats and species is essential for policy makers, managers and conservation advocates (Brooks et al., 2004; Kleiman et al., 2000; Margules and Pressey, 2000).

The success of PAs has generally been evaluated using measures such as the representativeness of PA networks in terms of their species diversity, or coverage of endemic and threatened species (Rodrigues et al., 2004), assuming that PAs provide effective protection once established. Alternatively, by investigating management 'inputs' – e.g. whether PAs have management plans, boundaries, staffing, and other management systems and processes (Jachmann, 2008), assuming that increased levels of management equates to successful protection. However, these analyses are not able to describe how conditions inside PAs change over time (Craigie et al., 2010), or evaluate the effectiveness of protection, by combining measures of inputs and measures of outcomes in a temporal framework; thus measuring how biodiversity outcomes change over time in relation to protection or implementation of management actions.

The objective of this paper is to use a 'systematic review' methodology (Pullin and Knight, 2009) to review the evidence that PAs

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deliver a positive change in two conservation outcomes: (a) habitat cover and (b) species populations, i.e. the ability of PAs to maintain or improve native habitat integrity, or native species populations, over time respectively. We further consider the impact of different PA management interventions, or characteristics, where measured, on biodiversity outcomes.

2. Methods

2.1. Search strategy

To locate relevant literature, we searched 14 databases, eight specialist sources and 13 websites in English (Table S1). We identified a list of relevant search terms and used Boolean operators and multi term searches (Table S2). Anonymous reviewers appraised the list of relevant search terms and the search strategy. The search was conducted between July and August 2010, covering all publications available up to that point. For a full description of the search strategy, search-terms, and inclusion criteria see Geldmann et al. (2012).

2.2. Study inclusion criteria

Two main criteria were used to determine study inclusion. First, we reviewed whether the publication assessed conservation interventions and biodiversity outcomes. We only included publications that measured the effectiveness of PAs targeting biodiversity conservation of native habitats/species. We excluded publications that looked at changes in alien species, or species not expected to improve with successful protection.

Second, we only included publications that used suitable counterfactuals (controls), following the BACI (before/after or control/intervention) framework. Counterfactuals were defined as: (a) before vs. after: e.g. PA establishment/implementation or PA management intervention, or (b) control vs. intervention: e.g. PAs compared to their immediate surroundings or to non-protected areas with similar characteristics.

2.3. Study characterization and quality assessment

For publications where multiple PAs were examined against different counterfactuals, such that the publication contained more than one examination of PA effectiveness, we divided these based on the type of counterfactual. All summaries and estimations of impact are based on this subdivision of results from publications that are henceforth referred to as: "studies".

For each study we first extracted detailed information on biodiversity outcome variables. This included information on the methods used to measure habitat or species population change (i.e. remote sensing, transect surveys, etc.), the rates of change, and the units of measurement. For studies that did not report the rate of change, we noted the given direction of change (improving/no effect/declining) compared to the counterfactual. For all studies of species populations we also estimated the fraction of species that did better inside the PA compared to the counterfactual, and also noted any reported trophic impacts (such as population changes due to predator–prey dynamics).

Second, we extracted information on PA management interventions and characteristics, as well as external drivers of habitat or species change. We recorded either the given effect size of the variable, or where this was not given, noted the direction of change (improving/no effect/declining) compared to the counterfactual. The management interventions and PA characteristics identified were then grouped into categories (with separate categories for habitat and species) that were defined post hoc (details of categories are provided in Tables S3 and S4).

Third, we extracted information on other biological and geographical variables, and study biases. These effects had not been measured using appropriate counterfactuals, but were mentioned in the publications as having potentially affected biodiversity outcomes.

zWhere multiple publications evaluated the same site using the same data, sites were only included once to avoid double counting. However, for habitat studies, PA effectiveness was evaluated at different scales (i.e. globally, regionally, nationally or site-level). In this case both studies were included, as results for one level is not simply part of the result of another. Thus, the results presented at different levels contribute different information on PA effectiveness.

3. Results

Of the 2599 publications selected through the systematic search strategy, we found 51 publications on habitat cover and 35 publications on species population trends that fulfilled the inclusion criteria.

Within 13 of the 51 habitat change publications there were multiple counterfactual scenarios. When separated these yielded a total of 76 studies. Three population trend publications covered more than one evaluation of PA effectiveness, yielding 42 studies in total across the 35 publications. Detailed descriptions of the data extracted from individual studies are presented for habitats (Tables S5 and S6) and populations (Tables 1 and S7).

3.1. Protecting habitats

Of the 76 studies on the effectiveness of PAs in retaining habitat cover, four were global, 35 evaluated regional, national or subnational networks of PAs, and 34 evaluated five or fewer PAs. There was a strong bias in study location; 35 were from Latin America, 18 from Africa, 16 from Asia, two from Oceania, and one each from Europe, and North America. There was also a strong bias in habitat focus. Sixty-eight of the 76 studies (89%) investigated changes in forest cover only, 67 (88%) of which were for tropical forest. The remaining eight evaluated multiple land-use types of which all but one (Alodos et al., 2004) included forests.

To determine changes in habitat cover, 63 studies (83%) used satellite remote sensing techniques, three used aerial photos, and five used a combination of both. The remaining five used in situ data collection, either estimation of disturbance across plots (Bleher et al., 2006; Liu et al., 2001; Tole, 2002), or interviews and questionnaires (Bruner et al., 2001; Mwangi et al., 2010). To analyze PA effectiveness in protecting habitat, 36 of the 76 studies used buffer analyses (comparing changes in habitat cover inside PAs to a surrounding buffer), 21 compared to similar areas outside the PAs, and 10 used matching estimator methods (Table S5).

Sixty-two of the 76 studies of habitat change (82%) found habitat loss to be higher outside PAs than inside, nine studies found habitat loss to be higher inside PAs than outside, and five could not detect an effect of protection (Tables 2 and S5). The three global studies were generally in agreement, finding that PAs were effective in reducing habitat loss. DeFries et al. (2005) compared PAs to their buffer, and found rates of habitat loss for 198 PAs to be 2.6 times lower inside compared to outside. Scharlemann et al. (2010) found that PAs lost about half as much carbon as forest outside PAs globally (ca. 2 times lower than outside PAs), and the loss in Oceania, the Neotropics, and in Tropical Asia to be higher outside PAs than inside. Joppa and Pfaff (2011), found that rates of habitat loss in PAs were 1.08 times lower than the counterfactual.

In 52 of the 76 studies the results reported, we were able to calculate the ratio of the habitat change in the PA compared to their counterfactual (Table S5). Where PAs had lower habitat loss com-