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.

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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 (Bennett 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
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.

Where 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-
<table>
<thead>
<tr>
<th>Source</th>
<th>Countries</th>
<th>Protected area</th>
<th>Monitoring period</th>
<th>Taxa</th>
<th>Counterfactual</th>
<th>BACI</th>
<th>Background trend</th>
<th>Effect of PA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balme et al. (2010)</td>
<td>South Africa</td>
<td>Phinda–Mkhuzi</td>
<td>2002–2007</td>
<td>Mammals</td>
<td>PA compared to buffer</td>
<td>CI</td>
<td>Increase</td>
<td>+</td>
</tr>
<tr>
<td>Blake et al. (2008)</td>
<td>Congo</td>
<td>6 PAs</td>
<td>2003–2005</td>
<td>Mammals</td>
<td>PA compared to buffer</td>
<td>CI</td>
<td>Increase</td>
<td>+</td>
</tr>
<tr>
<td>Caro (1999)</td>
<td>Tanzania</td>
<td>Katavi NP</td>
<td>1995–1996</td>
<td>Mammals</td>
<td>PA compared to buffer</td>
<td>CI</td>
<td>Increase</td>
<td>+</td>
</tr>
<tr>
<td>Devictor et al. (2007)</td>
<td>France</td>
<td>All protected areas</td>
<td>1989–2003</td>
<td>Aves</td>
<td>National estimates outside PA</td>
<td>CI</td>
<td>Increase</td>
<td>+</td>
</tr>
<tr>
<td>Eberhardt et al. (2007)</td>
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<td>Yellowstone NP</td>
<td>70 years</td>
<td>Mammals</td>
<td>Implementation of regulation</td>
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<td>Increase</td>
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<tr>
<td>Meijaard and Nijman (2000)</td>
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<td>Pulau Krajet</td>
<td>1997</td>
<td>Mammals</td>
<td>Translocation of population</td>
<td>BA</td>
<td>Decrease</td>
<td>+</td>
</tr>
<tr>
<td>Ottichio et al. (2000)</td>
<td>Kenya</td>
<td>Masai Mara</td>
<td>1977–1997</td>
<td>Mammals</td>
<td>PA compared to buffer</td>
<td>CI</td>
<td>Decrease</td>
<td>+</td>
</tr>
<tr>
<td>Pettorelli et al. (2010)</td>
<td>Tanzania</td>
<td>5 NPs, 3FR and 3 other PAs</td>
<td>2004–2007</td>
<td>Mammals</td>
<td>Different levels of protection</td>
<td>CI</td>
<td>Increase</td>
<td>+</td>
</tr>
<tr>
<td>Schlicht et al. (2009)</td>
<td>USA</td>
<td>Multiple</td>
<td>1988–1996</td>
<td>Insecta</td>
<td>Areas not managed with fire</td>
<td>CI</td>
<td>Decrease</td>
<td>–</td>
</tr>
<tr>
<td>Sergio et al. (2005)</td>
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<td>Dohana NP</td>
<td>1989–2001</td>
<td>Aves</td>
<td>Populations outside PA</td>
<td>CI</td>
<td>Stable</td>
<td>0</td>
</tr>
<tr>
<td>Stoner et al. (2007)</td>
<td>Tanzania</td>
<td>Burigi-Bharamulo NP</td>
<td>1980s–2000s</td>
<td>Mammals</td>
<td>PA compared to buffer</td>
<td>CI</td>
<td>Decrease</td>
<td>+</td>
</tr>
<tr>
<td>Stoner et al. (2007)</td>
<td>Tanzania</td>
<td>Greater Ruaha NP</td>
<td>1980s–2000s</td>
<td>Mammals</td>
<td>PA compared to buffer</td>
<td>CI</td>
<td>Decrease</td>
<td>+</td>
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<tr>
<td>Stoner et al. (2007)</td>
<td>Tanzania</td>
<td>Tarangire NP</td>
<td>1980s–2000s</td>
<td>Mammals</td>
<td>PA compared to buffer</td>
<td>CI</td>
<td>Decrease</td>
<td>+</td>
</tr>
<tr>
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<td>Tanzania</td>
<td>Selous-Mikumi NP</td>
<td>1980s–2000s</td>
<td>Mammals</td>
<td>PA compared to buffer</td>
<td>CI</td>
<td>Decrease</td>
<td>+</td>
</tr>
<tr>
<td>Stoner et al. (2007)</td>
<td>Tanzania</td>
<td>Ugalla NP</td>
<td>1980s–2000s</td>
<td>Mammals</td>
<td>PA compared to buffer</td>
<td>CI</td>
<td>Decrease</td>
<td>+</td>
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<tr>
<td>Stuhrsaker et al. (2005)</td>
<td>11 African countries</td>
<td>16 PAs</td>
<td>1966–2000</td>
<td>Biodiversity</td>
<td>PA compared to buffer</td>
<td>CI</td>
<td>N/A</td>
<td>+</td>
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<tr>
<td>Suárez et al. (1993)</td>
<td>Spain</td>
<td>Las Amoladeras and Layna Paramos</td>
<td>1989</td>
<td>Aves</td>
<td>PA compared to similar habitat outside</td>
<td>CI</td>
<td>Decrease</td>
<td>–</td>
</tr>
<tr>
<td>Theberge et al. (2006)</td>
<td>Canada</td>
<td>Algonquin</td>
<td>1988–1999</td>
<td>Mammals</td>
<td>PA compared to buffer</td>
<td>CI</td>
<td>Decrease</td>
<td>+</td>
</tr>
<tr>
<td>Wegge et al. (2009)</td>
<td>Nepal</td>
<td>Bardia NP</td>
<td>22 years</td>
<td>Mammals</td>
<td>Establishment of PA</td>
<td>BA</td>
<td>Increase</td>
<td>+</td>
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<tr>
<td>Western et al. (2009)</td>
<td>Kenya</td>
<td>Tsavo NP</td>
<td>30 years</td>
<td>Mammals</td>
<td>PA compared to buffer</td>
<td>CI</td>
<td>Decrease</td>
<td>0</td>
</tr>
<tr>
<td>Western et al. (2009)</td>
<td>Kenya</td>
<td>Mara NP</td>
<td>30 years</td>
<td>Mammals</td>
<td>PA compared to buffer</td>
<td>CI</td>
<td>Decrease</td>
<td>0</td>
</tr>
<tr>
<td>Western et al. (2009)</td>
<td>Kenya</td>
<td>Amboseli NP</td>
<td>30 years</td>
<td>Mammals</td>
<td>PA compared to buffer</td>
<td>CI</td>
<td>Decrease</td>
<td>0</td>
</tr>
<tr>
<td>Western et al. (2009)</td>
<td>Kenya</td>
<td>Meru NP</td>
<td>30 years</td>
<td>Mammals</td>
<td>PA compared to buffer</td>
<td>CI</td>
<td>Decrease</td>
<td>0</td>
</tr>
<tr>
<td>Whitehead et al. (2008)</td>
<td>New Zealand</td>
<td>Fiordland NP</td>
<td>2000–2006</td>
<td>Aves</td>
<td>Managed section compared to unmanaged</td>
<td>CI</td>
<td>Increase</td>
<td>+</td>
</tr>
</tbody>
</table>

Key: NP = National Park, FR = forest reserve, PA = protected area, BA = before/after, CI = control/intervention. See Table S7 for further information on the individual studies. Counterfactual defines the comparator which the PA was evaluated against and BACI whether the comparison was before/after or control/intervention. Background trend defines the overall direction of the majority of the populations (see ratio in Table S7) which can be decreasing even in successful PAs. Effect of PA describes whether protection was better than counterfactual (+) worse than counterfactual (−), or no difference could be detected (0).
pared with the counterfactual (43 studies), ratios ranged from 1.25 (Curran et al., 2004) to 22.7 (Nepstad et al., 2006) times lower loss, with an mean of 5.4 (S.D. = 4.9). For the nine studies where PAs had higher rates of habitat loss compared with the counterfactual, the difference ranged between 1.15 (Brower et al., 2002) and 3.97 (Liu et al., 2001) times higher loss. Differences between inside and outside were generally larger for Latin America and Africa, compared to Asia, suggesting that Latin American and African PAs are better at reducing deforestation within their borders (Table 2).

Studies using a buffer analysis reported higher levels of PA effectiveness (mean = 5.2, S.D. = 5.0) than studies which used regression modeling (mean = 4.2, S.D. = 5.4). For studies using matching estimators only one reported a PA/counterfactual ratio, finding 2 times more deforestation outside PAs compared to inside (Mas, 2005). Similarly, Joppa and Pfaff (2011) comparing the results of matching estimators and buffer analyses, also found rates of habitat loss in PAs to be smaller using matching. Such results show that methods used to evaluate PA effectiveness can alter the apparent effect size.

Three global studies examined deforestation rates between reserves under different IUCN reserve management categories (Joppa and Pfaff, 2011; Nelson and Chomitz, 2009; Scharlemann et al., 2010), all finding that PA effectiveness increased with IUCN categories that infer stricter protection. However, Joppa and Pfaff (2011) showed this effect to be partly explained by the larger size of category I and II reserves. All seven studies investigating the effectiveness of indigenous protected lands found positive impacts compared to non-protected areas. In the eight studies that compared indigenous or community managed reserves with state managed PAs, three found community reserves to perform better (Bray et al., 2008; Ellis and Porter-Bolland, 2008) and five found them to perform worse (Armenteras et al., 2006; Bleher et al., 2006; Gaveau et al., 2007; Nelson et al., 2001; Nepstad et al., 2006).

Twenty studies included the effect of PA management; ranging from implementation of management plans and staff numbers, to involvement of local NGOs. None of the studies could estimate the explicit effect of management. Of the 20 studies, eight calculated the difference between inside and outside, showing 2.4 (S.D. = 1.5) times lower deforestation inside PA boundaries.

Where studies used regression modeling to control for the effect of exogenous biological and geographical variables on habitat loss, the effect of these variables was often reported. Remote areas of higher or steeper terrain were generally reported to suffer less habitat loss (Joppa and Pfaff, 2011). Areas with high human population densities, located in areas with high demand for land, or with high fire frequency were reported more frequently to suffer greater habitat loss (Fig. 1A).

3.2. Protecting species populations

The relative impact of protection and management was positive in 31 of the 42 studies; in 12 of these, species populations still exhibited declined under protection, but less than in the counterfactual. Relative performance was worse with protection than without in five studies, and six studies found no effect of protection (Table 1 Individual study details, Table 3 Summary data).

The largest number of PAs included in any of the 42 studies was 16, spread across 11 African countries (Struhsaker et al., 2005). Seven of the 42 studies were at regional or national scale, and 35 (83%) were of five or less PAs. Like habitat studies, population studies also exhibited geographic bias with 57% from Africa, as well as a taxonomic bias with 74% studying mammals (Table 3). Thirty-four of the 42 studies measured changes in species population abundance, three measured changes in occurrence, and five used other measures such as spot counts, questionnaires, or nest mortality (Table S6).

Counterfactuals varied across studies. Fifteen of the 42 used a before/after (BA) counterfactual: Three of those compared the same area before and after establishment of the PA, and the other 12 compared the same populations within a PA before and after the implementation of specific management actions. The remaining 27 of the 42 population studies used a control/intervention (CI) counterfactual: 16 of those compared populations from one or several PAs to populations with the PAs immediate surroundings, five compared trends in PAs to non-protected land with similar characteristics but not adjoining the reserve, and six compared populations between PAs with varying legislation or management (Table 1).

In addition to the effect of protection per se, species populations in all studies were also affected by specific management actions (Table S6). Consequently, the impacts of protection and individual management actions are confounded. In addition, impacts of management and protection were evaluated using a range of dissimilar methods. It is therefore inappropriate and uninformative to calculate effect sizes. Instead, we report direction of change (improving/no effect/declining) compared to the counterfactual, as this was the only measure of success which could be justifiably compared between studies (Table 1).

The most commonly reported management actions were those aimed at reducing poaching (12 of 42 studies). Eleven of the 12 studies reported improved biodiversity outcomes linked to management actions, though of variable magnitude (Fig. 1B). Species were typically mammals and six of the studies examined large African herbivores. In Serengeti NP, reestablishment of anti-poaching efforts resulted in a shift from large declines in buffalo populations to increasing population in a short time period (Metzger et al., 2010). Similarly, elk populations in Yellowstone exhibited large population increases following anti-poaching regulations. In Costa Rica mammals in less strictly guarded reserves were 6–28% the relative density of that in reserves with strict anti-poaching regulation (Carrillo et al., 2000). More subtly, in Vietnam banteng populations (Bos javanicus bourniensis) declined only slightly more slowly when guard numbers increased (Pedrono et al., 2009). Three studies examined the use of fences. One noted stable roan antelope (Hippotragus equinus) populations compared to decreases outside fencing (Harrington et al., 1999) and a second noted no difference with bird populations remaining stable before and after fencing (Sergio et al., 2005). The third showed negative changes, with ca.

### Table 2

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

<table>
<thead>
<tr>
<th>Region</th>
<th>Counterfactual</th>
<th>Impact</th>
<th>Habitat</th>
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<tbody>
<tr>
<td></td>
<td>Buffer Regional Matched</td>
<td>Positive</td>
<td>Negative</td>
</tr>
<tr>
<td>Africa</td>
<td>4 11 2</td>
<td>11 4 3</td>
<td>61%</td>
</tr>
<tr>
<td>Asia</td>
<td>10 3 2</td>
<td>14 1 1</td>
<td>88%</td>
</tr>
<tr>
<td>Europe</td>
<td>1 0 0</td>
<td>1 0 0</td>
<td>100%</td>
</tr>
<tr>
<td>Latin America</td>
<td>19 7 5</td>
<td>30 4 1</td>
<td>100%</td>
</tr>
<tr>
<td>North America</td>
<td>1 0 2</td>
<td>0 0 0</td>
<td>100%</td>
</tr>
<tr>
<td>Oceania</td>
<td>0 2 0</td>
<td>2 0 0</td>
<td>100%</td>
</tr>
<tr>
<td>Global</td>
<td>1 2 1</td>
<td>4 0 0</td>
<td>100%</td>
</tr>
<tr>
<td>Summary</td>
<td>36 24 10</td>
<td>62 9 5</td>
<td>82%</td>
</tr>
</tbody>
</table>
50% declines in wildebeest (*Connochaetus taurinus*) populations after fencing, while lion (*Panthera leo*) populations increased to an estimated three times their natural carrying capacity (Tambling and Toit, 2005).

Ten studies evaluated specific conservation interventions designed to target threats or challenges in the PA (Fig. 1B). Types of actions include: Burning (Schlicht et al., 2009), grazing (Fellers and Drost, 1993; Herremans and Herremans-Tonnoeyr, 2000;...
variables that might be influencing population trends, such as im-

cination programs for buffalo and wildebeest (Sinclair et al., 2007),

Wegge et al., 2009), predator and invasive species exclusion (Suár-

et al., 1993; Tambling and Toit, 2004), and involvement of NGOs
targeted single-species, including provision of feeding and breeding
areas (Metzger et al., 2010), or have migratory ranges extending
outside PA boundaries (Thirgood et al., 2004), making even the
large number of natural ecological processes also influence population
changes, which makes quantifying the precise effect of protection
difficult due to substantial background variance. Events such as
droughts and floods, diseases and inter-specific competition affect
population numbers, and these events are usually not controlled
for in time-series studies (Owen-Smith et al., 2005; Sinclair et al.,
2007; Western et al., 2009).

Unfortunately, collection of population time-series data is costly (in time, money and human capacity) It is therefore not surprising that studies are skewed towards ‘charismatic’ species, and PAs where conservation has a high and direct monetary value (Balmford et al., 2009). While cost is a major factor influencing the implementation of population monitoring, and PA financing generally does not extend to monitoring outside PAs, nor do management agencies usually have the desire, will or capacity to undertake such activities within constrained budgets. Further, many species found within PAs are extirpated outside park boundaries (Metzger et al., 2010), or have migratory ranges extending outside PA boundaries (Thirgood et al., 2004), making even the identification of unprotected control populations challenging.

For the majority of species population studies identified in this review, PA aims were broad, and management objectives were to protect native ecosystems and their constituent species. Less than 12% of studies investigated single-species management interventions. However the importance of broad site-level management even for single-species conservation has been highlighted by several studies (Forrest et al., 2012; Liu et al., 2001; Palomares et al., 2000) and site-level interventions constitute the majority (80%) of suggested interventions for the conservation of threatened species (McCarthy et al., 2012). The effectiveness of PAs is likely to vary with how appropriately specific conservation interventions are tailored to individual species.

4.1. Moving forward

The Convention on Biological Diversity’s Aichi target 11 calls for 17% of terrestrial land surface area to be protected and effectively and equitably managed by 2020. Even if the coverage goal is
achieved, effective and equitable management is unlikely without site-level monitoring and adaptation. Conservation scientists and practitioners can improve understanding of PA based conservation by: (a) adopting a more experimental approach for the implementation of conservation activities; emphasizing the causal link between interventions and the outcomes being measured and (b) promoting sharing and publication of data in a standardized format, thus facilitating the use and collation of data from across studies.

Most of the 2599 studies considered for this review did not follow a BACI design. BACI design is being increasingly demanded by conservation scientists (Ferraro, 2009; Joppa and Pfaff, 2010), but is still rarely implemented. For too long, past practice and theory have been used to guide decision making in conservation, and in particular in PA decision making. Existing initiatives to collate data on population time-series such as the Living Planet database (Loh et al., 2005) facilitate the ‘scaling-up’ of multiple small-scale studies by making data freely available in standardized format. Similarly, more recent efforts are underway to collate data on PA management (Leverington et al., 2010) which will aid further analyses of PA effectiveness. Conservation journals could facilitate these efforts by adopting routine policies for data reporting and sharing following publication, and/or ensuring that existing data policies are consistently followed by researchers; currently only 9% of the raw data from high impact publications are made available online (Alsheikh-Alli et al., 2011).

Recent studies illustrate the potential for meta-analyses to identify patterns in population changes: amongst regions of Africa (Craigie et al., 2010), differences in species recovery correlated with the status of the Kaziranga Rhino population. Tiger Papers 1, 1–6.

References


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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.bioclin.2013.02.018.


