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Mismatches between conservation outcomes and management evaluation in protected areas: A case study in the Brazilian Cerrado

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ABSTRACT

Protected areas are one of the most widely adopted approaches to conservation, and assessment of their management effectiveness has become a widespread way of evaluating their performance. However, few studies examine how well qualitative management effectiveness assessments predict conservation outcomes. We explored this question in a savanna ecosystem under high conversion pressure: the Brazilian Cerrado. We used data on avoided conversion from 2002 to 2009 in 26 protected areas, derived from comparisons of protected and unprotected sites matched for potential covariates of conversion. We tested for correlation between avoided conversion and management effectiveness scores based on RAPPAM (Rapid Assessment and Prioritization of Protected Area Management) and found no evidence that the scores predict avoided conversion. We discuss plausible explanations including an insufficient evidence-base for management evaluation, the largely subjective nature of the assessment method and a limited emphasis on tracking results and effects of management actions. Further research of this nature can help the interpretation of management effectiveness scores and improve the assessment of protected areas performance.

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1. Introduction

Measuring the impact of conservation interventions is essential for improving effectiveness and guiding the allocation of limited financial resources (Ferraro and Pattanayak, 2006; Kapos et al., 2008; Sutherland et al., 2004). However, evaluation remains a challenging task as conservation generally takes place in complex and dynamic scenarios (Margoluis et al., 2009), and frequently its effects can only be perceived a long time after implementation (Kapos et al., 2009).

Protected areas (PAs) are one of the most widely adopted approaches to conservation (Chape et al., 2005). Evaluating how effective they are at safeguarding biodiversity is therefore a research priority (Bertzky et al., 2012) – in particular assessing how well they protect species (Craigie et al., 2010) and habitats (Joppa and Pfaff, 2011; Laurance et al., 2012) of concern.

In response to the need for evaluating PA performance systematically, various organisations joined efforts after the World Parks Congress in 1992 to develop a standard framework for assessing the effectiveness of PA management (Hockings et al., 2000). PA Management Effectiveness (PAME) was defined as how far management protects values and achieves goals and objectives (Hockings et al., 2006). The standard PAME assessment framework provided a common platform for questionnaire-based toolkits directed at managers or other experts, based on six main elements of management: context, planning, inputs, processes, outputs and outcomes (Hockings, 2003; Hockings et al., 2006).

PAME assessment has since been taken up widely; for example, the Convention on Biological Diversity's Programme of Work on Protected Areas encourages Parties to work towards assessing PAME for 60% of the total area of PAs by 2015 (CBD COP 10 Decision X/31, 19a). So far, 23% of countries have reached this target (Coad et al., 2013) and over 9000 assessments have been carried out (Leverington et al., 2010a), mainly through the Management Effectiveness Tracking Tool (METT; WWF, 2007), and the Rapid Assessment and Prioritization of Protected Areas Management (RAPPAM; Ervin, 2003) method. These assessments are often used for guiding priorities or resource allocation, to build support for PA management, as indicators of conservation outcomes for stakeholders and donors, and ultimately for improving management outcomes (Cook and Hockings, 2011).

Given the central role of the results of PAME assessments in guiding decision making, it is important to understand how well

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they predict conservation outcomes. However, empirical data on conservation outcomes in PAs are often subject to bias (Ferraro and Pattanayak, 2006). For example, PAs are commonly located in remote areas and so may exhibit high ecological integrity for reasons that have nothing to do with their performance (Joppa and Pfaff, 2010). A solution is to compare events in PAs with those in sites that are carefully matched for all factors (apart from protection status) that might influence conservation outcomes. This enables estimation of what would have happened to the conservation target in the absence of protection (Andam et al., 2008; Joppa and Pfaff, 2011; Nelson and Chomitz, 2011; Nolte et al., 2013b).

To date, only a small number of studies have explored how far the results of PAME assessments reflect quantitative measures of conservation outcomes (e.g. Nolte and Agrawal, 2013; Nolte et al., 2013a; Zimsky et al., 2010), or the relationships between management efforts and outcomes (Geldmann et al., 2013). We contribute to this debate by exploring new information from a matched-design study of PA outcomes (Carranza et al., 2013) to examine how management effectiveness scores relate to quantitative performance measures in a savanna ecosystem that has undergone three decades of conversion: the Brazilian Cerrado.

2. Methods

2.1. Study area

The Cerrado is a global hotspot of biodiversity (Myers et al., 2000) composed of a complex vegetation mosaic that includes savanna, forests and grasslands with high species richness, notably for birds (Silva, 1995) and vascular plants (Ratter et al., 2003). Over 40% of the original area of 200 million ha has been converted to date, largely for agriculture and cultivated pastures (Sano et al., 2010). PAs governed through the Brazilian System of Conservation Units (the SNUC; MMA, 2003) are one of the main conservation responses to this conversion (Klink and Machado, 2005; MMA, 2011). In 2010 the SNUC PA network covered 8% of the Cerrado (MMA, 2011), including strictly protected areas, which allow only recreation and research, and multiple-use areas, which involve greater direct use of natural resources (MMA, 2003).

2.2. PA performance

We used a metric of PA performance widely applied in previous studies using matching methods: the difference between outcomes (in this case % of natural habitat present in 2002 that was converted by 2009) in control sites and in areas inside PAs, which we term avoided conversion. We used data from Carranza et al. (2013) which measure avoided conversion within the Cerrado biome (as defined in IBGE, 2012) from 2002 to 2009 in 106 PAs created prior to 2002, by comparing areas inside PAs with control sites selected by matching for potential covariates of conversion such as distance to markets and soil quality (after Andam et al., 2008; Joppa and Pfaff, 2011; Nelson and Chomitz, 2011). Avoided conversion was measured using data from the Integrated Warning Deforestation System (SIAD; LAPIG, 2012), which are derived from MODIS satellite imagery. SIAD data are based on a threshold of 15% change in vegetation cover, including all types of native habitat in the Cerrado (i.e. forest, savanna and grassland physiognomies). In order to distinguish converted areas from vegetation changes caused by seasonal droughts, SIAD methodology includes visual inspection assisted by higher resolution Landsat TM and CBERS CCD imagery (Rocha et al., 2011).

Carranza et al. (2013) found that collectively, Cerrado PAs are highly effective in avoiding conversion, but their effectiveness nevertheless varies widely across PAs. This raises the question of whether PAME assessment scores predict this variation (see Section 2.4). To ensure that our measures of avoided conversion in PAs were robust, we restricted our analysis to those PAs in Carranza et al. (2013) with at least 50% of their area inside the Cerrado biome (as the conversion data did not include other biomes), and with 50% or more of their sampled area successfully matched with control sites. We included both strictly protected areas and multiple-use areas in the analyses. Finally, in order to test whether the results are robust to different thresholds and to which types of PAs we included, we repeated all of the analyses using a 30% threshold for both the area of each PA inside the biome and for the rate of successful matches in each PA, using a 70% threshold for both, and using only strictly protected areas.

2.3. PA management

We used PAME assessment scores from the version of RAPPAM which was used in Brazil in 2005 to assess over 200 PAs (IBAMA and WWF-Brasil, 2007). The RAPPAM questionnaires were completed by PA staff during workshops, and included 96 scored questions (all of which were completed). Each question had 4 options ("no", "predominantly no", "predominantly yes", and "yes") that received scores of 0, 1, 3, or 5, thereby producing ordinal scoring output (i.e. non-continuous ranked data). Based on RAPPAM methodology, these 96 scores are then grouped into 14 modules that are scored as the arithmetic mean of each group of questions. Modules are in turn grouped into five elements (context, planning, inputs, processes, and outputs), with each one scored as the arithmetic mean of its module scores. The final score (termed overall management effectiveness) is given by the arithmetic mean of element scores and converted into a percentage. In total, there are 116 scores for each PA in the 2005 assessment (96 questionnaire answers and 20 aggregate scores). The full questionnaire is available in the official report (see IBAMA and WWF-Brasil, 2007).

2.4. Predicting PA performance from management effectiveness scores

We examined how management effectiveness scores relate to the performance of PAs in avoiding conversion using a stepwise approach described below.

2.4.1. Main scores

We initially focused only on the main RAPPAM scores: the final score for overall management effectiveness and the scores for the five component elements (context, planning, inputs, processes and outcomes). We performed Spearman correlation tests between the estimates of avoided conversion in PAs and each of these six RAPPAM scores.

2.4.2. Correlates in the literature

We also tested for correlations between avoided conversion and a subset of other, carefully selected RAPPAM scores (Table 1). We searched the peer-reviewed literature for quantitative studies highlighting PA characteristics that have been found to correlate with conservation outcomes. We then looked for individual RAPPAM scores that might plausibly reflect those characteristics, and correlated these against our estimates of avoided conversion using Spearman correlation tests. Our literature search considered only those studies that involved multiple PAs and that identified potential correlates that we could reasonably link with one of the RAPPAM scores.

2.4.3. Further scores

Finally, we explored all possible correlations between avoided conversion in PAs and the remaining RAPPAM scores. Because of the increased probability, given so many tests, of rejecting the null

Table 1
Correlates of protected area performance suggested by a literature review, the RAPPAM scores that might plausibly reflect them, and Spearman correlation tests between these scores and avoided conversion across 26 protected areas in Cerrado.

Correlate	Reference	RAPPAM score	*r*	*p*
Area under contested ownership	Vanclay (2001)	07b) The situation of the land is regular	−0.25	0.218
Absence of land tenure conflicts	Nolte et al. (2013a)			
Demarcation of border	Bruner et al. (2001) and Vanclay (2001)	07c) Demarcation of frontiers is appropriate for the clear identification of the site's limits	−0.12	0.546
Guards per 100 km^2	Bruner et al. (2001) and Vanclay (2001)	16g) Prevention and detection of threats and law enforcement	−0.15	0.464

hypothesis of no correlation when it was true, we used False Discovery Rates (FDR; Pike, 2011) corrections for this analysis. The FDR procedure is less conservative than traditional methods such as Bonferroni tests (Bland and Altman, 1995), so it has greater power to identify genuinely significant patterns whilst reducing control over wrong discoveries, which is considered a good compromise (Pike, 2011). The FDR procedure provides a *q*-value – an adjusted *p*-value for each hypothesis test which is then used in place of the *p*-value to represent the probability that a comparison result could have occurred by chance.

We used R environment v 2.14.1 (R Core Team, 2012) for all Spearman correlation tests. Based on our sample size of 26 PAs, we had a power of 0.8 of detecting a correlation coefficient of at least 0.54 at a 0.05 significance (Olofsson, 2014). For the FDR-based multiple comparison procedures, we used the spreadsheet-based software provided in Pike (2011).

We performed all our analyses both including and excluding one major outlier in the dataset.

3. Results

3.1. Data overview

Out of the 106 PAs included in Carranza et al. (2013), 26 were covered in the 2005 RAPPAM assessment and met our other criteria (Fig. 1). The estimates of avoided conversion for this subset of PAs followed a similar distribution to those in the larger sample of 106 Cerrado PAs, indicating that our sample was representative of the biome (Fig. 2a). The distribution of the overall management effectiveness scores from RAPPAM for these 26 PAs was also similar to those for all the PAs in Brazil assessed with RAPPAM in 2005, and it overlapped that for a global compilation of PAME assessment scores (Leverington et al., 2010b), as illustrated in Fig. 2b. Note that the Cerrado RAPPAM scores in 2005 might be expected to be lower than the global average, as the latter included more recent assessments, and PAME assessment scores have improved over time (Leverington et al., 2010b).

3.2. Main scores

The scores derived from RAPPAM for overall management effectiveness showed no correlation with estimates of avoided conversion in Cerrado PAs from 2002 to 2009 (Fig. 3a). The five component element scores in RAPPAM also did not correlate with estimates of avoided conversion (Fig. 3b–f).

3.3. Correlates in the literature

The literature suggested three RAPPAM scores which might be expected to correlate with PA effectiveness (07b – the situation of the land is regular, 07c – demarcation of frontiers is appropriate for the clear identification of the site's limits, and 16 g – prevention and detection of threats and law enforcement; Table 1). However, none was correlated with our measure of how well PAs avoided conversion in the Cerrado.

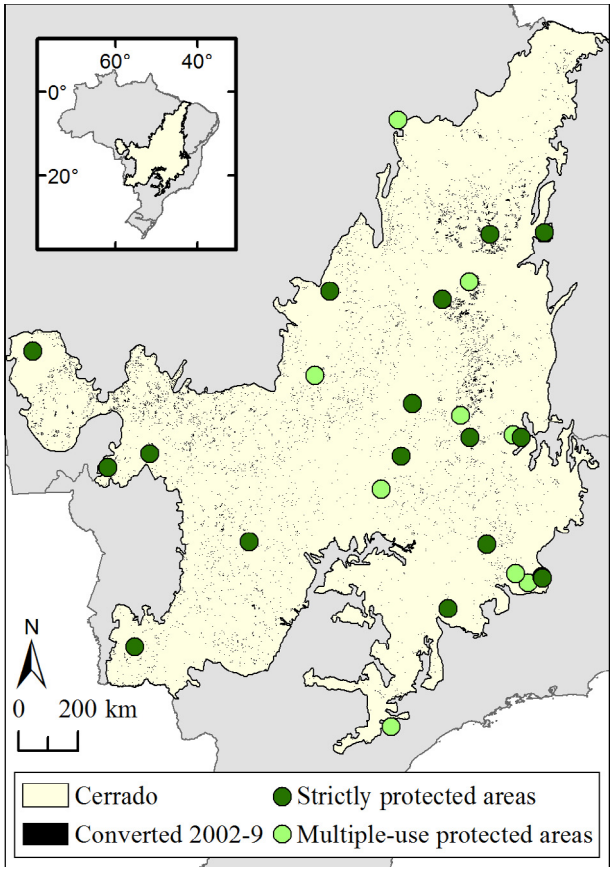

Fig. 1. Location of our sample of 26 protected areas and conversion in the Cerrado during the study period (2002–2009). The locator map shows the location of the Cerrado amongst other biomes in Brazil. Point locations for protected areas represent their geometric centre and may fall outside the area (data sources: IBGE 2012; LAPIG 2012; MMA 2012).

3.4. Further scores

We found no correlations, based on FDR adjusted *q*-values, between estimates of avoided conversion in PAs and any of the 116 individual RAPPAM scores. The frequency of *p*-values lower than 0.05 was similar to the expected frequency for the number of tests performed (Fig. 4a), and the frequency distribution of the correlation coefficient *r* was similar to a normal distribution (Fig. 4b). Six scores would have been significantly correlated with PA performance in avoiding conversion if FDR had not been used (Table 2). All but two of these were no longer correlated after removal of a

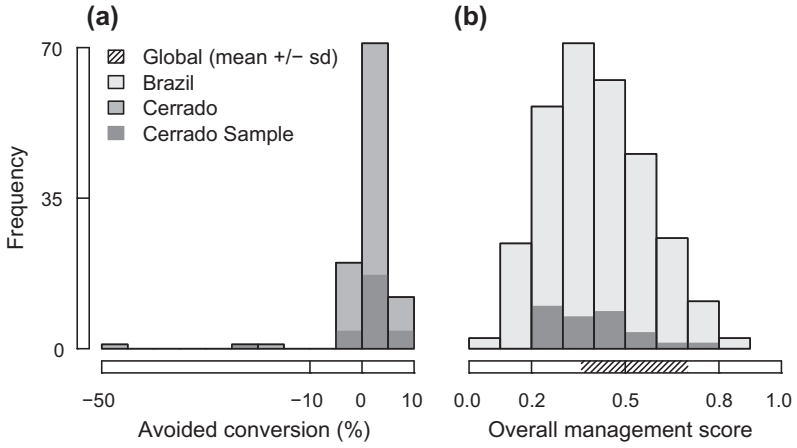

Fig. 2. Our 26 sampled protected areas (PAs) compared with larger sets of PAs. Left (a) compares the distribution of estimates of avoided conversion in our PA sample with those in all of the 106 PAs included in Carranza et al. (2013); right (b) compares the overall management effectiveness scores for our PA sample (from RAPPAM) with those for all 246 Brazilian PAs assessed in IBAMA and WWF-Brasil (2007), and with the global "overall mean score for management effectiveness" (±standard deviation) for 3184 PAs reported in Leverington et al. (2010b) for most recent assessments.

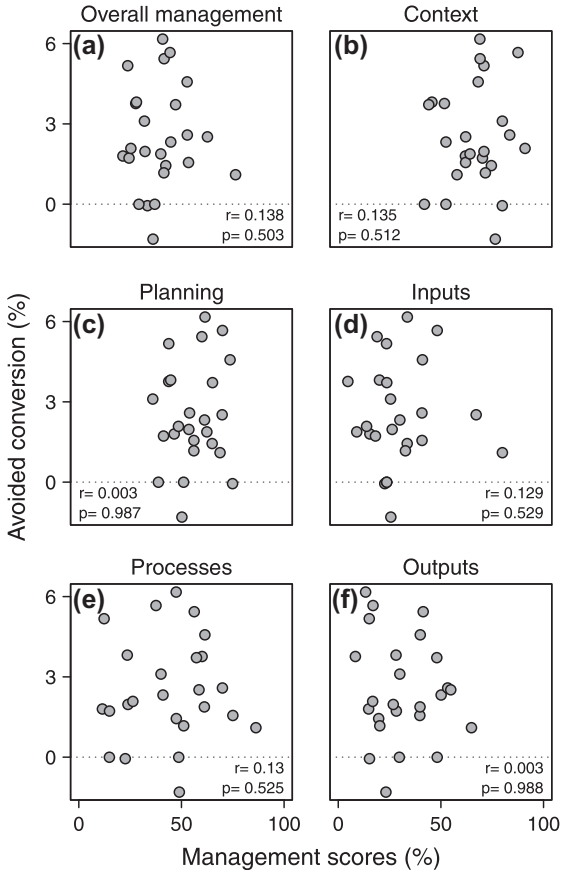

Fig. 3. Estimates of avoided conversion in protected areas (PAs) plotted against the main management effectiveness scores measured in RAPPAM (overall score and component elements) for 26 PAs in the Brazilian Cerrado. Results are shown for Spearman correlation tests between the estimates of avoided conversion in PAs and each of the six main RAPPAM scores (see text, Section 2.3). Where points overlap jitter was added to improve visualization; one major outlier was omitted (but included in the statistical tests).

major outlier from the dataset. Overall, there was no convincing evidence that any of these scores predicted the performance of PAs in avoiding conversion.

These results were essentially unaltered when we relaxed or tightened our criteria for which PAs were included in the analyses. Using 30% or 70% thresholds for both the area of each PA inside the Cerrado biome and for the rate of successful matches in each PA, or including only strictly protected areas, did not produce significantly different results (see Figs. A1, A2 and Table A1 for PAs meeting 30% thresholds; Figs. A3, A4 and Table A2 for PAs meeting the 70% thresholds; and Figs. A5, A6 and Table A3 for strictly protected areas).

4. Discussion

The main RAPPAM score for overall effectiveness and the main element scores cover a wealth of information on management efforts (Ervin, 2003). We therefore expected that these scores would reflect the performance of PAs in avoiding conversion – a key threat to the biodiversity of the Cerrado (Klink and Machado, 2005). We did not find the expected correlations. This echoes results for the Brazilian Amazon that tested the predictive power of both METT (Nolte and Agrawal, 2013) and RAPPAM (Nolte et al., 2013a) scores. However, Nolte et al. (2013a) found that an absence of land tenure conflicts recorded in RAPPAM was positively associated with reduced deforestation in Amazonian PAs; we did not find this relationship in the Cerrado (Table 1).

One plausible explanation for our findings is the largely subjective nature of management effectiveness assessments (Cook and Hockings, 2011; Cook et al., 2009). These assessments often rely exclusively on qualitative data or limited evidence (Cook et al., 2009), leading to a level of uncertainty that is rarely reported (Cook and Hockings, 2011). Whilst expert knowledge is an essential source of information (Margoluis et al., 2009), assessments based solely on subjective knowledge are also susceptible to bias – e.g. negative or positive aspects may be emphasised, even unconsciously (Burgman, 2001).

Although a full quantitative approach to PA monitoring may be beyond the resources available for most PAs, a combination of quantitative and qualitative data may help to improve the assessment of PA performance (Hockings et al., 2009). For example, Zimsky et al. (2010) found that the overall METT score did reflect the biological integrity of PAs in Zambia, where management evaluation was supported by empirical evidence. Laurance et al. (2012) also found that improved management (measured using a simpler questionnaire) reflected estimates of "reserve health" for a global sample of PAs where expert knowledge from scientists and empirical data were available (also see Timko and Innes, 2009). The

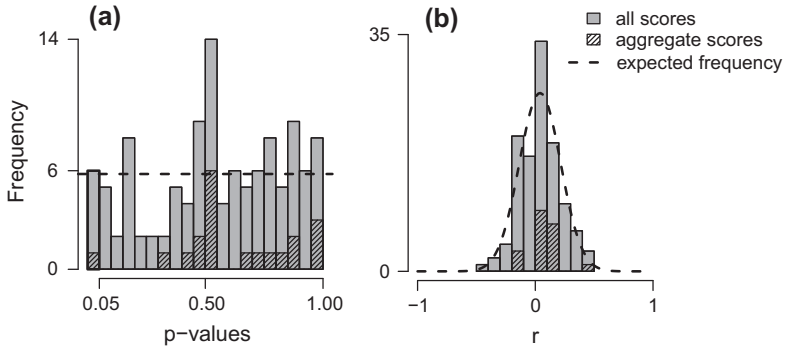

Fig. 4. Frequency distribution of (a) *p*-values and (b) coefficients for Spearman correlation tests between estimates of avoided conversion in protected areas (PAs) and each of the 116 management effectiveness scores in RAPPAM for 26 PAs in the Cerrado. Both distributions are similar to what would be expected from datasets that are not correlated (i.e. even distribution for *p*-values, and normal distribution for *r* values). ***All scores*** includes each individual question in RAPPAM and each aggregate score. ***Aggregate scores*** refers to modules (combined sets of question scores) and elements (combined sets of module scores) of management (see text, Section 2.3).

Table 2
Spearman correlation tests between estimates of protected areas (PAs) performance in avoiding conversion and all 116 PA management effectiveness scores included in RAPPAM for 26 PAs in the Cerrado. Only the test results which showed a significant correlation prior to False Discovery Rates (FDR) corrections are shown, whilst all others are indicated as ns (non-significant). None of the tests were significant after the FDR correction.

Management element	Management module	RAPPAM score	*r*	*q* (FDR-adjusted)	*p*	*p* (no outlier)
Context	Biological importance	3g[a]	0.43	0.902	0.030	0.023
	Socioeconomic importance	4a[b]	0.40	0.902	0.044	0.089
	Vulnerability	ns	ns	ns	ns	ns
Planning	Objectives	6c[c]	0.41	0.902	0.038	0.178
	Legal framework	ns	ns	ns	ns	ns
	Area design and planning	ns	ns	ns	ns	ns
Inputs	Human resources	ns	ns	ns	ns	ns
	Communication and information	10f[d]	0.44	0.902	0.026	0.046
	Infrastructure	ns	ns	ns	ns	ns
	Financial resources	Module	0.46	0.902	0.017	0.08
Processes	Planning	13a[e]	0.39	0.902	0.047	0.126
	Decision-making process	ns	ns	ns	ns	ns
	Research, assessment and monitoring	ns	ns	ns	ns	ns
Outputs	Outputs	ns	ns	ns	ns	ns

[a] The PA has minimum viable populations of key species (3g).
[b] The PA is an important source of employment for the community (4a).
[c] The policies and action plans are coherent with the PA's objectives (6c).
[d] There is effective communication among local communities (10f).
[e] There is an encompassing and current management plan (13a).

availability and use of evidence are both still limited in conservation evaluation (Bottrill et al., 2011; Pullin and Knight, 2005), and yet considered essential (Ferraro and Pattanayak, 2006; Sutherland et al., 2004).

Another plausible explanation for our findings is that good performance in the aspects of management assessed by RAPPAM may be necessary but not sufficient to ensure effective conservation. Measures that mostly address inputs and processes are often poor predictors of outcomes (Kapos et al., 2009), and adherence to particular standards of management may not assure conservation success (Kapos et al., 2008). Out of the 96 scored questions included in the version of RAPPAM used for this study (IBAMA and WWF-Brasil, 2007), 12 focused on outputs – making it just over 12% of the full questionnaire. Although assessing progress on management inputs and implementation is important, tracking results and effects of conservation actions provides more direct indicators of success (Kapos et al., 2008). A better balance could be achieved through monitoring key conservation outcomes independently or in addition to management evaluation (as recommended by Chape et al., 2005; Leverington et al., 2010a), even if the only evidence attainable is non-systematic.

We do not rule out the alternative that the estimates of avoided conversion in PAs did not correlate with RAPPAM scores because other factors – such as variation in underlying exposure to threats, the overall level of political support for conservation, or differences in PA designation – may be strong determinants of PA performance, which are not well captured in RAPPAM scores. Evidence for this is that broad management categories such as strictly protected and multiple-use (approximating to IUCN categories I–IV and V–VI, respectively – Dudley, 2008) are strong predictors of PA effectiveness in the Cerrado (Carranza et al., 2013) and elsewhere (Nelson and Chomitz, 2011; Nolte et al., 2013b), yet are not reflected in RAPPAM scores. It is also possible that management effectiveness scores may predict conservation outcomes that are not captured by our data – such as reducing disturbance or declines in species abundance (see Laurance et al., 2012).

It is worth considering that management evaluation plays an important role in the assessment of PA performance beyond indicating outcomes. As a qualitative method, it can draw on a wide range of information to capture a broad scope of effects (Margoluis et al., 2009), whereas quantitative data are limited to more conspicuous, observable outcomes. Management effectiveness evaluation helps understand the context in which interventions take place (Hockings et al., 2009), and stimulates communication and participation of different actors (Zimsky et al., 2010). As a result of the widespread uptake of the standard framework, a wealth of

data about PA management has been assembled (Leverington et al., 2010b), helping fill in the knowledge gaps about PA systems.

Finally, two important caveats should be considered. Our study is based on a limited sample of PAs – although one that would be sufficient to detect strong associations between avoided conversion and management effectiveness scores (with the standard 80% confidence). Secondly, our non-penalized tests (i.e. those we conducted without the use of FDR corrections) focus solely on RAPPAM questions linked to existing hypotheses of PA performance, and on high-level RAPPAM scores. Despite these points, our results and other recent findings (e.g. Nolte and Agrawal, 2013; Nolte et al., 2013a) indicate that management effectiveness scores should not be assumed to be reliable measures of conservation outcomes. Our study demonstrates that recent advances in techniques to estimate these outcomes more directly have considerable merit in helping to complement qualitative management data and improve the assessment of PA performance. Further research of this nature involving PA systems facing different threats and including other measures of conservation outcomes would be a valuable contribution in this area.

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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.biocon.2014.03.004.

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