McCallum, J. W., Vasilijevi, M., & Cuthill, I. (2015). Assessing the benefits of Transboundary Protected Areas: A questionnaire survey in the Americas and the Caribbean. Journal of Environmental Management, 149, 245-252. DOI: 10.1016/j.jenvman.2014.10.013

Authors' preprint (text is identical to version accepted for publication)

Assessing the benefits of Transboundary Protected Areas: A questionnaire survey in the Americas and the Caribbean

Jamie W. McCallum[a, b, *], Maja Vasilijević[b], Innes Cuthill[a]

[a] School of Biological Sciences, Life Sciences Building, 24 Tyndall Avenue, Bristol BS8 1TQ, UK

[b] Transboundary Conservation Specialist Group, World Commission on Protected Areas, International Union for the Conservation of Nature, Gland, Switzerland

* Corresponding author. Present address: Conservation Programmes, Zoological Society of London, Regents Park, London, NW1 4RY, UK. Tel.: þ44 7703135222.

E-mail addresses: jamie.mccallum@zsl.org (J.W. McCallum), maja.vasilijevic1@ gmail.com (M. Vasilijević), I.Cuthill@bristol.ac.uk (I. Cuthill).

Published in Journal of Environmental Management 149 (2015) 245e252

doi: 10.1016/j.jenvman.2014.10.013

Abstract

There are more than 3000 protected areas (PAs) situated on or near international boundaries, and amongst them there is an increasing trend towards the establishment of transboundary cooperation initiatives. Proponents of Transboundary PAs (TBPAs) highlight the potential for biodiversity protection through spatial, management and socio-economic benefits. However, there have been few formal studies that assess these benefits. It is possible that the relaxation of boundary controls to optimise transboundary connectivity may increase the risk of impacts from invasive species or illegal human incursion. We sought to investigate the validity of these proposed benefits and potential risks through a questionnaire survey of 113 PAs, of which 39 responded and met our inclusion criteria. 82% felt that transboundary cooperation has benefits for biodiversity and, across PAs, the self-reported level of transboundary communication was positively associated with some improved spatial, management and socio-economic benefits. However, 26% of PAs reported that they never communicated with their internationally adjoining protected area, indicating unrealised potential for greater gains.

1. Introduction

A Protected Area (PA) is a defined space designed to "achieve the long-term conservation of nature with associated ecosystem services and cultural values" (Dudley et al., 2008). In part this is delivered by protection from various threats (Struhsaker et al., 2005; Andam et al., 2008; Maiorano et al., 2008; Gaston et al., 2008; Craigie et al., 2010). A Protected Area that Adjoins an International Boundary (PAAIB) is a subset of the PA concept. In 2007, the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) identified 3043 protected areas that sit on or close to international boundaries (Lysenko et al., 2007). PAAIBs are therefore a substantial part of the global PA network. However, in an age of increasing globalization, international boundaries and frontier zones are becoming more highly populated areas of cultural and commercial transition, regulation and development (Van Schoik et al., 2007). This increase in population, development and trade can result in negative impacts on biodiversity from either side of the international boundary, both inside and outside PAAIBs. The effects of these impacts may be hard to control because the source may originate in another country with different socio-economic pressures, environmental laws and enforcement capabilities. Illegal transboundary activity may also have security or political implications. As a result, selecting optimal management strategies for PAAIBs is an important, yet difficult, task.

Transboundary Protected Area (TBPA) initiatives are one possible approach for managing these threats. TBPA initiatives seek to cooperatively protect and maintain ecosystems and/or species that are ecologically connected across international boundaries. Two or more contiguous PAAIBs may decide to identify and map a shared ecosystem (Sandwith et al., 2001) and then adopt and adhere to a cooperative management strategy. Equally there may be more informal, local arrangements between PAAIB staff, communities and/or non-governmental organisations (NGOs). In each case, TBPA proponents highlight the potential for spatial, management, socio-economic and political benefits through transboundary cooperation. Below, we analyse each of these elements in turn and explore their validity as well as possible obstacles to their realisation.

Availability of habitat is a critical factor in the persistence of species (Morrison et al.,

1992) and in Struhsaker et al. 's (2005) study of PA efficacy, conservation goals were shown to be best met by large PAs. Because they combine two or more PAAIBs, TBPAs should provide more contiguous, varied and core habitat, resulting in increased dispersal opportunities and access to suitable resources. These should in turn support increased species richness and resilience (Diamond, 1975; Kitchener et al., 1980; Edenius and Sjoberg, 1997; Claudet et al., 2008; Prugh et al., 2008). This viewpoint is supported in the literature with references to TBPA in relation to increased habitat for species as varied as the Andean condor (Vultur gryphus) (Lambertucci et al., 2014), wolf (Canis lupus) (Falucci et al., 2013) and Marco Polo sheep (Ovis ammon polii) (Schaller and Kang, 2008). It has also been cited as valuable in the marine realm (Mackelworth, 2012). Increased overall area can also restrict access for invasive species (and unwanted human activity) within core habitat, because of the increased distances between edge and core.

However, by relaxing boundary infrastructure to optimise these spatial advantages, TBPAs may increase the risk of negative effects. Habitat change (DeFries et al., 2005), invasive species (Pauchard and Alaback, 2004), pollution (Collins, 2010) and extraction (Gavin et al., 2010), all pose a major threat to biodiversity inside PAs (Craigie et al., 2010) and may be more widely felt in TBPAs due to their geographical characteristics and any relaxation of international boundary controls. Furthermore, many of the proposed spatial advantages of TBPAs are derived from broader theories of ecology or from politico-economic studies (e.g. Wolmer, 2003; Duffy, 2007; Ramutsindela, 2007) because it is difficult to measure these effects in the same place at the same time (Busch, 2008).

TBPAs can also present opportunities for cooperative ecosystem management, creating a better safeguard for biodiversity (Talukdar and Sinha, 2013; Schaller and Kang, 2008; Plumptre et al., 2007; Sandwith et al., 2001). This cooperative management might include better overall habitat and species maintenance, improved science over wider spatial scales and shared crisis management, brought about by joint early warning, threat analysis and containment. For example, treatment of all infected individuals within an ecosystem (rather than those on just one side of a boundary) could improve the chances of controlling an outbreak of disease. And transboundary law enforcement can be effective in curtailing and deterring illegal activity (Talukdar and Sinha, 2013) and eliminating cross-boundary sanctuaries. These cooperative management activities may also enable participants to benefit from shared human and material resources, providing economies of scale and reducing expenditure. Assuming that these efficiency savings are directed carefully, they may in turn improve biodiversity conservation. However, TBPA communication and management requirements may place additional pressure upon PAAIB managers and they may find that the potential advantages are overshadowed by the requirements of maintaining the TBPA relationship (Pedynowski, 2003). Furthermore the theoretical value of such cooperation may be impossible to put into effect due to geographical, cultural or political impediments.

Socio-economic and political activity fostered by transboundary cooperation may reduce some drivers of illegal activity, in turn reducing likely impacts such as resource-exploitation, poaching and smuggling within a TBPA (Groff and Axelrod, 2013). Transboundary tourist activity can enable sustainable use of the shared natural asset leading to increased revenues (Scovronick and Turpie, 2009; Plumptre et al., 2007), which may or may not be directly reinvested in biodiversity conservation, but should at least ensure maintenance of the asset. It is also assumed that local cooperation can lead to wide-scale national political cooperation between nations, reducing the risk of conflict and the plethora of challenges that this throws up for biodiversity conservation. Such initiatives do require management, law enforcement and the education of nearby human populations in order to ensure sustainable interaction (Altrichter et al., 2006; Jacobsen, 2010). However, the potential socio-economic benefits of TBPAs may not be fully apparent to governments. As a result TBPAs may not have the human or material resources (Mackelworth, 2012) to deliver the necessary safeguards (Colwell et al., 1997), even with the shared resources of a TBPA partner. Furthermore, the ability of PAs to alleviate poverty is unproven (Naughton-Treves et al., 2005; Struhsaker et al., 2005) and may be difficult to realize in conjunction with conservation (McShane et al., 2011). This may be even more challenging in a TBPA context.

The trade-offs and possible contradictions raised above have not been scientifically tested sufficiently to provide decision makers with the robust evidence required to make the large financial, political and ecological decisions required to initiate, or sustain, a TBPA initiative. The main problem is that direct experimental comparisons are very hard to make; a TBPA site cannot exist at the same time in the same place as a non-TBPA site (Busch, 2008).

In the absence of clear evidence, relevant management decisions are often shaped by socio-economic, political and security agendas and by subjectivity (Colwell et al., 1997). There is therefore some urgency to address these issues, because of the increase in biodiversity loss (IUCN, 2013) and the ongoing development of transboundary conservation projects.

2. Aims

The general aim of this research is to help identify conservation approaches that are likely to be successful. In particular we aimed to test spatial, management, socio-economic and political benefits and risks and identify the trade-offs implicit in TBPA schemes. Furthermore we wanted to understand how these variables might be influenced by transboundary communication levels.

Our results should help PAAIB managers and policy makers present an informed case when considering TBPA schemes and should help them to direct their resources effectively to optimise planning, funding, coordination and management of such sites for the benefit of biodiversity protection.

3. Methods

Given the difficulties of directly quantifying the effects of TBPAs on biodiversity through field studies, a TBPA questionnaire survey was selected as the best means of collecting data. Questionnaires directed at experienced personnel on the ground can be effective in measuring PA and conservation trends, threats and levels of success (e.g. Hockings, 2003; Ervin, 2003; Goodman, 2003). System-wide assessments, based on qualitative scoring or broad-scale quantitative data can help to identify common patterns (Ervin, 2003). While it is recognised that respondents in surveys of this type may be self-selecting, Hockings (2003) suggests that, "... the subjective responses of PA managers are likely to be based on years of fieldlevel experience, and these responses may better capture the realities and complexities of the PA than many monitoring programs" (Hockings, 2003).

Members of the Transboundary Conservation Specialist Group (TBC-SG) of IUCN World Commission on Protected Areas (WCPA) provided contact details for 113 PAAIBs in the Americas and the Caribbean. At the time of this research, contact details were not available for all PAAIB globally and therefore we focused, as an initial study, on the Americas and Caribbean, where we had a full dataset. The PA manager in each PAAIB was sent an invitation to respond to an online survey. It was understood that not all of the PAs would respond, even if they did receive the invitation. However, some research suggests that any response level above 25% is high (Young and Larson, 2011). On this basis, an initial list of 113 targets was deemed large enough to provide sufficient data to address the main aim of the investigation.

The questionnaire format was designed to follow standardised social science protocols (King et al., 1994); in all cases it was completed by the protected area manager. Beyond basic data such as the name of the PA and the country in which it sat, PAs were also asked the closest distance from their perimeter to the international boundary. Only those whose perimeter was less than 1 km from the international boundary were included and therefore classified as a PAAIB. They were also asked about personnel size (0, 1-5, 6-20, 21-50, >50) and scored these on an ordinal scale from 0 to 4. (See Appendix for a full list of questions).

In order to measure whether cooperation levels correlated with spatial, management and economic benefits, a good measure of each PAAIB's current level of cooperation with any nearby PAAIB was required. While they were asked about their relationship with any contiguous PAAIB, this was also assessed with a less subjective and more quantitative measure. Each PAAIB was asked how often their representatives communicated with any contiguous PAAIB and this was scored according to frequency. It was also important to know about any obstacles to further cooperation, as this might provide insights into any actions that might simply and easily increase cooperation levels. These included lack of resources (such as communications equipment), personnel, logistics (security, travel, geography, time) and social factors (political restrictions, no shared language, lack of interest from one party).

The likely spatial benefits for each PAAIB were explored by asking them four binary questions with a spatial implication and combining the total to provide an aggregate score. These questions asked whether the international boundary was spanned by a single ecosystem, if there were any species with a transboundary territory, if there was a PAAIB within 1 km on the other side of the international boundary and whether it directly expanded the total area of connected habitat. The secondary element of these spatial considerations was to understand if increased cooperation did correlate with reduced boundary infrastructure such as roads, ditches, fences and boundary markers. It was also of interest to determine whether each PAAIB felt that any of these impeded the transboundary movement of species.

In order to assess the potential risks associated with an increase in transboundary habitat, respondents were also asked about existing transboundary risks to biodiversity conservation. These were scored as categories including human (poaching, smuggling, resource extraction, illegal migration, human conflict, pollution) and biological (invasive species, disease). This was also useful in enabling us to understand whether these factors increased with cooperation, due to a presumed reduction in international boundary controls.

In order to determine whether the proposed management benefits of TBPA schemes are borne out on the ground, more information was sought about their areas of cooperation. They were asked whether they collaborated in each of 17 different areas, which were scored into four main cooperation categories of biodiversity maintenance and protection, law enforcement, countering bio-threats and socio-economic activity. Each category was scored according to the total number of areas checked.

Because the theory of TBPAs emphasises the economic benefits (particularly tourism) of such schemes, PAAIBs were asked which of their revenue streams might be enhanced by transboundary cooperation. It was then possible to test for a correlation between communication frequency and several possible income streams, which included tourism, government funding and nongovernmental organisation (NGO)/intergovernmental organisation (IGO) funding. This was supported by questions about how the PAAIB cooperated with local communities, including whether they provided employment to local communities or involved them in land-use planning. Some respondents might have felt that because the questionnaire had IUCN support, that there may be some funding associated with their output. This might have influenced their responses, thus financial responses were considered with some caution and the questionnaire was designed so that there was no implied pathway to a particular response or an incentive for any particular response.

Questions were translated into Spanish and Portuguese and contacts were uploaded to survey-specific pages on the online Survey Monkey site (http://surveymonkey.com). 113 introduction emails were sent to PAs, with a request for participation and the survey remained open from November 2011 to February 2012.

Associations between pairs of ordinal variables, or pairs of binary variables, were analysed non-parametrically using Kendall's rank correlation, correcting for ties (Kendall's tau-b); associations between ordinal and binary data were analysed, correcting for ties, using Kendall's tau-c (Kendall, 1958; SPSS Inc., 2010). P-values quoted are based on exact probabilities for contingency tables and binary-ordinal associations but, because of computing limitations, for ordinal-ordinal correlations Monte Carlo estimation based on 10,000 permutations, were used. The statistical significance from the Kendall's statistics (reported as τ) were very similar to the, perhaps more familiar, chi-squared and Spearman rank correlations for nominal and ordinal associations respectively. Kendall's tau was used because it is a unified measure of association across these different types of data. Comparisons between median response scores between North American and Caribbean/Latin American PAAIBs were done with Mann-Whitney U tests (abbreviated M-W U) with exact p-values quoted. All simple association and M-W U tests were carried out using SPSS v.18 (SPSS Inc., 2010); Kendall's partial correlations were computed using package ppcor (Kim, 2012) implemented in R (R Core Team, 2013).

4. Results

Of the 113 requests for participation, 37 were in N. America and 76 in Latin America and the Caribbean. 53 PAs completed the survey, a response rate of 46%, which is high for this type of online survey (Young and Larson, 2011). Of these 53 respondents, some did not meet a priori inclusion criteria: 14 were discarded as they either responded to less than 50% of questions (4), completed the questionnaire twice (2) or because their perimeter was over 1 km from the international boundary, meaning that they were not a PAAIB. Of the remaining 39 sites, 22 were situated in N. America (11 in the US and 11 in Canada) and 17 in 11 countries across Latin

America and the Caribbean. Percentages are quoted to the nearest calculated integer but it is important to note that, given that the calculations were based on 39 sites, the precision of these figures is approximately to the nearest 2.5% (1/39th).

82% felt that transboundary cooperation has benefits for biodiversity (one of our questions directly addressed this point), the figure being similar for N. American (86%) and Caribbean/Latin American (77%) respondents (Fisher exact test $p = 0.677$). 67% felt that transboundary cooperation could deliver improved income potential from at least one source, with N. Americans slightly less optimistic (59%) than Caribbean/Latin American respondents (77%), but not significantly so (Fisher exact test $p = 0.318$). Although it does not necessarily follow that increased income can lead to improved biodiversity protection, 69% of respondents suggested that it could, with again N. Americans non-significantly more positive than Caribbean/Latin American respondents (77% vs. 59%; Fisher exact test $p = 0.299$). Most of those that did not respond positively, wrote “not necessarily” or that money itself has no value without proper monitoring infrastructure in place. These subjective opinions were also correlated with personnel numbers to see if there was any significant bias introduced by staffing levels. Personnel numbers had a near-significant positive correlation with the degree to which the PA considered cooperation to be good for biodiversity protection ($\tau = 0.266$, $p = 0.063$), and view that transboundary protection could improve financial opportunities ($\tau = 0.235$, $p = 0.066$). There was no hint of an association between personnel numbers and the view that improved finance could benefit biodiversity ($\tau = 0.000$, $p = 1.000$). Whether any associations of other variables with the valuation of transboundary cooperation's effectiveness are in fact an incidental by-product of differences in personnel numbers is therefore examined on a case-by-case basis later. For similar reasons, where it could have been a confounding variable we also examined differences in the responses of N. American vs Caribbean/Latin American PAs. Personnel numbers tended to be higher in the former than latter, but not significantly so (median category for N. American personnel numbers: 21-50; for Caribbean/Latin: 6-20; M-W $U = 153.5$, $p = 0.324$).

In order to measure TBPA success, it was necessary to understand the levels of cooperation experienced by each PA. PAs were asked about their level of cooperation on a ranked scale from no cooperation (0), through informal ad hoc cooperation (2) to legally binding agreement at government level (5) with intermediate steps in between. According to these measures over 70% of sites cooperated at least some of the time including those who claimed to communicate but not directly collaborate on projects. Some PAAIB which checked "other" for their level of cooperation filled in text identifying that they "never" communicated and these were therefore classified in the "never" category and not regarded as TBPAs. 79% of respondents expected the same or greater cooperation in the future. They were also asked about the frequency of their communications with any contiguous PAAIB (Table 1). Because the correlation between frequency of communication and level of cooperation was highly significant ($\tau = 0.513$, $p < 0.001$), and because frequency of communication is a more objective numerical measure of real cooperation (and more likely a better measure than the legal status of any arrangement), this was used as a proxy for cooperation level (Fig. 1).

There was also a positive correlation between frequency of communications and the number of personnel in a PAAIB ($\tau = 0.311$, $p = 0.020$), which suggests either that levels of cooperation may be influenced by number of personnel, who have more time to communicate, or that those PAAIBs which are already cooperating, may generate enough resources to hire more staff. In subsequent tests potential confounding effects of personnel numbers on relationships between levels of cooperation and other variables by using partial correlation, were examined.

Lack of resources such as communications equipment (51%) and funds (46%) were widely seen as impediments to cooperation (Table 2). Of those who specified "other" issues, five were focused on border control and official travel restrictions and at least one suggested that staff made the effort to cooperate in their own time. Many sites felt that these obstacles could be overcome with more funding and general resources (12 sites), more agency and political support (8 sites), more contact (6 sites), more staff (5 sites), increased planning (4 sites) and less travel restrictions (4 sites). However neither cooperation level ($\tau = 0.186$, $p = 0.155$), nor communication frequency ($\tau = 0.044$, $n = 39$, $p = 0.742$) correlated significantly with the number of inhibitors to cooperation, with the trends being positive rather than the expected negative relationship. The number of inhibitors to cooperation also did not differ between N. American respondents and the rest (M-W $U = 173.5$, $p = 0.707$).

97% of PAAIBs stated that the international boundary was spanned by a single ecosystem, and 97% were home to species with a transboundary territory (Table 3). 90% stated that they had a contiguous PAAIB and 79% felt that it expanded the total area of connected habitat (Fig. 2).

Communication frequency correlates with the summed spatial benefit score ($\tau = 0.433$, $p = 0.002$) suggesting that either PAAIBs with existing habitat/landscape connectivity are considered and thrive as TBPAs, encouraging further cooperation, or that cooperation does indeed facilitate increased connectivity. The correlation is similar for N. American ($\tau = 0.415$, $p = 0.042$) and Caribbean/Latin American ($\tau = 0.468$, $p = 0.028$) PAAIBs.

28% of sites had no boundary demarcation, with 28% identifying a natural barrier (such as river), while over 66% identified at least some anthropogenic feature that marked the international boundary (56% border markers, 5% roads and 5% fences). 22% had both natural and anthropogenic boundary demarcation. Man-made boundary infrastructure did not correlate with communication frequency ($\tau = 0.015$, $p = 0.917$). Communication frequency did not correlate with transboundary human activity ($\tau = 0.178$, $p = 0.210$) or biological threats from invasive species ($\tau = 0.323$, $p = 0.075$) (Table 4).

A high number of PAAIBs conduct cooperative activity on at least some biodiversity protection and management related activities (62%), with 36% on law enforcement activities, 23% on joint approaches to bio-threats and 38% on economic activity. 15% mentioned "other activities", which included fire management, training/education, interpretation and tourism management (including minimisation of tourist impacts) (Table 5). The association between increased communication frequency and greater cooperation on biodiversity management activities was explored and the correlation was found to be highly significant ($\tau = 0.495$, $p < 0.001$). Communication frequency also has significant positive associations with cooperation on bio-threats ($\tau = 0.493$, $p < 0.001$) and socio-economic activity ($\tau = 0.460$, $p < 0.001$), but the association with law enforcement activity was weaker and nonsignificant ($\tau = 0.214$, $p = 0.077$). These relationships remained unchanged when controlling for personnel numbers using partial correlations, although the law enforcement association became significant (biodiversity management: partial $\tau = 0.446$, $p < 0.001$; bio-threats: partial $\tau = 0.425$,

$p < 0.001$; socio-economic activity: partial $\tau = 0.480$, $p < 0.001$; law enforcement: partial $\tau = 0.235$, $p = 0.037$). Likewise, controlling for geographic region (N. America vs Caribbean/Latin America) had little effect on the associations (biodiversity management: partial $\tau = 0.492$, $p < 0.001$; biothreats: partial $\tau = 0.489$, $p < 0.001$; socio-economic activity: partial $\tau = 0.466$, $p < 0.001$; law enforcement: partial $\tau = 0.240$, $p = 0.034$).

49% of PAAIBs felt that law enforcement could be effective in restricting poaching and smuggling. A further 33% felt that it could help prevent resource extraction and 28% saw it as helping to prevent illegal migration through the PAAIB.

Table 6 shows in more detail the areas of likely improvement in financial opportunities. Tests showed a positive correlation between communication frequency and both tourist visitors ($\tau = 0.378$, $p = 0.0032$) and facilities ($\tau = 0.370$, $p = 0.004$), but not infrastructure ($\tau = 0.015$, $p = 0.917$) or the overall number of income streams being enhanced ($\tau = 0.084$, $p = 0.515$). The correlations between communication frequency and tourist visitors (partial $\tau = 0.287$, $p = 0.011$) and facilities (partial $\tau = 0.261$, $p = 0.023$) remained similar after controlling for personnel numbers (Fig. 3). The same is true when controlling for geographical region (tourist visitors partial $\tau = 0.376$, $p = 0.001$; facilities partial $\tau = 0.380$, $p = 0.001$). 69% of PAAIBs provided some degree of employment for local communities, 44% involved them in resource planning and distribution and 59% took a joint approach to shared environmental threats. Furthermore, 64% of PAAIBs felt that increased cooperation could positively influence local political cooperation, and 62% thinking that it could positively influence national political cooperation.

5. Discussion

The research questions were organised around the main themes of expected TBPA benefit. We now examine the results in this framework, discussing the spatial, management and socioeconomic benefits in turn.

The majority of TBPAS in the sample subjectively felt that cooperation had benefits for biodiversity in a range of areas. This view was felt irrespective of the resources available. The expected value generated by such schemes was reinforced by the fact that 79% of sites expected the same or more cooperation in the future. This would be unlikely if they were not gaining some benefit. However, only just over 60% of sites cooperated in some way, with a further 10% communicating without material cooperation. According to Zbicz (1999), this type of communication does rate as the lowest level of TBPA cooperation.

Some of this discrepancy between actual and foreseen cooperation is probably due to various current impediments to cooperation, and this is what the PAAIBs self-report. However, neither cooperation level ($\tau = 0.186$, $p = 0.155$), nor communication frequency ($\tau = 0.044$, $n = 39$, $p = 0.742$) correlated significantly with the number of inhibitors to cooperation, indeed the trends being positive rather than the expected negative relationship. This suggests that communication and cooperation can be achieved, in spite of potential obstacles.

According to these survey results, TBPA initiatives are correlated with increased habitat, which should in turn support increased species richness and resilience (Prugh et al., 2008) and make TBPAS more effective for biodiversity conservation (Struhsaker et al., 2005). The numerous species examples reported by the PAAIBs in the study reinforce the notion that TBPA initiatives do indeed provide more available habitat for terrestrial mammals, with birds and fish also identified as being likely beneficiaries.

These tests do not tell us whether PAAIBs with existing habitat/ landscape connectivity are more likely to become TBPAs due to their spatial suitability, encouraging communication, or whether communication does indeed facilitate increased connectivity. It may be a combination of both. Either way there is a correlation between communication frequency and improved biodiversity protection through management, so even if spatial suitability is the catalyst, then it still ultimately may enable TBPA cooperation.

In spite of this overall positive perception, it would be inaccurate to suggest that TBPAs remove all obstacles to habitat connectivity. Over 25% of sites identify at least one type of boundary infrastructure that does impede transboundary movement of native species. A large minority of sites experienced habitat subdivision by roads and fences. In addition, over 50% of sites identified smuggling, poaching and invasive species (including plants and pathogens as well as mammals) as ongoing and distinct transboundary threats. Critically these did not correlate in either direction with communication frequency, which suggests that TBPAs do not significantly increase the risk of negative transboundary effects through the reduction of international boundary controls. This may be because cooperation mitigates these potential threats or that existing infrastructure has little impact on them. This is an important finding because the presumed increase in transboundary threat level is a serious and obvious impediment to such schemes.

Survey results showed that greater communication has a direct correlation with joint biodiversity management, bio-threat mitigation and socio-economic activity. This is most likely because personnel are able to plan, deter, detect and respond to threats earlier, over a wider area and with greater material and human resources, if they are working together with another group with similar aims. However, law enforcement effectiveness showed a non-significant relationship with communication frequency. This may be because of the close association between law enforcement, national security and the sensitivity of such personnel widely cooperating across an international boundary. The majority of respondents felt that law enforcement (i.e. people rather than infrastructure) was the most effective way of combating transboundary anthropogenic threats.

The results showed that increased communication had a positive correlation with revenue streams. This included tourism as well as personnel as a proxy for income. While revenue is not a guarantee of improved biodiversity protection, it can provide opportunities for it. Because resources for conservation are limited, it is important that those who might invest in such schemes are aware that there is likely to be an economic (as well as ecological) return on their investment. Given that 89% of sites were partially government funded and that 48% of sites felt that increased funding was likely from government due to their involvement as a TBPA, it is also pertinent that an overwhelming majority of sites believed that political stability was more likely under a TBPA regime. This may well be because the understanding born of cooperating to manage and protect a shared resource, may lead to improved understanding and cooperation on a range of issues, including those that might be more controversial. This virtuous circle between funding, biodiversity protection and political cooperation (linked to territorial integrity) along with management of shared resources is exactly what TBPA proponents claim to be one of its great virtues, and which its implementers seem to agree with.

We urge other researchers to carry out similar research into PAAIBs in the rest of the world to see if our results generalise, or whether they differ with socio-economic or cultural factors. This is particularly relevant as approximately half the respondents were from the USA and Canada, two highly developed nations. However, we note that all the key associations that we document are similar in magnitude when analysing the N. American and Caribbean/Latin American PAAIBs separately, and all the significant associations remain when this regional split is controlled for.

6. Summary

There is good evidence from practitioners that increased communication frequency has an association with improved spatial, management and socio-economic benefits all of which can be shown to have a long-term benefit for biodiversity conservation inside TBPAs. However this is not always the case and major impediments do still exist.

One major gap is to attempt to generate a first step of communication between contiguous PAAIBs where they have limited time and resources (including personnel). The bridging of this gap could enable further cooperation, leading to some of the benefits listed previously, including improved resources. It could be bridged through the provision of improved and cheaper communication systems, which could overcome most of the geographical and even any linguistic impediments. Improved cooperation, economies of scale, increased finance and political stability in areas of transition and disruption, appears to provide strong opportunities for biodiversity protection and maintenance.

Acknowledgements

The survey was conducted with the support of the IUCN WCPA Transboundary Conservation Specialist Group. In particular, Dorothy Zbicz from International Environmental and Marine Policy, and Michael Schoon from Arizona State University who helped with concepts and planning. Olivier Chassot from the Tropical Science Centre, Costa Rica and Catarina Grilo from the Intersectorial Oceanographic

Commission, Portugal, helped with survey translations into Spanish and Portuguese respectively and Wayne Freimund and Diana Bedoya prepared TBPA target lists and contact details for the Americas. Dr. Jonathan Green and the Conservation Science Group at the University of Cambridge added important insights into structure, questions and statistical analysis. Marcus Rowcliffe from the Institute of Zoology at the Zoological Society of London also helped with general guidance in the preparation of the text. We particularly thank two anonymous reviewers for their thorough and constructive criticisms.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http:// dx.doi.org/10.1016/j.jenvman.2014.10.013.

References

Altrichter, M., Boaglio, G., Perovic, P., 2006. The decline of jaguars (*Panthera onca*) in the Argentine Chaco. Oryx 40, 302e309.

Andam, K.S., Ferraro, P.J., Pfaff, A., Sanchez-Azofeifa, G.A., Robalino, J.A., 2008. Measuring the effectiveness of protected area networks in reducing deforestation. Proc. Natl. Acad. Sci. U. S. A. 105, 16089e16094.

Busch, J., 2008. Gains from configuration: the transboundary protected area as a conservation tool. Ecol. Econ. 67, 394e404.

Claudet, J., Osenberg, C.W., Benedetti-Cecchi, L., Domenici, P., Garcia-Charton, J.A., Perez-Ruzafa, A., Badalamenti, F., Bayle-Sempere, J., Brito, A., Bulleri, F., Culioli, J.M., Dimech, M., Falcon, J.M., Guala, I., Milazzo, M., Sanchez-Meca, J., Somerfield, P.J., Stobart, B., Vandeperre, F., Valle, C., Planes, S., 2008. Marine reserves: size and age do matter. Ecol. Lett. 11, 481e489.

Collins, J.P., 2010. Amphibian decline and extinction: what we know and what we need to learn. Dis. Aquat. Org. 92, 93e99.

Colwell, M.A., Dubynin, A.V., Koroliuk, A.Y., Sobolev, N.A., 1997. Russian nature reserves and conservation of biological diversity. Nat. Areas J. 17, 56e68.

Craigie, I.D., Baillie, J.E.M., Balmford, A., Carbone, C., Collen, B., Green, R.E., Hutton, J.M., 2010. Large mammal population declines in Africa's protected areas. Biol. Conserv. 143, 2221e2228.

DeFries, R., Hansen, A., Newton, A.C., Hansen, M.C., 2005. Increasing isolation of protected areas in tropical forests over the past twenty years. Ecol. Appl. 15, 19e26.

Diamond, J.M., 1975. The island dilemma: lessons of modern biogeographic studies for the design of natural reserves. Biol. Conserv. 7, 129e146.

Dudley, N., Shadie, P., Stolton, S., 2008. Guidelines for Applying Protected Area Management Categories Including IUCN WCPA Best Practice Guidance on Recognising Protected Areas and Assigning Management Categories and Governance Types. In: Series: Best Practice Protected Area Guidelines Series, vol. 021. Gland : IUCN, 2013 x, 86pp. þ iv, 31pp. : ill.

Duffy, R., 2007. Peace parks and global politics: the paradoxes and challenges of global governance. In: Ali, S.H. (Ed.), Peace Parks: Conservation and Conflict Resolution. MIT Press, Cambridge, Massachusetts.

Edenius, L., Sjoberg, K., 1997. Distribution of birds in natural landscape mosaics of old-growth forests in northern Sweden: relations to habitat area and landscape context. Ecography 20, 425e431.

Ervin, J., 2003. Rapid assessment of protected area management effectiveness in four countries. Biosci 3, 833e841.

Falucci, A., Maiorano, L., Tempio, G., Boitani, L., Ciucci, P., 2013. Modeling the potential distribution for a range-expanding species: wolf recolonization of the Alpine range. Biol. Conserv. 158, 63e72.

Gaston, K.J., Jackson, S.E., Cantu-Salazar, L., Cruz-Pinon, G., 2008. The ecological performance of protected areas. Annu. Rev. Ecol. Evol. Syst. 39, 93e113.

Gavin, M.C., Solomon, J.N., Blank, S.G., 2010. Measuring and monitoring illegal use of natural resources. Conserv. Biol. 24, 89e100.

Goodman, P.S., 2003. Assessing management effectiveness and setting priorities in protected areas in KwaZulu-Natal. Biosci 53, 843e850.

Groff, K., Axelrod, M., 2013. Baseline analysis of transboundary poaching incentives in Chiquibul, National Park, Belize. Conserv. Soc. 11, 277e290.

Hockings, M., 2003. Systems for assessing the effectiveness of management in protected areas. Biosci 53, 823e832.

IUCN, 2013. What is a protected area?. http://www.iucn.org/about/union/commissions/wcpa/wcpa_overview/.

Jacobsen, S.K., 2010. Effective primate conservation education: gaps and opportunities. Am. J. Primat. 72, 414e419.

Kendall, W.H., 1958. Ordinal measures of association. J. Am. Stat. Assoc. 53, 814e861. Kim, S., 2012. ppcor: Partial and Semi-partial (Part) Correlation. R package version 1.0. http://CRAN.R-project.org/package=ppcor.

King, G., Keohane, R.D., Verba, S., 1994. Designing Social Enquiry: Scientific Inference in Qualitative Research. Princeton University Press, Princeton, New Jersey.

Kitchener, D.J., Chapman, A., Dell, J., Muir, B.G., 1980. Lizard assemblage and reserve size and structure in the western Australian wheatbelt some implications for conservation. Biol. Conserv. 17, 25e62.

Lambertucci, S.A., Alarcon, P.A.E., Hiraldo, F., Sanchez-Zapata, J.A., Blanco, G., Donazar, J.A., 2014. Apex scavenger movements call for transboundary conservation policies. Biol. Conserv. 170, 145e150.

Lysenko, I., Besancon, C., Savy, C., 2007. Global List of Transboundary Protected Areas. UNEP-WCMC, Cambridge.

Mackelworth, P., 2012. Peace parks and transboundary initiatives: implications for marine conservation and spatial planning. Conserv. Lett. 5, 90e98.

Maiorano, L., Falcucci, A., Boitani, L., 2008. Size-dependent resistance of protected areas to land-use change. Proc. R. Soc. Lond.; B 275, 1297e1304.

McShane, T.O., Hirsch, P.D., Trung, T.C., Songorwa, A.N., Kinzig, A., Montferri, B., Mutekanga, D., Than, H.V., Dammert, J.L., Pulgar-Vidal, M., Welch-Devine, M., Brosius, J.P., Coppolillo, P., O'Connor, S., 2011. Hard choices: making trade-offs between biodiversity conservation and human well-being. Biol. Conserv. 144, 966e972.

Morrison, M.L., Marcot, B.G., Mannan, R.W., 1992. Wildlife Habitat Relationships: Concepts and Applications. University of Wisconsin Press, Madison.

Naughton-Treves, L., Holland, M.B., Brandon, K., 2005. The role of protected areas in conserving biodiversity and sustaining local livelihoods. Annu. Rev. Environ. Resour. 30, 219e252.

Pauchard, A., Alaback, P.B., 2004. Influence of elevation; land use and landscape context on patterns of alien plant invasions along roadsides in protected areas of south-central Chile. Conserv. Biol. 18, 238e248.

Pedynowski, D., 2003. Prospects for ecosystem management in the crown of the continent ecosystem, Canada-United States: survey and recommendations. Cons. Biol 17, 1261e1269.

Plumptre, A.J., Kujirakwinja, D., Treves, A., Owiunji, I., Rainer, H., 2007. Transboundary conservation in the greater Virunga landscape: its importance for landscape species. Biol. Conserv. 134, 279e287.

Prugh, L.R., Hodges, K.E., Sinclair, A.R.E., Brashares, J.S., 2008. Effect of habitat area and isolation on fragmented animal populations. Proc. Natl. Acad. Sci. U. S. A. 105, 20770e20775.

R Core Team, 2013. R: a Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna.

Ramutsindela, M., 2007. Transfrontier Conservation in Africa. At the Confluence of Capital, Politics and Nature (PhD dissertation). University of Capetown, Capetown, S. Africa.

Sandwith, T., Shine, C., Hamilton, L., Sheppard, D., Phillips, A. (Eds.), 2001. Transboundary Protected Areas for Peace and Co-operation. IUCN, Gland.

Schaller, G.B., Kang, A., 2008. Status of Marco Polo sheep *Ovis ammon polii* in China and adjacent countries: conservation of a vulnerable subspecies. Oryx 42, 100e106.

Scovronick, N.C., Turpie, J.k, 2009. Is enhanced tourism a reasonable expectation for transboundary conservation? An evaluation of the Kgalagadi Transfrontier Park. Environ. Cons. 36, 149e156.

SPSS Inc, 2010. PASW Advanced Statistics 18. SPSS Inc., Chicago.

Struhsaker, T.T., Struhsaker, P.J., Siex, K.S., 2005. Conserving Africa's rain forests, problems in protected areas and possible solutions. Biol. Conserv. 123, 45e54.

Talukdar, B.K., Sinha, S.P., 2013. Challenges and opportunities of transboundary rhino conservation in India and Nepal. Pachyderm 54, 45e51.

Van Schoik, D.R., Lelea, E., Cunningham, J., 2007. Transboundary biodiversity: turning a potential tragedy into a true partnership. In: Hoffman, K. (Ed.), USMexican Border Environment and Transboundary Ecosystem Management. The Southwest Consortium for Environmental Research and Policy (SCERP), Phoenix, Arizona. Monograph 15, (Chapter 1).

Wolmer, W., 2003. Transboundary conservation: the politics of ecological integrity in the Great Limpopo Transfrontier Park. J. S. Afr. Stud. 29, 261e278.

Young, A.M., Larson, B.M.H., 2011. Clarifying debates in invasion biology: a survey of invasion biologists. Environ. Res. 111, 893e898.

Zbicz, D.C., 1999. Transboundary Cooperation in Conservation: A Global Survey of Factors Influencing Cooperation Between Internationally Adjoining Protected Areas. PhD Dissertation. Nicholas School of the Environment, Duke University.

Tables

Table 1. TBPA communication frequency scores from a questionnaire survey of 39 protected areas adjoining international boundaries.

How often do representatives of your protected area communicate via phone/email/fax with the internationally adjoining protected area?	No.	%	Score
Weekly	6	15	4
Monthly	6	15	3
Quarterly	11	28	2
Annually	6	15	1
Never	10	26	0

Percentages are rounded to the nearest integer, because from a sample of 39, further decimal places would give a misleading degree of accuracy. This approach accounts for the total being 99%.

Table 2. Obstacles to TBPA cooperation from a questionnaire survey of 39 protected areas adjoining international boundaries.

Please tick any obstacles to cooperation with the internationally adjoining protected area	No.	%
Lack of suitable communication equipment	6	15
Lack of resources	20	51
Shortage of time	12	31
No shared language	3	8
Political restrictions	10	26
Lack of money	18	46
Security risk	4	10
Difficulty of traveling between protected areas	18	46
One or more parties not interested	2	5
Impassable geographical feature	3	8
Other (please specify)	11	28

Percentages are rounded to the nearest integer, because from a sample of 39, further decimal places would give a misleading degree of accuracy.

Table 3. Species identified as having transboundary territory in questionnaire survey of 39 protected areas adjoining international boundaries, along with number of mentions.

Species	**Number of mentions**
Bear (all species with bear in common name, except polar bear)	15
Bobcat (*Lynx rufus)*	2
Caribou (*Rangifer tarandus)*	6
Coyote (*Canis latrans)*	2
Deer (all species with deer in common name)	13
Elk (*Cervus canadensis)*	3
Fox (all species with fox in common name)	1
Iguana (all species with iguana in common name)	1
Jaguar (*Panthera onca)*	6
Lynx (all species with lynx in common or scientific name)	5
Monkey (all species with monkey in common name)	3
Mountain goat (*Oreamnos americanus)*	7
Moose (*Alces alces)*	9
Peccary (all species with peccary in common name)	2
Pig (all species with pig in common name)	1
Polar bear (*Ursus maritimus)*	1
Porcupine (all species with porcupine in common name)	1
Pronghorn (*Antilocapra americana)*	2
Puma (*Puma concolor)*	9
Sheep (all species with sheep in common name)	6
Tapir (all species with tapir in common name)	3
Wild boar (*Sus scrofa)*	1
Wolf (*Canis lupus)*	11
Wolverine (*Gulo gulo)*	6
Fish (all species)	8
Bird (all species)	15

Table 4. Transboundary threat counts from a questionnaire survey of 39 protected areas on international boundaries.

Please tick any threats that your protected area faces from across the international boundary	**No.**	**%**
Poaching	19	49
Smuggling	19	49
Resource extraction	19	49
Illegal migration	12	31
Human conflict	3	8
Disease	5	13

Invasive species	17	44
Pollution	10	26
Other (please specify)	11	28

Table 5. TBPA cooperation areas from questionnaire survey of protected areas adjoining international boundaries, with count number and % of positive results.

Which of the following issues does your protected area currently cooperate with the internationally adjoining protected area?	**No.**	**%**
Biodiversity management and research		
Habitat and/or biodiversity protection	22	56
Ecosystem-based management	14	36
Scientific research	16	41
Conserving resources for future generations	14	36
Watershed management	10	26
Access for indigenous communities	5	13
Law Enforcement and protection		
Anti poaching activity	9	23
Anti-smuggling activity	8	21
Elimination of illegal resource extraction	3	8
Reduction in illegal migration	1	3
Bio threats		
Alien invasive management	8	21
Pathogen prevention and elimination	1	3
Pollution control	2	5
Socio-economic activity		
Tourism	13	33
Timber harvest	0	0
Harvest of non-timber products	1	3
Other (please specify)	6	16

Table 6. Number of revenue streams enhanced by cooperation from questionnaire survey of 39 protected areas adjoining international boundaries.

Which of these revenue streams can be enhanced by cooperation?	**No.**	**%**
Incentives to encourage transboundary cooperation	9	23
Research permits	5	13
Tourism	17	44
Shop	3	8
Hunting permits	1	3

Development projects	11	28
NGO funding	14	36
IGO funding	9	23
Government funding	16	41
Transboundary commercial activity	5	13
Cultural events and exchanges	13	33
Other (please specify)	4	10

Figures & legends

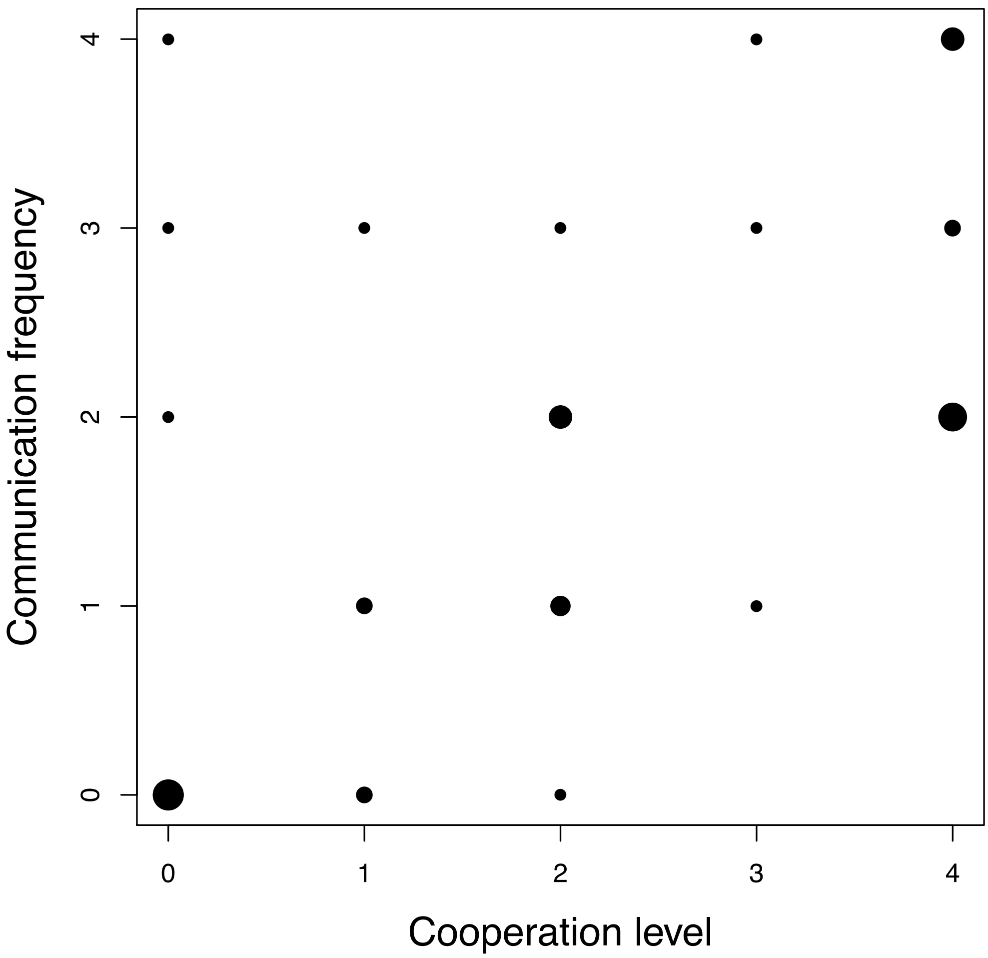

Fig. 1. Frequency of transboundary communication by transboundary cooperation level from a questionnaire survey of 39 protected areas adjoining international boundaries.

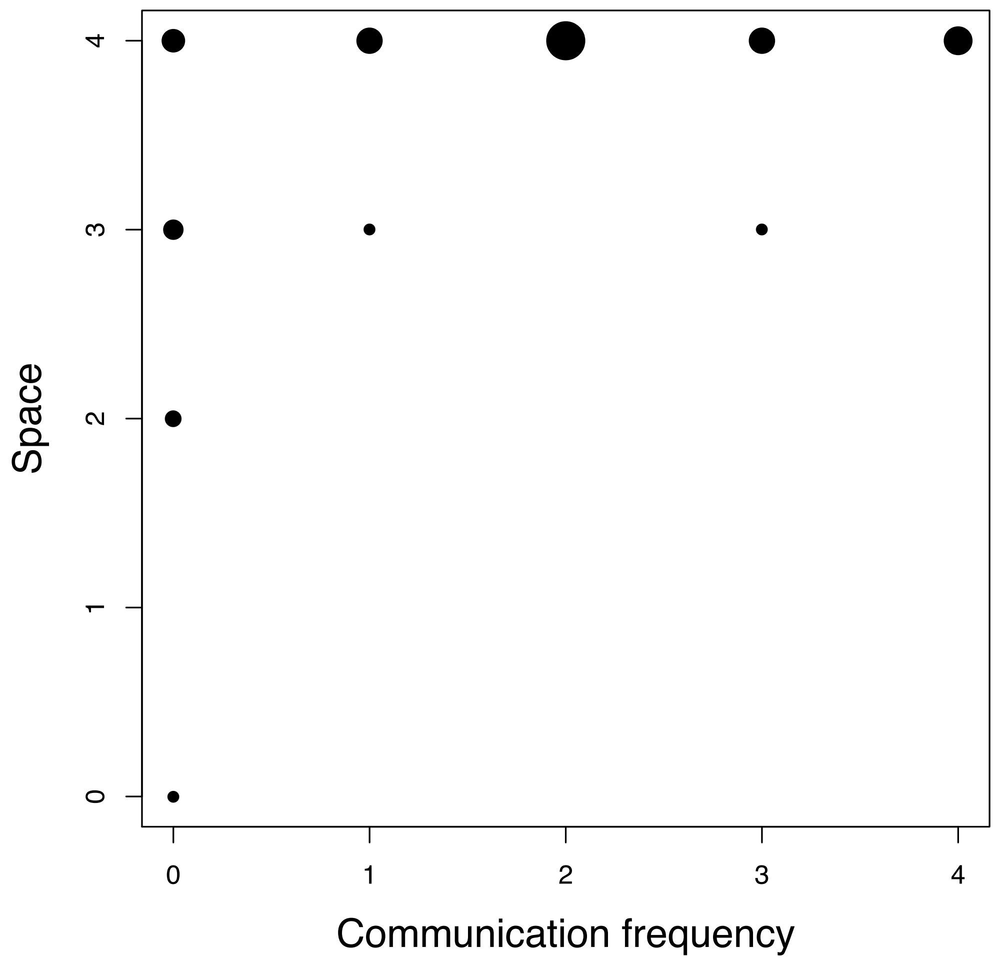

Fig. 2. Frequency of transboundary communication by proxy spatial benefit score from a questionnaire survey of 39 protected areas adjoining international boundaries.

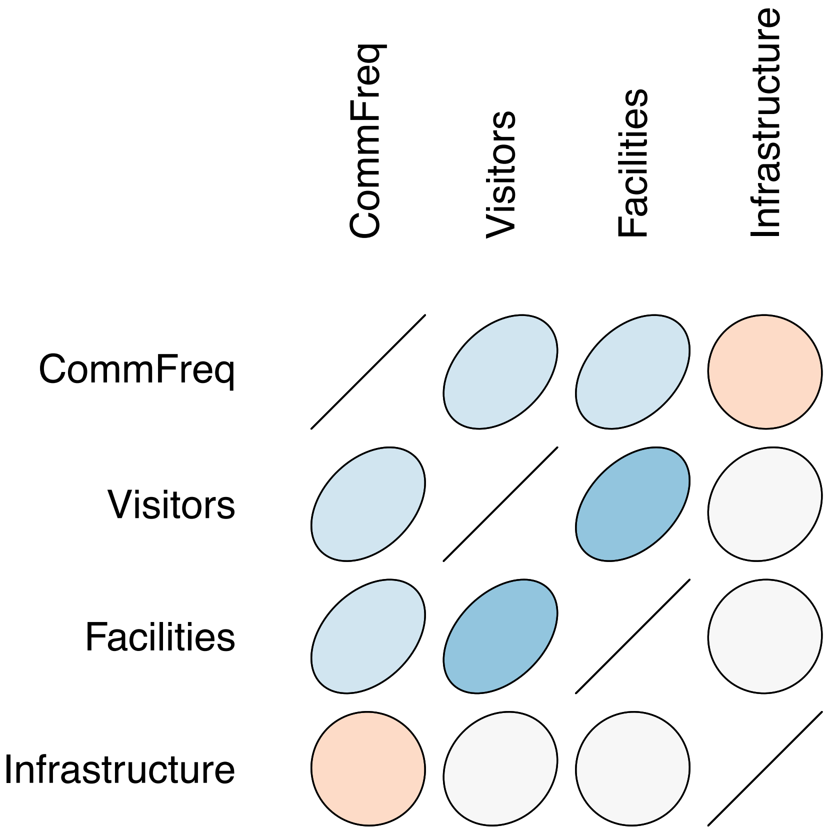

Fig. 3. Visual representation of Kendall correlations between frequency of communication (CommFreq) and number of visitors, facilities and PA infrastructure from questionnaire survey of 39 protected areas adjoining international boundaries. The degree of ellipsis and intensity of colour plots the magnitude of the Kendall correlation (circle = no correlation, cigar-shaped = strong correlation). The orientation of the ellipse and the colour indicates the sign of the correlation. So, dark red cigar = strong negative correlation, dark blue ellipse = strong positive correlation, with shades of pink and light blue representing weaker correlations. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)