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Cross-boundary collaboration: key to the conservation puzzle

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Abstract

Conservation science is advancing rapidly, yet the majority of research overlooks a key factor that can play a major role in shaping the outcomes of conservation initiatives: collaboration. Here, we review the importance, benefits and limitations of incorporating collaboration into conservation and specifically into systematic conservation planning, providing a general framework for considering collaboration in conservation planning. Recent work shows that cross-boundary collaboration can have positive and negative impacts on the outcomes of conservation and management efforts for protected areas, ecosystems, threatened and invasive species. The feasibility of collaboration, its likely effects and associated trade-offs should be explicitly incorporated into conservation science and planning. This will ensure that conservation decisions avoid wasted funding when collaboration is infeasible, promoting collaboration when the benefits outweigh the costs.

Biodiversity does not stop at political boundaries

While many conservation efforts and programs stop at the border between countries, the species they aim to conserve and the threats they aim to halt often do not. Spatially, conservation plans are usually performed within national boundaries or at the scale of sub-national jurisdictions [1-3]. However, the conservation features we are trying to manage, such as endangered species, threatened ecosystems and invasive species, are often spread over large spatial scales and cross multiple boundaries (Boxes 1-3). Because of this, it is common for conservation features to be distributed across national, state and other jurisdictional boundaries, meaning that conservation outcomes will often be conditional on decisions made across multiple jurisdictions. Although the importance of cross-boundary collaboration in conservation efforts is increasingly recognised in the literature, it has yet to be explicitly incorporated into most conservation planning and programs [4-5].

Types of collaboration

Different types of collaboration can be classified by the number of actors, the reciprocity of their relationships, the spheres in which they collaborate, the stakeholder networks of collaboration (local, regional etc.), and the spatial extent of collaborations. Here we define collaboration as two or more organisational actors with a shared interests and/or collective responsibility working together to pursue complex goals (see Glossary) [6]. There are many types of collaborations relevant to conservation that can occur – from full collaboration, where partners negotiate share goals, to varying degrees of collaborative activity (see Glossary). Collaboration can occur among a range of different actors and/or across spatial boundaries (political, municipal and others). Actors range from governments (local, state and national), councils, public and private agencies, non-governmental organisations (NGOs), project partners, to a network of additional stakeholders [7-10].

The most common form of cross-boundary collaboration is that between direct neighbours that share terrestrial or maritime geographic boundaries. These include a broad range of collaboration avenues, such as shared or coordinated protected areas and joint management plans (e.g., the Natura2000 network), trans-boundary protected areas and peace parks [11], shared conservation action plans for recovering threatened species or ecosystems; integrated river basin management programs, joint plans for mitigating invasive alien species impacts (Box 3), joint research projects and other spatially-based collaborative efforts. Collaboration can also take place when partners do not share an immediate geographical border, but share management responsibilities, such as managing common-pool resources in

fisheries [12], or protecting species that spend different parts of their life cycle or migration phases in different locations ([13], see example in Box 1).

Here, we review the benefits and limitations of collaboration across geographical, jurisdictional and political boundaries at multiple large spatial scales. Collaboration in conservation takes place at all scales, including smaller scales such as across local districts, land agencies and local communities. However, as the scale increases, we expect differences in the way that decisions are made to become much larger due to differences and heterogeneity in cultural and social values, economies, politics, thus creating more potential barriers to collaboration. We therefore explore the potential benefits and limitations of cross-boundary collaboration at the sub-regional and above scales, which include direct state boundaries, the regional scale (among multiple neighbouring countries), continental and global scales.

Limitations and benefits of collaboration in conservation

Collaboration in conservation activities (see Glossary) can potentially enhance the preservation of ecosystems, species, and common-pool natural resources. This is especially true when different actors share not only the natural resources but also have common interests, agree on common practices, have social, economic and other ties and share information that can help build collaborative conservation plans [14]. However, collaboration can also be a complex, risky, costly and time-consuming process [15,16]. A range of potential benefits and costs involved with collaboration might be considered before or during decisions to enter into collaboration with another actor for the purposes of conservation (see examples and further references in Appendix 1).

Benefits of collaboration for conservation

The collaboration of conservation efforts can save limited conservation resources, and can be especially valuable where neighbouring countries share the same ecological regions or biomes and thus share multiple species and other conservation features (Appendix 1). Multiple studies have discussed the advantages of coordinating spatial conservation efforts (Appendix 1; [6, 9, 17-19]). Large-scale or cross-continental collaboration has the potential to improve management efficiency by identifying and controlling broad-scale threats (Appendix 1). Collaboration among countries can lead to more efficient conservation plans by targeting conservation to areas that have the highest ‘global’ benefits relative to costs, leading to a potentially higher return on investment of conservation funds [16,20-22].

Research from the Mediterranean Basin, in both the terrestrial [16] and marine [21,23] realms, has shown that substantial funds can be saved and a significantly smaller area is required to achieve similar conservation targets for threatened vertebrates when spatial conservation plans are coordinated across Mediterranean countries. However, interestingly, countries gain differing amounts by participating in collaborative conservation plans [21]. The differences in how much each country gains from collaboration depend on how much endemic and unique biodiversity it holds, and the relative cost of conservation actions in that country relative to attributes such as its size (Appendix 1 [24]).

At the continental scale, Moilanen et al. [22] found that coordinated conservation prioritisation of 8,463 vertebrates across 30 countries led to 50% higher conservation efficiency in terms of the area of species ranges protected. Similarly, coordination of vertebrate conservation across 70 European wetlands led to a 30% increase in area efficiency compared to no cooperation [3]. In the EU, coordination among member states for cost-effective prioritisation of protected areas considerably increased species representation of 2,676 plant and 181 mammal species [19]. Similar to Mazor et al. [21], some countries (Spain, Italy and Greece) benefitted more when following a coordinated approach, partly because they sustained a large number of range-restricted and endemic species [19].

An important factor in understanding the potential benefits of collaboration is an understanding of the likelihood of successful collaboration between actors ([25]; Appendix 1). Recent progress has been made in this area by Levin et al. [26] who looked at this question in the context of marine conservation for Mediterranean countries. The study demonstrated that existing economic, social and political collaboration among countries can be quantified based on shared environmental treaties, tourism and trade data, and showed how these data may potentially serve as a proxy for the likelihood of two countries to successfully collaborate in conservation.

Limitations of collaboration

While large-scale collaboration can have many advantages, it also has shortcomings that need to be considered (Appendix 1 [16,19,25]. These limitations range from biological through to political and socioeconomic (Box 2; [27]). From a socioeconomic and political perspective, local involvement can be central to the success of conservation programs [28,29], whereas collaboration (e.g. in enforcing marine protected "no-take" areas) has often been proposed to enhance top-down policy rather than accounting for the costs of that collaboration to all the actors involved in a bottom-up approach (e.g. when no-take areas are designated, some actors

may lose out if their resource area has particularly high biodiversity). Centralized conservation or top-down decision-making can generate antagonism and apathy locally [28]. There can also be issues when investment is prioritised away from certain countries that provide little benefit to the 'global' goal, as countries value species in different ways, and often prefer to retain local native species for reasons such as national pride, parochialism, or ethical responsibility [30,31]). Geographical barriers can further affect cross-boundary conservation efficiency due to the inability to observe conservation outcomes in far-away areas, such as conservation planning across migration routes of birds that cross states and continents (Box 1).

Collaboration, especially across international boundaries and involving multiple countries, often requires greater increased resources in comparison with independent planning due to increased transactions costs (see Glossary) and more complex logistics [Appendix 1; 12,16,22,27]). International programs and treaties involve greater transaction costs to cover large-scale planning, communication, and execution of conservation plans, which may lead to delays and increased financial cost due to numerous barriers such as language, culture, and political agendas [32]. Punt et al [31] compared the conservation outcomes of marine protected areas under three collaboration scenarios: (i) full coordination, (ii) no coordination (autarky) and (iii) "strategic behaviour", where a country invests less in one conservation feature (e.g., a species or ecosystem) because others are already protecting it. They found that both autarky and strategic behaviour lead to under-investment in biodiversity conservation. Strategic behaviour led to what they term "location leakage", in which countries invest less in species protected by others [31].

One risk associated with collaboration is the risk of a country "free-riding" (Appendix 1) whilst others do the work. Although this is rarely dealt with in the conservation literature, this is a common theme of economic and political literature, and approaches such as game theory can be adopted to explore the basic problems and difficulties of cooperation [33-36]. A final challenge that is not unique to collaboration, but is rather a potential issue for large scale conservation planning in general, is that regional and continental scale conservation planning attempts to account for collaboration tend to prioritize species richness and rarity, as well as threatened species and ecosystems, and may tend to ignore some local populations with unique local genetic diversity or important cultural or other values to local communities [16]. Well-coordinated plans that consider risk, uncertainties, and multiple scales and types of values (Figure 1), can integrate these considerations and emphasise both representation of

genetic diversity and local cultural or socio-economic values [10,16,19]. In these cases, when stakeholders have been integrated at all levels of the scale hierarchy (including local knowledgeable actors) from the beginning of the process (Figure 1), collaboration might ameliorate rather than limit the challenges of scale.

Avenues for successful collaboration in conservation

Assessing collaboration needs for conservation requires strategies at different spatial scales, from global to local.

Multi-country, global and regional scale: International policies and agreements

International conservation policy is a crucial area for advancing collaboration [37] due to the global scale and anthropogenic nature of threats to biodiversity. There are already in place a wide range of international conservation policy mechanisms, partnerships and agreements in place for protecting cross-boundary species and traded species (Box 1 [4,37-42]). These include the Convention for Biological Diversity (CBD, 194 parties on 6 May 2014; http://www.cbd.int/) and the Convention on International Trade in Endangered Species (CITES, 180 parties on 6 May 2014; http://www.cites.org/).

Policy reforms and novel approaches to international policies are needed to better address global conservation needs and threats [24]. New policies for migratory species (e.g. the US Neotropical Migratory Bird Conservation Act; Box 1) aim to improve trans-boundary management of migratory species through investment in the places where species are most at risk [24]. However, in some cases it is argued that complex regulations might reduce funds available for conservation due to the regulatory investment needed to enforce them [43,44]. A collaborative market-based approach to dealing with international trade in endangered species, that legalises a regulated, coordinated and enforced trade in rhinoceros horn, recently met with support as existing legislation and trade bans (CITES) have failed to prevent declines [45].

Cross-country scale: Transboundary parks

One of the major tools used for collaborative conservation has been the establishment of conservation areas that span political boundaries [46], which are referred to as Transboundary Conservation Areas (i.e., trans-frontier, cross-boundary, trans-boundary and Peace Parks). Currently, there are an estimated 250 transboundary park complexes around the world, consisting of more than 3000 individual protected areas and spanning across a surface of 460 million hectares [47]. Most of these parks exist within the terrestrial domain, but recently

transboundary parks have been initiated in the marine realm [11]. One of the largest (>1.2 million km^2) and most well-known examples for cross-boundary efforts is the Yellowstone to Yukon (or "Y2Y") initiative in the Northern Rocky mountains of the US and Canada, which incorporates over 300 organizations, scientific, public, private and other [48].

Within-country scale: Partnership approaches

Partnership approaches refer to collaborations across different spatial and governance scales (often at the within-country scale) creating stakeholder networks. In Australia, for example, there has been a growth in networks of lands managed for connectivity conservation across tenures and at various spatial scales, ranging from local and landscape to sub-continental scales [49,50]. Examples for partnership approaches to conservation initiatives include The Great Eastern Ranges and Gondwana Link partnerships, in which a number of organisations, communities and individuals work collaboratively to reconnect and conserve landscape, by focusing both on existing protected areas, and on the purchase and restoration of other areas [51,52]. These collaborative conservation efforts are referred to under different names, such as conservation management networks, biosphere reserves, wildlife corridors and biolinks, and are often joint efforts of governmental organizations, non-governmental organizations as well as other interested authorities and stakeholders. Rivers and their watersheds, due to their natural connectivity, are often managed by a joint authority that crosses boundaries, in collaboration with local municipalities, governments and other stakeholders. An example for this is the Australia's Murray Darling Basin Authority, which was established in 2008 for the integrated management of the basin's water resources [53].

New tools and approaches

More recently approaches from other fields have been applied to conservation problems that have considerable potential for understanding collaboration. The most significant of these are game theoretic approaches [33:35] and social network analysis [10, 14, 25, 54]. Game theory allows insights into the strategies that different organisations and stakeholders are likely to adopt given their objectives and expected pay-offs, and the situations in which different types of collaboration are likely to be feasible [33]; most advances have been made in theoretical modelling aiming to understand why stakeholders refrain from collaborating, for example when setting high seas fishing quotas and closures [36]. Potentially, game theory could also be useful as part of field studies playing games with stakeholders to understand their decision making process in relation to each other and in relation to uncertainty (e.g. climate change negotiations [34]); however games are often played with students/volunteers rather than with

real world stakeholders [34] and more exploration is needed to make full use of this tool in practical conservation. Social network analysis provides a set of methods to systematically analyse and interpret the network of relationships between organisations [54]. By understanding how the network structure contributes to factors such as how knowledge and information are generated and distributed over the network [14], this can provide valuable insights for understanding when and why collaborative approaches are likely to be most useful. These two approaches have only recently been applied to conservation decision-making, and with further development will potentially provide important insights for understanding and operationalizing collaboration in a conservation context.

Moving forward - new framework for incorporating collaboration into conservation

The importance of between-country collaboration is only recently developing in the ecology and conservation literature, while research on multi-national collaboration is well developed in the disciplines of international relations and environmental policy [55:58]. Significant research will be needed to understand how the different facets of collaboration should explicitly be taken into account at a range of different scales and contexts to provide a general framework of conservation science, policy and practice. By explicitly evaluating the advantages and disadvantages of a collaborative approach, weighing the benefits against the costs, and addressing uncertainties and risks (Figure 1), successful collaboration and better cross-boundary management of threatened species can be achieved.

Using insights from collaboration challenges and benefits at different scales, as reviewed above, we frame a series of steps aimed at assessing the potential for between-country conservation collaborative. This process starts with identifying the conservation problem that occurs across country borders and the partners and countries involved. Partners then identify their goals and assess how these align with those of other partners' objectives. Game theory and social network analysis are two useful tools that can be adopted during this process. The benefits of collaboration should outweigh the costs and an analysis of limitations can then help to identify barriers to collaboration. The next step is to decide on the avenues and actions of the collaboration and their feasibility. If costs outweigh the benefits, independent actions might be preferable; if there are clear benefits and lower costs, collaborative action should be pursued. Continued monitoring should be employed to allow revising decisions in the future.

The following areas are priority areas for future research:

- Develop approaches to better predict whether collaboration between two entities is

likely to be successful and which types of collaboration might be most appropriate and to identify gaps in conservation plans due to previous lack of collaboration [8,9,26,31, 55].

- Integrate theoretical concepts, such as game theory and network analysis into modeling the consequences of different collaboration strategies in conservation (see [12]).
- Study the types and consequence of uncertainties related to incorporating collaboration into prioritizing conservation actions.

Insight from such work is are expected to lead to a better quantitative understanding of the role of collaboration in conservation planning and prioritization, linking ecological, socio-political, economic and other considerations. This will help advance an integrated framework for incorporating both within and cross-country collaboration into conservation at multiple spatial scales.

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Glossary of terms

Collaboration:

We follow McNamara's [59] definition for collaboration as a case where two or more organisational actors working together to "pursue complex goals based on shared interests and a collective responsibility for interconnected tasks which cannot be accomplished individually" [59: pg. 391]. This can range from working with within existing structures and policies, through to creating new formal or informal linkages or even working so closely together that the boundaries between organisations are blurred. Within this definition it is important to note that there may still be some divergent interests within the organisations collaborating.

(Systematic) Conservation Planning: A procedure for spatially determining the location of conservation management actions that promotes the persistence of biodiversity (and other natural features) in a systematic and repeatable manner. It utilises data on biological and ecological features while also considering other factors such as costs, threats and land use [60:62].

Transboundary protected areas (or parks): Protected areas that span political boundaries [6], usually between two countries and sometimes more.

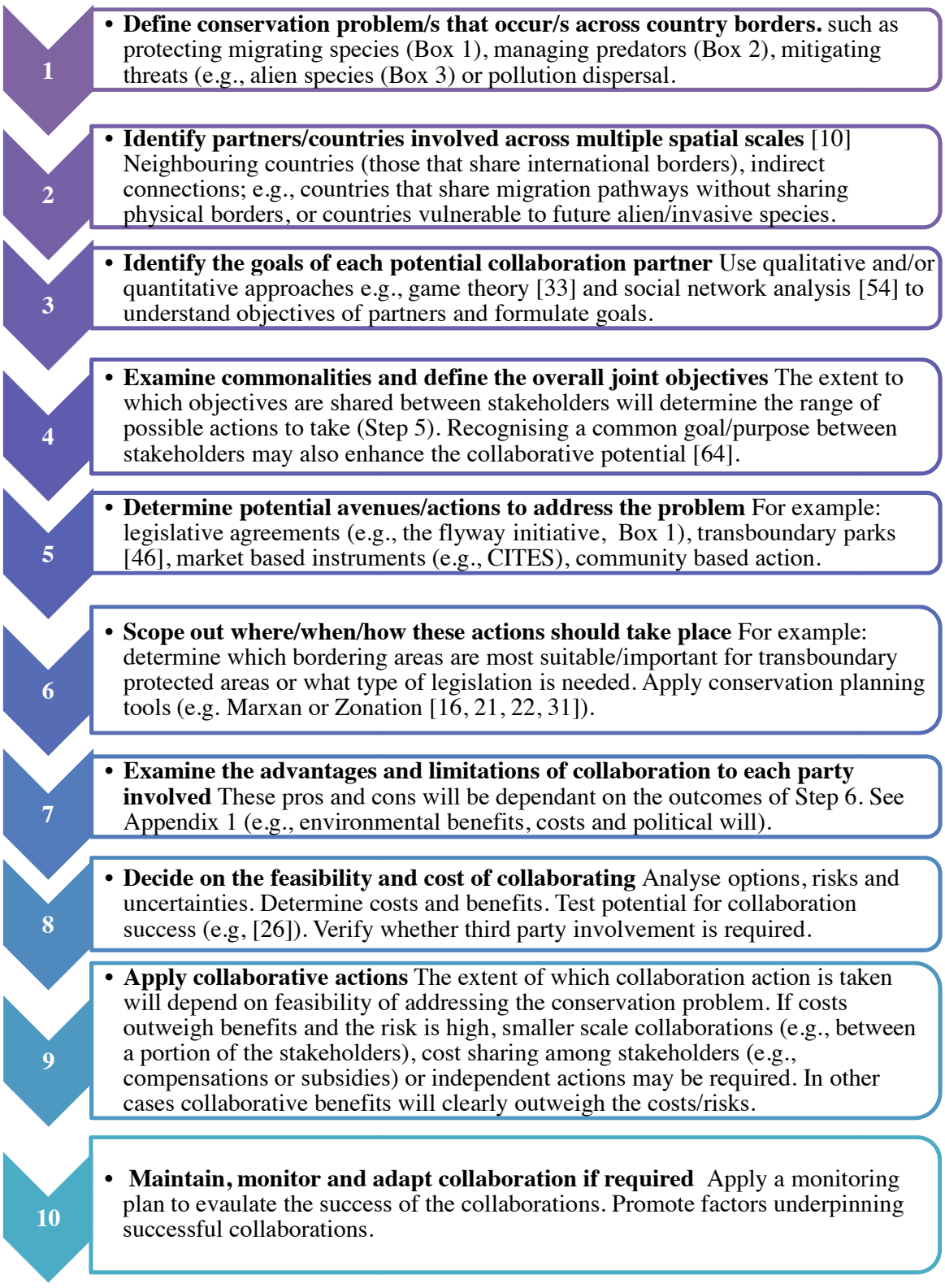
Peace parks: Transboundary protected areas established with multiple aims comprising the conservation of biodiversity and associated cultural resources as well as regional peace and stability [63].

Transaction costs: In economics, a transaction cost is the cost incurred in making an economic exchange. Here we refer to transaction costs as the costs associated with the

interactions and exchanges involved in coordination/cooperation/collaboration around conservation issues.

Figure 1.

Proposed framework for addressing collaborative conservation issues across geographical, jurisdictional and political boundaries at large spatial scales. The steps in this framework aim to define a systematic process whereby a quantitative analysis of the cost and benefits of collaboration are performed by conservation planning tools. These steps help synthesise the current work in the literature and the main discussion of this paper.


1
• **Define conservation problem/s that occur/s across country borders.** such as protecting migrating species (Box 1), managing predators (Box 2), mitigating threats (e.g., alien species (Box 3) or pollution dispersal.
2
• **Identify partners/countries involved across multiple spatial scales** [10] Neighbouring countries (those that share international borders), indirect connections; e.g., countries that share migration pathways without sharing physical borders, or countries vulnerable to future alien/invasive species.
3
• **Identify the goals of each potential collaboration partner** Use qualitative and/or quantitative approaches e.g., game theory [33] and social network analysis [54] to understand objectives of partners and formulate goals.
4
• **Examine commonalities and define the overall joint objectives** The extent to which objectives are shared between stakeholders will determine the range of possible actions to take (Step 5). Recognising a common goal/purpose between stakeholders may also enhance the collaborative potential [64].
5
• **Determine potential avenues/actions to address the problem** For example: legislative agreements (e.g., the flyway initiative, Box 1), transboundary parks [46], market based instruments (e.g., CITES), community based action.
6
• **Scope out where/when/how these actions should take place** For example: determine which bordering areas are most suitable/important for transboundary protected areas or what type of legislation is needed. Apply conservation planning tools (e.g. Marxan or Zonation [16, 21, 22, 31]).
7
• **Examine the advantages and limitations of collaboration to each party involved** These pros and cons will be dependant on the outcomes of Step 6. See Appendix 1 (e.g., environmental benefits, costs and political will).
8
• **Decide on the feasibility and cost of collaborating** Analyse options, risks and uncertainties. Determine costs and benefits. Test potential for collaboration success (e.g, [26]). Verify whether third party involvement is required.
9
• **Apply collaborative actions** The extent of which collaboration action is taken will depend on feasibility of addressing the conservation problem. If costs outweigh benefits and the risk is high, smaller scale collaborations (e.g., between a portion of the stakeholders), cost sharing among stakeholders (e.g., compensations or subsidies) or independent actions may be required. In other cases collaborative benefits will clearly outweigh the costs/risks.
10
• **Maintain, monitor and adapt collaboration if required** Apply a monitoring plan to evaulate the success of the collaborations. Promote factors underpinning successful collaborations.

BOX 1

Essential collaboration: Migratory species

Many species regularly move across international borders on land and in the sea in the form of regular migratory movements, nomadism or following resource fluctuations [13]. Of the world's 9,856 bird species, nearly a quarter (23%) are migratory, and 92% of these (2,200 species) migrate over country borders [65]. Severe declines in migrant species' populations are occurring worldwide, even for species such as African ungulates that are well represented in protected areas [66,67]. Significant threats to migrants range from local- to broad-scale impacts of habitat loss, pollution, illegal hunting, fishing, infrastructure development, invasive species, diseases, and climate change [66,68]. Effective conservation of migratory species often requires coordinated action along the length of the migratory route, to ensure protection of necessary resources at different stages [13, 69]. Impacts of threats on migratory species depend not only on the extent of the threat, but also on where (and when) it occurs [70]. Adequately safeguarding migrant breeding grounds is insufficient if threats in other countries lead to loss of critical staging areas and bottlenecks, or if populations sustain heavy pressure (e.g. hunting, habitat loss) during passage [71].

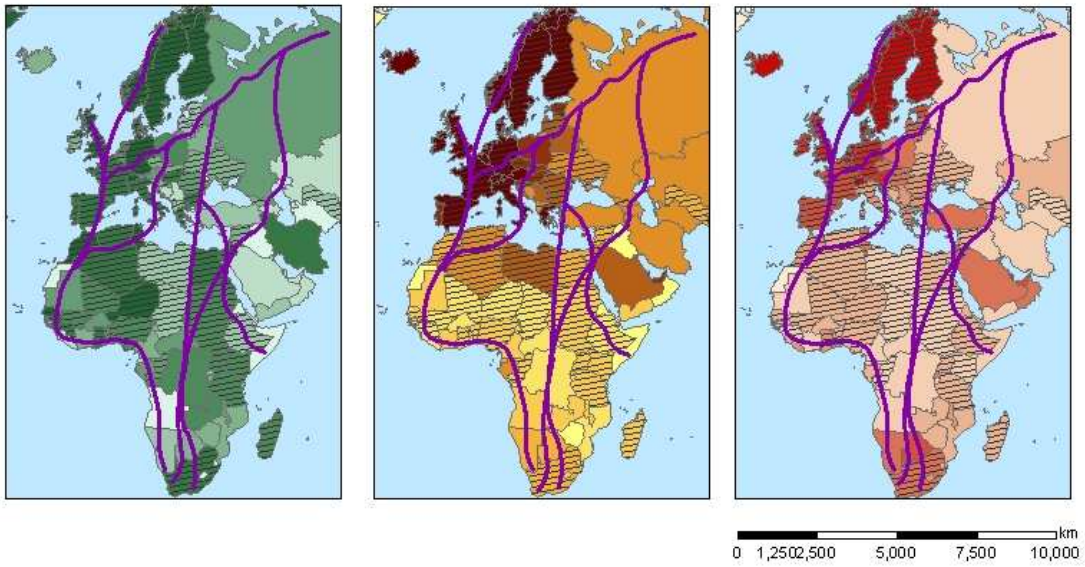
By using a 'whole-of-flyway' approach to modelling scenarios for protecting migratory birds, researchers demonstrated that including information on migratory connectivity into planning improves the efficiency of resource allocation for conservation of migratory species [70,72,73]). Accounting for dependencies among potential conservation sites requires knowledge not only of migratory connectivity, but also information on the feasibility of undertaking collaborative migratory species management [13,24].

Migratory species conservation can only be achieved by addressing underlying cross-boundary causes of environmental degradation such as unsustainable urbanisation, agricultural and forestry policies, human dependency on fossil fuels, and poverty – issues that have different levels of traction in different countries. Some threats are being tackled through international programs of collaboration (government and non-government) whereby wealthier countries aid less wealthy ones through policy links to conservation funds, e.g., the US Neotropical Migratory Bird Conservation Fund linked to the Neotropical Migratory Bird Conservation Act of 2006, which has allocated >US$46.5 million in grants, of which 75% has been spent outside of the U.S.A. in 36 countries (US Fishery and Wildlife Service; URL: http://www.fws.gov/birdhabitat/Grants/NMBCA/index.shtm). A recent example of legislative

collaboration across international boundaries for migratory species conservation is the flyway initiative for migratory birds (Box 1, Figure a), which involves internationally agreed cross-boundary management and conservation objectives, including an understanding of shared economic costs, to ensure connectivity across the entire migratory route ([24]; Appendix 1).

Box 1:

Figure 1. The African-Eurasian migratory bird flyway (purple lines), showing contracting parties to the African-Eurasian Waterbird Agreement (AEWA; dashed countries), and international collaborative effort for conserving migratory bird species. A flyway is the total geographic area used by a bird population, species or group of species throughout its annual cycle, and can span up to 10,000 km over several continents. All AEWA species cross international boundaries during migration and international cooperation is required for threat management. Some of the barriers to collaboration include physical barriers such as the Mediterranean Sea and the Saharan Desert, (left panel) institutional barriers such as history of involvement with international conservation policies (darker areas represent countries that have been signed to the highest number of international policies for the longest time; data from the CBD, CITES, RAMSAR, WHC), (centre) poverty and anthropogenic threats such as unsustainable resource use over-ruling conservation goals (darker areas represent higher social and economic development, data from the Human Development Index;http://hdr.undp.org/en/statistics/hdi/), and (right) political instability that impacts the costs, uncertainty and resilience of different management scenarios (Darker areas represent lower corruption, data from the Corruption Perceptions Index 2012; http://www.transparency.org/research/cpi/).


km
0 1,250 2,500 5,000 7,500 10,000

BOX 2

Costly collaboration: conserving mobile predators across boundaries

At the regional scale, many species distributions, populations and movements cross over jurisdictional boundaries and require large areas of habitat [13]. This is especially common for large predators. Large carnivores, such as wolves, lynx, bears and tigers, disperse widely in order to find food. For example, the estimated core home range of a wolf pack ranges from 100 to 1000 km^2 depending on the location in Europe [74,75], and a dispersing animal can travel 1000 km in several days [76].

By the beginning of the 20^{th} century, large carnivores (lynx, wolf and bear) had disappeared from much of Western Europe [77]; for example in Scandinavia, the wolf had disappeared by 1966 due to persecution. As a response to this threat the species was listed under the Bern Convention in 1972 and the Habitat Directive in 1992; both list the wolf as a protected species, which makes persecution illegal [78]. In Scandinavia, a new population of 50 wolves had established itself in 1998 [79] and wolves are now back in 32 European countries [80]. However, large carnivores in general, and wolves specifically, bring up a range of issues including human-wildlife conflict (e.g., attacks on livestock), and competition with hunters through predation on wild ungulates [81,82]. For example, compensation for livestock killed by wolves in Italy amounts on average to more than €1,800,000 but illegal killing is still widespread and the scheme viewed as ineffective as a conservation tool [83]. In Norway, Nilsen et al. [75] showed that the quota of moose (*Alces alces*) available to local hunters might need to be lowered with the return of the wolf. Poaching of wolves is widespread and common in Scandinavia [84]. Controlling the population through legal quota hunting is not possible because it is not allowed under the international agreements of the Bern Convention (signed by 29 of the currently wolf containing countries) and the Habitat Directive in 1992, which is signed by 19 countries that now have wolves [78,85].

In studies focusing on attitudes of local people towards large carnivores such as wolves and bears, there is increasing support that being able to respond to conflicts locally is crucial to maintain acceptance and tolerance among the ones that bear the costs of large carnivores [86:89]. In summary, international collaboration and conventions have increased human-wildlife conflicts and the costs of conservation in the case of large carnivores. In the light of further increases of local populations of large carnivores across Europe and the further spread into new areas, researchers are now calling for a more multi-scale management and policy for

large carnivore conservation to be able to give control to local people and improve acceptance levels [80].

[Comment to Editor: If space available a photograph of a wolf in the wild will be added here]

Further reading related to Box 2:

Karanth, K. U. & Sunquist, M. E. (2000). Behavioural correlates of predation by tiger (*Panthera tigris*), leopard (*Panthera pardus*) and dhole (*Cuon alpinus*) in Nagarahole, India. *J. Zool., Lond.* **250**: 255–265.

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Box 3

New challenges for collaboration: Invasive Alien Species cross borders

Species movements across jurisdictional boundaries might also include invasive alien species. These invasions are often assisted by human movements in the form of trade or, tourism between countries as well as human caused landscape alterations (e.g., the Suez Canal) [90]. For example, high risk of biological invasions results from the complex global network of cargo ships routes [91:93]. The number of new exotic vertebrate species detected in the wild has significantly increased in recent centuries and decades [94]. In Europe, nearly 11,000 species of plants and animals are currently classified by the EU as alien species, a significant minority of which are dangerously invasive. Unintentional or intentional introductions of organisms can cause harm to human health and infrastructure and the environment, as well as to agricultural crop and livestock industries [90,95,96]. Invasive alien species alter the structure and function of environmental systems [96], and are among the top drivers of global environmental change [97].

It is difficult and expensive to eradicate an invasive species once it has become successfully established. The costs of damage, management and research for vertebrate pests (birds and mammals) in Australia alone are around AUD$1 billion per year. Costly biosecurity surveillance therefore plays a prominent role in protecting national borders from new and emerging invasive species and pests. Numerous plans, papers and reports have recommended actions to prevent the movement and establishment of harmful organisms, and legislative enforcement now exists in many countries worldwide, for example the US National Invasive Species Plan (The National Invasive Species Council; URL: *www.invasivespecies.gov*), and the New Zealand 1993 Biosecurity Act (Parliamentary Commissioner for the Environment 2000; URL: http://www.pce.parliament.nz/assets/Uploads/Reports/pdf/under_seige_full.pdf)Most reports have focused on individual sectors (i.e. health, agriculture or environment), and only recently has the focus turned to building a comprehensive, integrated biosecurity system. Authors have stressed the need for preventative measures, which are more effective than retrospective control efforts [90]. These include identifying the pathways and vectors by which harmful organisms are moved, and developing mechanisms to manage and minimize this movement [98]. Preventative planning requires significant collaboration (e.g. information sharing, biosecurity planning) between countries, but can result in benefits for multiple countries, when countries both with and without an invasive alien species work towards preventing its spread (see Appendix 1).

Appendix 1.

(Comment to Editor: This section has a separate reference list with its own numbering, attached below)

Summary of advantages and limitations of collaboration in conservation planning and examples

Context for collaboration	Potential advantages	Potential limitations and challenges
Ecological/ environmental	Increased efficiency, more species can be conserved in the same area (e.g. Mediterranean Basin [Appendix reference 1]) or for the same cost. Coordinated threat mitigation due to sharing of expertise (in many cases likely to have much greater benefits). For example: (i) Identification of threats likely to spread to countries. For example management of the invasion of *Sonneratia caseolaris* plant species at Mai Po Inner Deep Bay in Hong Kong was facilitated by the coordinated East Asian Australian Flyway initiative [1]; (ii) More effective management of broad-scale threats, e.g. World Health Organization and its global network of national disease centres; (ii) More effective management of species moving between countries (due to threat reduction) (e.g., management efforts for Elephant movement in the Great Limpopo Transfrontier Park [2])	Loss of highly threatened species/ecosystems due to delay in action [4]. Less area might be protected in one country if other countries provide more effective protection, requires consideration of to consider issues of between-country per-capita equitability in conservation More data needed due to increased spatial scale, therefore more resources needed to gather, collate, manage and distribute data (resulting in less resources for conservation). Data collection takes time, especially at large scales and across borders, which may lead to delays in conservation action and in further decline of endangered species or further range expansion of alien species.

	Collaboration can enable collection of more data to inform decisions, and the integration of different types of knowledge which can better inform conservation decisions (e.g. indigenous knowledge, local/traditional knowledge, experts etc.), Collaboration is especially relevant when mapping species ranges across boundaries (common knowledge bases) and across different spatial scales (from regional to landscape or continental scales (e.g., the Global Invasive Species Programme and databases). Less uncertainty in conservation outcomes due to threats being mitigated at the scale of threat impact, rather than local-scale threat management that cannot deal with threats operating outside the country [3,4].	Parties may not be willing to share information, between countries, organizations or even between individuals due to conflicts of interests.
Economic/costs	Can increase economic efficiency of limited conservation resources use, [5,6]. Economic variation among partners can mean conservation activities can be allocated in a more economically efficient way, or rich countries can subsidize poorer (e.g. US Neotropical Migratory Bird Conservation Fund; FWS website) Future transaction costs of collaboration are likely to	Additional costs involved resulting from the "transaction costs" of collaboration. These include costs involved in negotiation and sharing information (meetings, translating, reports etc.), as well as increased costs due the extra time required amongst other factors such as increased administrative burden [3]. Economic variation among partners complicates the process of balancing financial input (Transboundary

	be reduced by collaborative activities occurring in the present.	marine protected areas; see examples in [8]).
	Leads to reduced redundancy and higher complementarity in conservation efforts and dollars [5,7].	Substantial funding and time may be required to agree on, manage and enforce increased jointly agreed regulation, e.g., in the context of the CITES convention import bans of trophies [9].
	Need for third party and/or external involvement (e.g., international organization) may lead to more commitment of parties to a given agreement, which would not have been enforced otherwise.	Need for third party involvement (outsider funding) leads to delays and further resources needed (e.g., Peace Parks)
Social/cultural	Increased cultural exchange and interaction between countries, e.g., the Prespa Park between Greece, Albania and the Former Yugoslav Republic of Macedonia [10].	Language and cultural barriers (e.g., changing local communities management of natural resources in Gashaka-Gumti National Park between Nigeria and Cameroon [11]).
	Increased education of local peoples to improve sustainability of resource use and ensure long-term availability of key resources, leading to sustainable policies to assist development, e.g. BirdLife's Sustainable Hunting Project (BirdLife International; URL: http://www.birdlife.org/datazone/sowb/casestudy/35.	Resource use vs. resource conservation? Local livelihood needs to be traded off against global or regional needs and this becomes more central with increasing scale of decisions. Top-down decisions at the international scale may lead to less incentive for bottom-up involvement (see paper Discussion). This may be the case when high-

		level diplomacy determines plans and especially when local communities are not engaged from the beginning of planning process or at other stages. Cultural differences in how species are perceived can lead to complication and delays in conservation efforts (e.g., exploitation or eradication of species in some countries and protection or tourism gain in others; see Box 2).
Political/ Institutional	Historical alliances can lead to future alliances, e.g., the Waterton-Glacier International Peace Park between US and Canada as a symbol of friendship and peace. Greater obligation to achieve commitment, e.g., the IUCN Transboundary Protected Area Group. Easier to raise international support (IUCN) Engaging in conflict resolution can increase conservation success, e.g., the proposed Siachen peace park between India and Pakistan [12], WCS Greater Virunga Landscape agreements (http://www.albertinerift.org/WildPlaces/GreaterVirunga.aspx)	Political instability, conflict territorial disputes reduce or halt conservation efforts. For example the Spratly Islands International Marine Peace Park was delayed [13]. Corruption can lead to uncertainty in outcomes and reduce the incentive to collaborate. “Free rider” problem (with certain country gaining without doing anything can limit the success collaborative efforts, or cause exclusion of high risk countries Mistrust between countries or agencies (e.g. due to historical events or political differences) can delay action due to perceived risk. Dilution of an agency’s perceived achievement (due

		to investment outside of a country's boundaries) can make it harder for political parties to show the public that they are having an impact Mission conflict (due to differing objectives) can mean multiple (and often conflicting) objectives need to be achieved (e.g. economic growth vs. satisfying global CBD protected area targets) Different governance models, legal and institutional frameworks in each country can delay outcomes and lead to "paper parks" that take time to become effective (e.g., Pelagos Sanctuary for marine mammals joint between three Mediterranean countries [14]).

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