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**Abstract**

Funding available to support conservation must be invested effectively given declines in biodiversity and ecosystem services. Unfortunately, conservation dollars often come with restrictions on where they can be spent. We introduce a method to demonstrate to supporters of conservation how much more could be achieved if they allow greater flexibility over conservation funding. Specifically, we calculate conservation exchange rates that summarize gains in conservation outcomes available if funding originating in one location can be invested elsewhere. We illustrate our approach by considering NGO funding and major federal programs within the United States and a range of conservation objectives focused on biodiversity and ecosystem services. We show that large improvements in biodiversity and ecosystem service provision are available if geographic restrictions on conservation funding can be loosened. We demonstrate how conservation exchange rates can be used to spotlight promising opportunities for relaxing geographic funding restrictions.

**In a nutshell**

1. Funding for biodiversity and ecosystem services would have greater impact with fewer geographic constraints on conservation dollars.
2. If donors to a U.S. NGO require conservation funding to be spent in their home state, it costs 68% of the improvement in biodiversity that would have been possible absent such restrictions.
3. We introduce a new approach that demonstrates by how much allowing a small amount of flexibility increases conservation impact.
4. We summarize this information in `conservation exchange rates', analogous to exchange rates between financial currencies.
5. Spatial exchange rates demonstrate large biodiversity gains are available from relaxing constraints on conservation funding.

## Introduction

Expanding protected area networks provides a renewed focus for the international conservation community with the development of a post-2020 framework for protecting biodiversity and related initiatives led by national governments (Convention on Biological Diversity 2020; Haaland et al. 2021). Already, governments, multilateral organizations, NGOs, businesses and other groups invest on the order of USD $100 billion each year to arrest declines in biodiversity (Organization for Economic Cooperation and Development 2020; Seidl et al. 2020). The severity of ongoing losses of species and habitats (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services 2019) demand that available funding is used effectively. Fortunately, there are still conservation bargains to be had. These are locations rich in biodiversity where protection can be achieved relatively cheaply and where ecosystems will be threatened if action is not taken, meaning the value added by conservation efforts would be large (Conde et al. 2015). However, financial support for conservation often comes with restrictions on where funds can be used. This can result in the most promising opportunities to improve conditions for biodiversity missing out on funding (Waldron et al. 2013).

Geographic limitations on conservation funding are commonplace. In private land conservation, large financial donations not associated with a particular project or initiative are unusual (Clark 2007) and downstream effects on the geographic availability of funds can shape spending on land protection over large spatial scales (Larson et al. 2016). People's motivations for donating to charitable causes including conservation vary but can include both purely altruistic reasons as well as motivations tied to benefits enjoyed by the individual (Bekkers and Wiepking 2011). Some motivations are more compatible with supporting distant projects than others and willingness-to-pay studies show the amount people are willing to give to support conservation activities declines with distance (Yamaguchi and Shah 2020;

Glenk et al. 2020) and across geographic borders (Dallimer and Strange 2015; Haefele et al 2019). Geographic restrictions on spending are also embedded in public funding programs. In the U.S., the federal government gives grants to states to support land conservation. Many of these federal programs follow prescribed funding formulas that may not align with where the greatest conservation opportunities are found (Southwick Associates 2013; Congressional Research Service 2019).

Large conservation gains would be possible if funders could be persuaded to allow greater flexibility over where money to support conservation can be spent. But how can this be achieved? Public and private funders are unlikely to be moved simply by growing the existing chorus of appeals for more flexible conservation dollars (e.g., Kark et al. 2009, Jeanson et al. 2020). As a practical way forward, we provide a means to demonstrate to organizations, programs and individuals supporting conservation the potential efficiency gains available were they to allow greater flexibility over funding. We express these as 'conservation exchange rates' that show how much greater conservation gains could be if dollars to support conservation came with fewer geographic restrictions. We provide a means to tailor these exchange rates to particular funders by quantifying them for different combinations of funder and potential investment opportunities. This includes showing how much more could be done to advance biodiversity goals if funders in one location allowed their conservation dollars to be directed towards a particular joint initiative shared with a neighboring region, perhaps one tied to a transboundary ecosystem or migratory species (Vogdrup-Schmidt et al. 2019b; Mason et al. 2020).

We illustrate our methods with an application to funding allocations among states in the conterminous United States (U.S.), where funding is to be used to establish new protected areas. We first describe exchange rates that result when prioritizing protected areas to support species conservation before broadening also to include ecosystem services. Conservation studies applying spatial optimization to prioritize future areas for protection (Groves and Game 2016), including applications to the U.S. (Withey et al. 2012; Kroetz et al. 2014), provide important antecedents for our analyses. However, these analyses typically assume conservation resources can be re-allocated freely across space, but see Kark et al. (2009), Ando and Shah (2010) and Pouzols et al. (2014) for exceptions. Beyond conservation, our approach builds on several literature precedents, including efforts to encourage 'effective altruism' (MacAskill 2015; Freeling and Connell 2020).

**Conservation exchange rates and how to calculate them**

We based our definition of exchange rates in conservation on the concept of financial exchange rates between currencies. Assuming no arbitrage, financial exchange rates reflect the ratio of prices for an identical basket of goods in two currencies. Because it seemed more relevant to conservation applications, we used the reciprocal measure (how much can conservation objectives be advanced for a given level of investment) to calculate conservation exchange rates. E.g., if considering conservation funding originating in New York being invested in Texas, the relevant exchange rate would be

$$\frac{Conservation\ gain\ per\ dollar\ in\ Texas}{Conservation\ gain\ per\ dollar\ in\ New\ York}$$

To derive our exchange rates, we need a representation of the available funding landscape for conservation and how this compares to the landscape of conservation priorities. When seeking to represent the current funding landscape in the U.S., we first rely on data on philanthropic giving to a major conservation NGO (The Nature Conservancy, TNC; Fishburn et al. 2013). We then consider funding programs for conservation run by the U.S. federal government (Southwick Associates 2013; Congressional Research Service 2019).

To represent the landscape of conservation priorities, we calculate the conservation gain per dollar offered by investing in different places. We base our exchange rate estimates on funding being allocated according to an optimization model. Specifically, we solved an optimization problem where the goal was to allocate available conservation funds to deliver the shared national conservation goal while subject to constraints on where funds could be spent. Initially, we assumed funds could only be spent in the state where they originated. While admittedly a stringent assumption, funding constraints of this type are commonly encountered in conservation (Pouzols et al. 2014). By examining optimal solutions to this spatially constrained problem, we can calculate the marginal gain in the national conservation objective available if a state's budget constraint can be relaxed by a small amount. We represent exchange rates between pairs of states as ratios of these marginal gain statements. Most prior studies have emphasized potential gains if conservation funding can be freely reallocated in space (e.g., Underwood et al. 2009a), which seems unlikely. In contrast, spatial exchange rates calculate potential conservation gains from allowing even a small amount of additional flexibility, e.g., a donor or funding program allowing a portion of a planned gift to be allocated to a conservation project in a neighboring region, where it could still benefit shared species or ecosystems.

We first derived exchange rates when focused on terrestrial vertebrate species currently assessed as being vulnerable to extinction or worse by IUCN. Our optimization framework involved allocating the budget to different counties where funds were used to acquire new protected areas. While we recognize the value in applying our methods over different spatial extents and grains, our chosen illustration required patterns of relative variation in conservation return on investment between U.S. states. For that purpose, working with county-grain variation suffices. For our optimizations, we adapted an existing framework that focuses on prioritizing counties based on how investing in them will affect the number of species expected to persist in 2040 in light of projected land cover change (Webpanel 1, Armsworth et al. 2020). This framework accounts for species persistence, ecological complementarity and the ecological contribution of private land, as well as spatially heterogeneous conservation costs and conversion threats. We extended this existing framework by imposing state-level budget constraints, allowing us to calculate conservation exchange rates between states. A full specification of the optimization problem is given in Webpanel 1, which also describes the behavior of the optimal solution and numerical techniques we used to find it. The optimal solution shares characteristics with the efficient design of emissions trading systems when abatement costs and environmental damages are spatially heterogeneous (Muller and Mendelsohn 2009). In the optimal solution, available funding within each state is shared among counties offering the largest gains in the national biodiversity objective per dollar spent, in such a way as to equalize marginal gains across these counties within the state. State funding constraints prevent these marginal gains from also being equalized across states, as would be optimal if no state funding constraints applied.

To parameterize our optimization model, we integrated data on ranges of terrestrial vertebrate species (birds, mammals, reptiles and amphibians; IUCN 2016; Birdlife International and Handbook of the Birds of the World 2016); on costs faced by TNC and public agencies in the U.S. when protecting land (Le Bouille et al., submitted); and on the threat of future habitat conversion (Wear 2011). For the initial analysis, we included data on spatial variation in philanthropic giving to U.S. conservation, using TNC as an example (Fovargue et al. 2019). Later we used data on state and federal funding for conservation (Southwick Associates 2013; Congressional Research Service 2019).

We examined the sensitivity of the exchange rates to the choice of conservation objective. To do so, we considered six additional conservation objectives. First, we used the same framework but considered all terrestrial vertebrate species not only those considered vulnerable. Next, we examined conservation objectives that equally weighted ecosystem services and biodiversity goals, using our focus on vulnerable vertebrate species to represent the latter. For ecosystem service benefits, we first included avoided losses of forest carbon due to land conversion for agriculture and development. Next we considered a set of ecosystem service indicators that emphasized investing near to people: improving recreational opportunities and open space amenities near people; maintaining natural land cover near withdrawal points for water for public supply or domestic use; and an additional benefit function that valued both recreation and maintaining water quality in this way while emphasizing benefits to low-income households. For comparability with the biodiversity models, we focused on improving these outcomes in 2040 drawing on land cover, population and income projections to do so. Finally, to examine the degree to which our results were a consequence of relying on the same cost and conversion threat data across scenarios, we included an optimization focused on avoiding habitat conversion without considering the importance of remaining habitats for biodiversity or ecosystem services.

**Conservation exchange rates reveal potential biodiversity gains**

We illustrate our conservation exchange rate approach by first considering an application to philanthropic giving to TNC, a large, nonprofit land trust, and to conserving vulnerable terrestrial vertebrate species through land protection. If donors require conservation funding be spent in their home state (Fig. 1a) instead of being directed towards top priorities for protection (Fig. 1b), it would cost 68% of the potential improvement in conservation status of vulnerable vertebrates that could have been achieved had no such geographic restriction applied (Fig. 2a). Focusing on state-level budget constraints makes sense for this application. TNC is structured into semi-autonomous state chapters that play a key role in soliciting gifts from donors and in protecting land (Fishburn et al. 2013). As one might expect therefore, the amount TNC spends on land protection in different states correlates strongly with philanthropic giving to the organization from within states (Spearman's $r_s$=0.54, $p< 10^{-4}$, n=48).

Even if unwilling to give completely unconstrained gifts, funders could still greatly increase the biodiversity impact of their giving by allowing financial support to be used for particular shared regional programs. Our exchange rates highlight obvious candidates, as shown by arrows in Figure 1(c) for neighboring states. For example, a donor in Washington, a state which gives at a relatively high rate, could be asked to support a Lower Snake River catchment program, allowing funds to be invested in western Idaho. Donors in Washington state could multiply their biodiversity impact by a factor of 11.5 by supporting such a program with potential gains from Oregon donors being larger still.

The more geographic flexibility donors allow, the greater the biodiversity impact that is possible and Fig. 3a shows exchange rates for all pairs of states, not just neighboring ones. To understand why some exchange rates are larger and others smaller, we need to examine spatial covariation between available funding and conservation priorities in more detail. For the TNC application, coastal states like California and New York are among the top givers (11.7% and 10.6% of overall donations respectively), although large donations also come from the area around Chicago, Minneapolis/St. Paul, Jackson Hole and other cities (Fig. 1a). These are not places that offer the highest return on conservation investment when focused on vulnerable vertebrate species. Instead, the greatest conservation impact would be made if able to invest in parts of the southern U.S., particularly in Texas and coastal Louisiana (Fig. 1b), where vulnerable endemic species overlap areas where land can be protected relatively cheaply. These differences manifest as striping in Fig. 3a. Horizontal striping indicates states that emerge as consistently higher (red) or lower (blue) priorities for investment. Vertical striping indicates consistent improvements (red) if funding originating in some states could be directed towards places that represent higher conservation priorities.

Having used this first example to illustrate the idea of conservation exchange rates, we explored the generality of our approach and of the particular exchange rates obtained through two sets of sensitivity tests (Webpanel 2). First, we recalculated conservation exchange rates when assuming six alternative objectives that conservation organizations and their funders might pursue. Exchange rates for these alternative objectives are highly correlated to those for vulnerable species protection (Fig. 2c). Moreover, the direction of exchange favored between pairs of states remained unchanged in 72-81% of cases (Fig. 2d). Some consistency in exchange rates should be expected because of correlations built into the assumed benefit functions themselves and because of the role of the shared covariates of cost and threat (black bar in Figs. 2cd). The results indicate some states (e.g., Texas) are consistently high priorities for funding for the different conservation objectives (Fig. 3). At the same time, exchange rates are more variable in magnitude when pursuing some conservation objectives than others, reflecting differences in patterns of spatial variability in underlying conservation benefit measures (Fig. 2b). Constraining funding to be spent in states where it was given again imposes a large efficiency cost compared to having full flexibility over where funds can be allocated. These efficiency costs range from 77-86% for the additional objectives we consider and are somewhat larger than they are when focused only on vulnerable vertebrate species (Fig. 2a).

Our second set of sensitivity tests examined how considering different sources of conservation funding would change our exchange rate estimates. We calculated exchange rates when considering one particular federal conservation program (the Land and Water Conservation Fund (LWCF) (Congressional

Research Service 2019) as well as for federal conservation funding in aggregate (Southwick Associates 2013). Our exchange rate estimates proved very insensitive to the source of funding data we used. This lack of sensitivity in exchange rates applied even though the overall conservation budgets involved were large enough to result in diminishing returns in conservation benefits on offer in some states (Webpanel 2).

**Putting conservation exchange rates into practice**

Exchange rates can help inform: individual donors seeking to enhance the impact of their giving to conservation; NGOs planning future philanthropy and conservation campaigns; policy debates over public funding programs; and prioritization of possible of transboundary initiatives. Taking first the example of philanthropy, NGOs tailor messaging to potential donors to align with individuals' motivations for giving (Bekkers and Wiepking 2011). Some donors are motivated by benefits realized within their local communities, while others are motivated more by how effectively their gifts are being used to achieve an organizations' mission (Kolhede and Gomez-Arias 2022). Messaging using conservation exchange rates is well-suited for donors in this second category. Figure 4 provides an example of what this might look like. It presents an infographic illustrating trade-offs involved in requiring donations be used in state versus allowing them to be used for conservation projects in adjoining states. The infographic is tailored for potential donors in Colorado, interested in conserving vulnerable species and providing ecosystem services to low-income communities. When soliciting a gift, philanthropy staff typically present potential donors with alternative projects needing funding. Communication products like Figure 4 provide a justification for including projects in neighboring regions within the menu of opportunities presented to those donors who are motivated by evidence on the efficacy of potential gifts.

Geographical constraints on where conservation funding can be spent have other implications. For example, these constraints impose some dispersion on allowed funding patterns, meaning locations that might not have otherwise been priorities at least receive some conservation investment. As well as broadening the set of species, ecosystems and human communities that benefit from conservation (Kareiva and Marvier 2003), more dispersed funding strategies may also move a larger pool of donors to give. The history and structure of large conservation organizations both responds to and reinforces these dynamics. For example, TNC's state chapter structure positions the organization to reach potential donors across the breadth of its geographic footprint. Conservation NGOs must balance spreading projects out to encourage more people to give against targeting available funds more narrowly towards locations where they will have the greatest impact (Ando and Shah 2010). Spatial exchange rates can help when balancing trade-offs like this. Developing more ways to connect data on conservation needs and effectiveness with information on the different ways people are motivated to give will enable more effective conservation philanthropy strategies.

Conservation exchange rates are also relevant to how public funding for conservation is allocated, with intergovernmental grant-giving providing an obvious example. State governments in the U.S. receive funding to support conservation projects from the federal government through State and Tribal Wildlife Grants (US Fish and Wildlife Service 2020), the LWCF (Congressional Research Service 2019) and other programs. Intergovernmental grant programs like these often follow fixed funding formulas. The LWCF, for example, allocates some funding on an equal basis across states and some based on a state's population relative to the U.S. population, while imposing a restriction that no more than 10% of total funding can go to a single state (Congressional Research Service 2019). Spatial exchange rates can inform policy debates about adjusting these funding formulas or how best to complement them with any additional funding that can be allocated more flexibly.

Another potential application of our conservation exchange rates is to inform the design of boundary spanning initiatives. Because ecological systems can stretch across administrative boundaries, governments and NGOs establish transboundary initiatives to encourage cooperation in delivering conservation priorities (Mason et al. 2020). These initiatives also enable some sharing of resources. Exchange rates provide a means to evaluate in what places the ecological gains available from establishing a boundary spanning initiative would be greatest. For our application, the Lower Snake River watershed in the Pacific Northwest mentioned earlier is one potential candidate (Figure 1c). The exchange rates indicate the central Appalachians to be another (Figure 1c). Again, this is a region where the greatest conservation priorities (endemic species in Virginia and West Virginia) do not align with the greatest funding base. Indeed, the central Appalachians have provided a focus for recent transboundary initiatives in the public and NGO sector (e.g., Appalachian Landscape Conservation Cooperative 2021; TNC 2018).

## Conclusions and next steps

Conservation efforts are under-funded relative to the scale of losses of biodiversity and ecosystem services, a problem exacerbated because conservation organizations are unable to deploy available funding where it will have most impact. We provide a method - conservation exchange rates - to demonstrate to interested funders how much greater their impact will be if they allow more flexibility in where funds can be invested. While many funding programs and private donors will be unmoved by generic appeals for more flexibility, some may find more compelling data that showed they could have three times the impact with their conservation support if they allowed funds to be targeted towards shared regional priorities. Our method identifies numerous opportunities for regional conservation programs that would meet this standard.

Various extensions of our work would be worthwhile. We based our calculation of exchange rates on buying unconverted land to establish protected areas. It would be interesting to consider other conservation approaches, including habitat restoration, which are characterized by distinct spatial patterns of benefits and costs (Bodin et al. 2022). Also, while we focused here on conservation funding, there are other ways people support conservation, such as through donating easements (Baldwin and Leonard 2015) or volunteering (Armsworth et al. 2013), which are more spatially constrained than are financial donations. Another interesting extension therefore would be to explore how exchange rates could inform strategies for blending different types of support in conservation projects. We also focused our discussion on larger conservation organizations, whose work spans administrative boundaries. But conservation success also depends critically on the contributions that local communities and smaller organizations make (Kothari 2006, Land Trust Alliance 2020). For these groups, exchange rates could suggest priorities for forming partnerships to bridge gaps between where support for conservation is most available and where conservation projects are most needed.

A particularly important next step would be to generalize our methods beyond the US so they can inform global conservation funding discussions. Countries with the most financial resources to support conservation are not those where the combination of biodiversity need, conservation cost, threat and institutional capacity promise the greatest conservation ROI (Waldron et al. 2013; Butchart et al. 2015). Yet, institutional constraints often require resources to support biodiversity conservation be used inside countries' own borders (Pouzols et al. 2014). Extending our approach to derive global conservation exchange rates therefore will be important. Once again, the most immediate opportunities to relax constraints on funding may well come from promoting shared regional or thematic programs (Dallimer and Strange 2015, Vogdrup-Schmidt et al. 2019a). For example, biodiversity gains supported by U.S. funding sources would be even greater than those we found if they were to encompass thematic connections like: California donors being asked to support a program focused on Mediterranean-type ecosystems (Underwood et al. 2009b), donors in southern Florida being asked to support a wider Caribbean program (Maunder et al. 2008), or East Coast donors being asked to support an Atlantic Americas Flyway program (Kirby et al. 2008).

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**Figure Captions**

Figure 1

Counties ranked by (a) donation levels to a major NGO and (b) conservation return-on-investment when seeking to protect vulnerable, terrestrial vertebrate species. Redder counties receive more donations in (a) and are a higher priority for investment in (b). (c) Conservation exchange rates between neighboring states (arrows), assuming states allocate funds to priority counties within their borders. Direction of arrows indicates movement of funds improves conservation outcomes and arrow color shows size of exchange rate.

Figure 2

a) Efficiency cost when funds are spent in donor state, as percentage of gain possible without this constraint. Conservation objectives: biodiversity only (vulnerable species – white; all species - light grey); biodiversity and avoiding losses of forest carbon (striped) or ecosystem services that depend on proximity to people (recreation, water quality, and benefits to low income communities - dark grey); averted habitat loss considering only cost and threat (black). b) Variation in relevant exchange rates. c) Correlation of log exchange rates and d) direction agreement when protecting vulnerable species (white bars in ab)) versus remaining objectives. Significance in b): $p \ll 0.001$ (***).

Figure 3

Log of conservation exchange rates for all pairs of states. Conservation objectives: biodiversity only for (a) vulnerable species or b) all species); biodiversity and c) avoiding losses of forest carbon (striped) or ecosystem services that depend on proximity to people (specifically: d) recreation, e) water quality, and f) benefits to low income communities); g) averted habitat loss considering only cost and threat.

Exchange rates show how much larger or smaller the conservation gain per dollar would be if funds generated in one state (horizontal axis) were spent in another (vertical axis).

Figure 4

Infographic illustrating how exchange rates can be used by donors and by philanthropy staff at an NGO. Example formatted for donors in eastern Colorado interested in improving conservation of vulnerable species and providing ecosystem service benefits to low-income households and who would consider investing in conservation opportunities in adjoining states. Numerical values are exchange rates when transferring funds from Colorado. E.g., if Colorado donors allowed gifts to be used in Nebraska instead of Colorado, each dollar could have 6.1 times greater conservation impact. Text descriptions based on the relevant state-constrained optimization. Image credits: NE – D. Menke; OK – E. Hornbaker; CO, KS, NM – R. Hagerty.

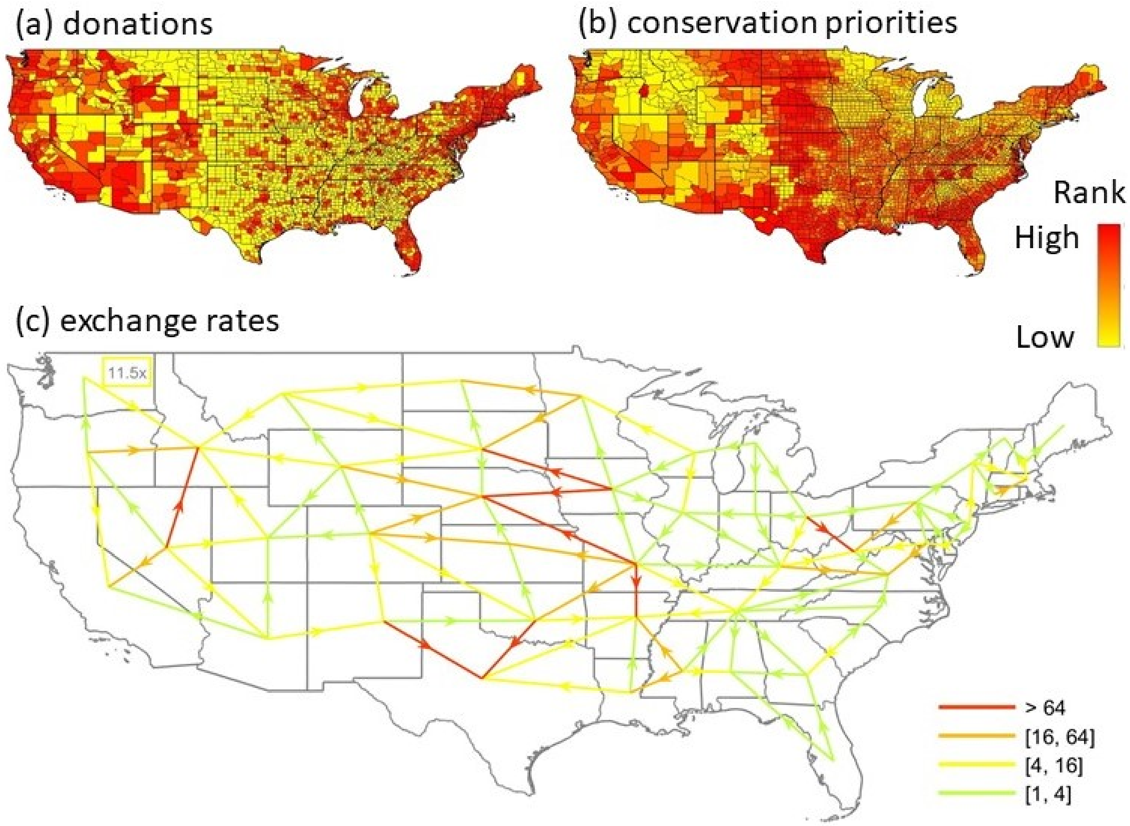


Figure 1.

Counties ranked by (a) donation levels to a major NGO and (b) conservation return-on-investment when seeking to protect vulnerable, terrestrial vertebrate species. Redder counties receive more donations in (a) and are a higher priority for investment in (b). (c) Conservation exchange rates between neighboring states (arrows), assuming states allocate funds to priority counties within their borders. Direction of arrows indicates movement of funds improves conservation outcomes and arrow color shows size of exchange rate.

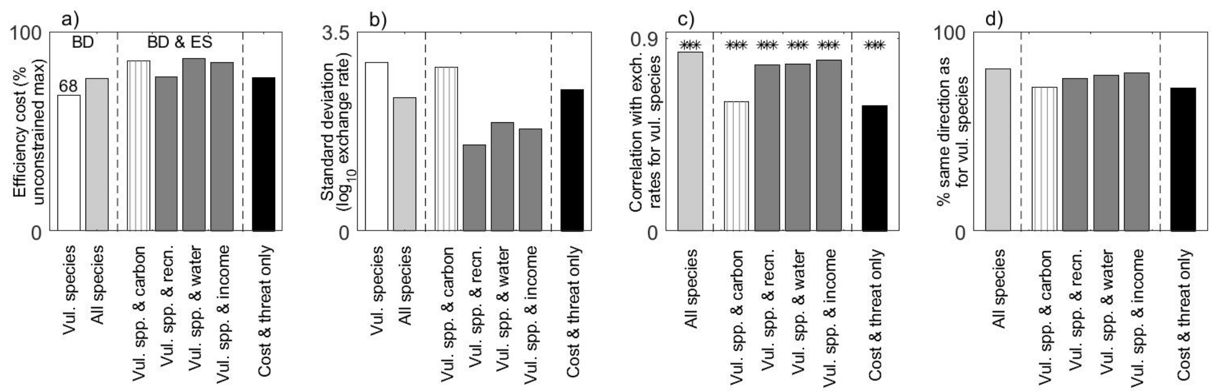


Figure 2

a) Efficiency cost when funds are spent in donor state, as percentage of gain possible without this constraint. Conservation objectives: biodiversity only (vulnerable species – white; all species - light grey); biodiversity and avoiding losses of forest carbon (striped) or ecosystem services that depend on proximity to people (recreation, water quality, and benefits to low income communities - dark grey); averted habitat loss considering only cost and threat (black). b) Variation in relevant exchange rates. c) Correlation of log exchange rates and d) direction agreement when protecting vulnerable species (white bars in ab)) versus remaining objectives. Significance in b): p<<0.001 (***).

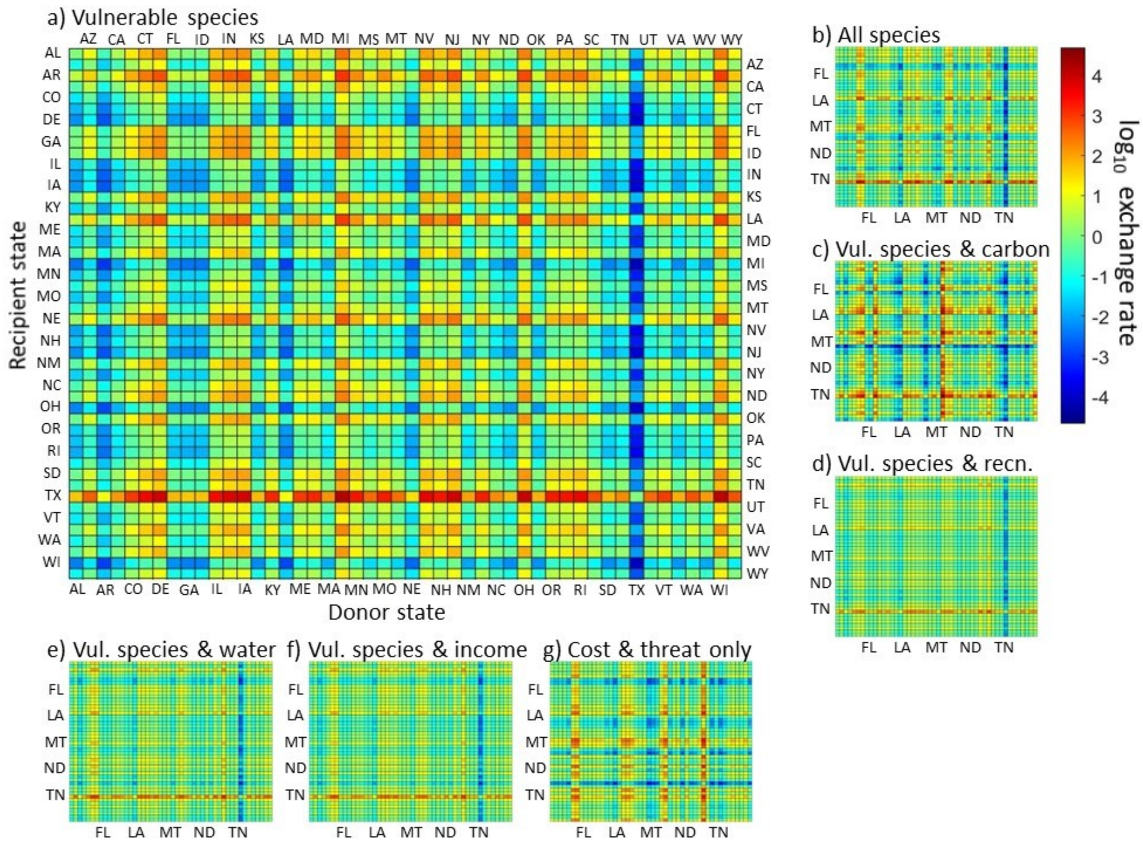


Figure 3

Log of conservation exchange rates for all pairs of states. Conservation objectives: biodiversity only for (a) vulnerable species or b) all species); biodiversity and c) avoiding losses of forest carbon (striped) or ecosystem services that depend on proximity to people (specifically: d) recreation, e) water quality, and f) benefits to low income communities); g) averted habitat loss considering only cost and threat. Exchange rates show how much larger or smaller the conservation gain per dollar would be if funds generated in one state (horizontal axis) were spent in another (vertical axis).

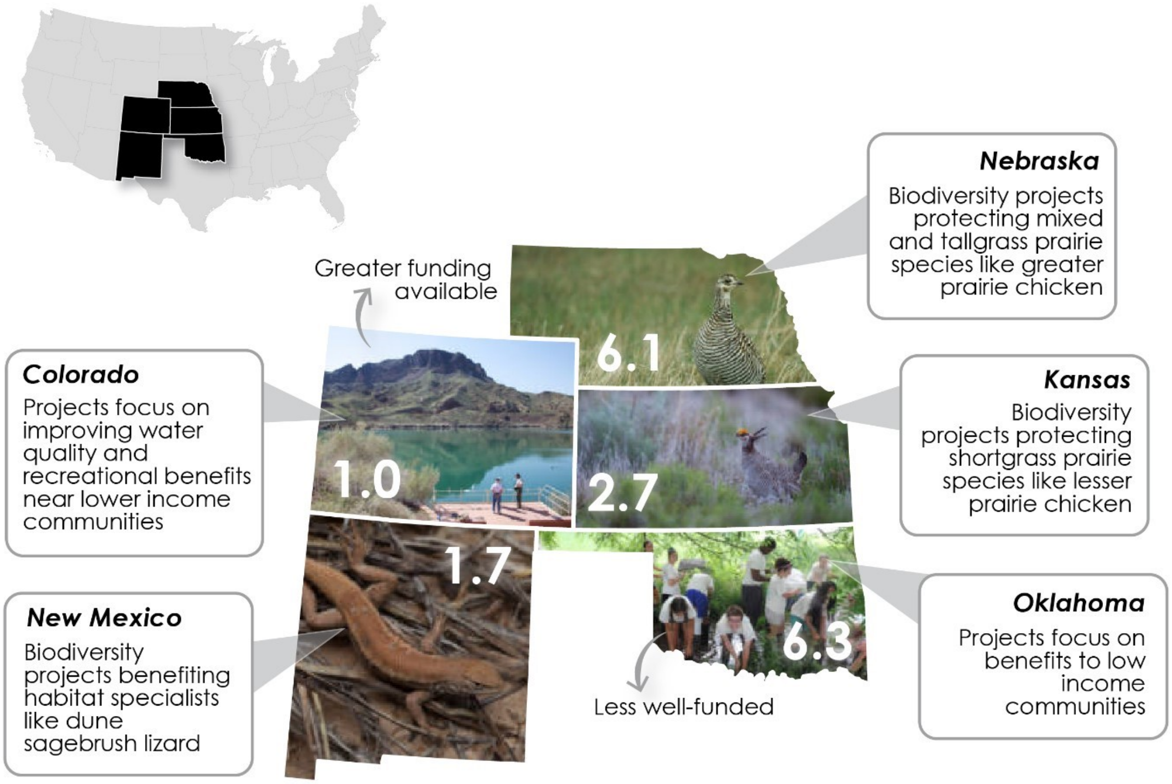


Figure 4

Infographic illustrating how exchange rates can be used by donors and by philanthropy staff at an NGO. Example formatted for donors in eastern Colorado interested in improving conservation of vulnerable species and providing ecosystem service benefits to low income households and who would consider investing in conservation opportunities in adjoining states. Numerical values are exchange rates when transferring funds from Colorado. E.g., if Colorado donors allowed gifts to be used in Nebraska instead of Colorado, each dollar could have 6.1 times greater conservation impact. Text descriptions based on the relevant state-constrained optimization.