Limitations of outsourcing on-the-ground biodiversity conservation

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Abstract

To counteract global species decline, modern biodiversity conservation engages in large projects, spends billions of dollars and engages many organizations working simultaneously

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within regions. To add to this complexity, the conservation sector has hierarchical structure, where conservation actions are often outsourced by funders (foundations, government, etc.) to local organizations that work on-the-ground. In contrast, conservation science usually assumes that a single organization makes resource allocation decisions. This discrepancy calls for theory to understand how the expected biodiversity outcomes change when interactions between organizations are accounted for. Here, we used a game theoretic model to explore how biodiversity outcomes are affected by vertical and horizontal interactions between three conservation organizations: a funder that outsourced its actions, and two local conservation organizations that work on-the-ground. Interactions between the organizations changed the spending decisions made by individual organizations, and thereby the magnitude and direction of the conservation benefits. We showed that funders would struggle to incentivize recipient organizations with set priorities to perform desired actions, even when they control substantial amounts of the funding and employ common contracting approaches to enhance outcomes. Instead, biodiversity outcomes depended on priority alignment across the organizations. Conservation outcomes for the funder were improved by strategic interactions when organizational priorities were well aligned, but decreased when priorities were misaligned. Meanwhile, local organizations had improved outcomes regardless of alignment due to additional funding in the system. Given that conservation often involves the aggregate actions of multiple organizations with different objectives, strategic interactions between organizations need to be considered if we are to predict possible outcomes of conservation programs or costs of achieving conservation targets.

Introduction

Billions of dollars are spent yearly on biodiversity conservation but the continuing species loss indicates that there is still a shortfall (e.g., McCarthy et al. 2012). In response, conservation science identifies cost-effective approaches to biodiversity protection (e.g. Murdoch et al. 2010; Venter et al. 2014). However, most studies assume that a single organization decides to spend and then undertakes a conservation project to attain its objectives (Blom 2004; Polasky et al. 2008; Ando and Mallory 2012, and many others). In contrast, conservation projects commonly involve multiple organizations and actions are often outsourced by funders to local organizations. This fact has not attracted much attention in conservation science because the organizations are often non-profits with parallel objectives. However, recent theory has highlighted the potential for interactions between organizations to influence the quantity and character of conservation outcomes, even if they are pursuing similar goals (Albers et al. 2008; Bode et al. 2011; Punt et al. 2012; Gordon et al. 2013). Understanding such influences is critical for conservation scientists who engage in conservation prioritization. It is also important for practitioners, who are very much aware that interactions among organizations in the conservation sector influence biodiversity outcomes, but do not necessarily have the theory or tools to predict their effects.

Most conservation landscapes contain multiple organizations, as do many public-good sectors (Bilodeau and Slivinski 1997). Economic theory suggests that the number of conservation organizations in a region is a balance between the vast number that would be observed if there were no transaction costs and organizations specialized different conservation needs, and the reduced number that results from coordination among agencies for cost effectiveness (Economides and Rose-Ackerman 1993, Albers and Ando 2003). This expectation is supported by data that shows that many conservation organizations are found in a region (Armsworth et al. 2012), and they interact to promote outcomes and act at different scales (Mills et al. 2014).

To pursue their individual objectives, conservation organizations interact to varying degrees, from complete independence, through to merging to address the same objectives (Bates 2005). Variation in objectives include differences in target species for conservation (e.g., birds vs. whales), approach (education, policy, land acquisition, etc.), or region (e.g., international vs. local). Organizations strategically interact as they compete for limited funding and each organization's actions affect outcomes for the others. These interactions can be horizontal, as when equivalent organizations submit competing applications for funding. They can also be vertical, as when a funder outsources a project to an organization that can implement it. The result is conservation outcomes that promote both individual and shared conservation priorities (Macdonald 2002; Kark et al. 2009; Labich et al. 2013, etc.).

One example of multiple organizations strategically working together s is the Greater Cumberlands Deal in Tennessee, USA. Completed in 2007, this 52 600 hectare project involved state and federal government agencies, and two private companies partnering with The Nature Conservancy. The project provided fee-simple additions to existing state parks, a new wildlife management area, and a conservation easement on a large forest tract owned by two conservation forestry companies (investment firms that manage forest lands for multiple objectives including ecological conservation). This configuration of five or more organizations — with some providing funding and some doing on-the-ground conservation work — is common for large conservation deals and is very different from the assumed single decision maker.

The theoretical literature has recently begun to consider the presence and impacts of multiple conservation organizations by using game theory (Albers and Ando 2003; Bode et al. 2011). Following precedents in this literature, we examine multiple conservation organizations, each pursuing their own goals. We extend on past writings by considering the role of large scale funders and recognizing that conservation organizations must compete for the funders' support. This formulation has similarities to a principal-agent problem in other economic settings because one organization can only obtain its objective by outsourcing action to another organization with slightly different objectives (Ross 1973; Jensen and Meckling 1976). We examine how the strategic choices of a given configuration of organizations influence the biodiversity protected by a funder's investment by studying common configurations of conservation funding and action that are potentially misrepresented by a single player assumption.

Modeling approach

To examine the consequences of funders outsourcing conservation action to local organizations, we needed a modeled system with several characteristics. First, the model required organizations with similar, but not identical, objectives. Second, resources needed to be limited, so that competition arose in response to constrained outcomes. Finally, the conservation sector required both vertical and horizontal structure: the organizations that controlled the funding would not implement the conservation action themselves. This basic set of characteristics was as general and flexible a representation of multiple organization conservation as we could construct.

Model formulation

Figure 1 illustrates our model. Here, the conservation objectives of two land trusts were related to the priorities of the funder and each other (dashed lines in Fig. 1). Land trust 1 had a set of priority species (S_1) that it aimed to protect (circles in Fig. 1), perhaps bird species found in a watershed. Land trust 2 also had a set of priority species (S_2), found in a different location. This could be general wildlife conservation in a different watershed. These types of differing objectives are common across land trusts within a region (Foti and Jacbos 1989;

Chang 2011). The funder also had a set of prioritized species (S_F). For instance, these could be species that provided ecosystem services in the downstream river valley system. Each land trust worked to protect species in their individual focal regions (1 and 2), but there was some overlap of species across regions (Γ_{1F}, Γ_{F2}, Γ_{12}; subscripts indicate overlapping regions).

Conservation organizations receive funding from multiple sources with differing restrictions placed upon its use. Game theoretic principles have been productively used to study the structure and dynamics of other sectors of the economy (Gibbons 1992; Coleman 1985; Hotelling 1970) and non-governmental sectors (Bilodeau and Slivinski 1997) so we used them to define the system. For simplicity, we assumed each land trust had two types of funding to allocate to conservation projects; unrestricted internal funding that could be allocated to any project (b_i) and potentially restricted funding provided by the funder. To simplify the model and aid interpretability, we assumed each land trust had only two options when it came to allocating funding. They could either invest in projects in their own preferred region (e.g. priority region 1 for land trust 1) or they could invest in projects in the region preferred by the funder. By investing in funder priorities they could protect some of their species due to the species overlap, but could also supplement their unrestricted internal budget by attracting additional investment from the funder. The funder considered allocation by the land trusts (p_1, p_2), for instance by estimating allocations across past projects, or from allocations detailed in public documentation, and then distributed a proportion (p_F) of its funds in response to the decisions of the land trusts. The outcome was therefore determined by three budget allocation choices: each land trust decided what proportion (p_i) of their total budget (β_i) to allocate toward funder priorities, with the remainder spent in their own region, and the funder decided what proportion (p_F) of its budget (β_F) to give to land trust 1, with the remainder going to land trust 2. Each organization maximized the number of its species protected by choosing its budget allocation (p_i) while considering the budget allocation choices of the other agencies.

$$\max_{p_i} S_i(p_F, p_1, p_2)$$

We assumed that no organization would change its conservation objective during the funding round, that no land trust could spend in more than two regions, and that each organization's entire budget was spent.

A proportion of each focal region's species list (S_i) was protected according to the species area relationship (SAR) and funding ($p_i\beta_i$) allocated to the region. We scaled each organization's possible budget to the amount of money that it would take to protect their entire region. Thus area protected is equivalent to available budget.

$$S = cA^z$$

We used the SAR for simplicity, but other relationships between spending and conservation outcome would also be appropriate benefit functions. We scaled each organization's possible budget to the amount of money necessary to protect their entire region. Thus area protected is equivalent to available budget. Each organization's benefit was the sum of the species protected by spending on land conservation in their own region, plus the number of species protected by spending in regions where there was priority overlap, minus double counted species (see *Supplementary Information* for details). We used $z = 0.25$ to represent conservation landscapes (Pimm et al. 1995), although resource allocation is rarely affected by its precise value (Bode et al. 2009). The constant c dropped out in all calculations. We also calculated the total number of species protected across all regions, and the number of species protected if there was only a single organization working in a region.

These model dynamics allowed us to examine the biodiversity implications of linked strategic decisions. To illustrate the calculations, consider the situation where the funder decided to allocate 20% of its budget to land trust 1 ($p_F = 0.2$) and 80% to land trust 2, and the land trusts each spent 50% of their entire budget on funder priorities (p_1 and $p_2 = 0.5$). In our model, each organization's total budget is enough to purchase 10% of their priority region to represent the resources of a midsize conservation organization. Thus, with these allocations, 0.06 % of region 1 (0.5*(0.2*0.1 +0.1)), 0.15 % of region F, and 0.09 % of region 2 would be protected. If there was a 50% overlap in species lists between the regions, land trust 1 would be able to protect the number of species in its region that are protected with that amount of area (depends on SAR parameters) plus about 50% of the species in the area protected in the funders region (subtracting a small number due to double counting, see *Supplementary information* for details). The benefit to the other organizations was calculated similarly. Below we explain how we used game theory to identify the likely budget allocation choices of the organizations.

Solution methods

The species maximization functions above describe the benefit that each organization will receive from a chosen budget allocation, given the choices of the other organizations. Simultaneously solving the three functions for the unknown variables p_F, p_1 and p_2, provides p_F*, p_1*, and p_2*; the location(s) where the benefit functions intersect. This solution satisfies the Nash equilibrium condition where no organization could improve its benefit by unilaterally changing its funding allocation strategy. The Nash equilibrium gives the expected behaviour of three rational actors because any organization would achieve worse outcomes by altering its choice. We focus on the Nash equilibrium because it is commonly used to study the strategic decisions of rational actors (Morris 1994).

We numerically identified the equilibrium conditions by calculating reaction surfaces (the optimal choice of one organisation given the choices of the others) for each organization and then identifying the choice sets where the three organizations' reaction surfaces intersect. We modelled 5% increments of budget allocation between 0 and 1, to balance a smooth representation of the decision space and computational demands. The intersection of the reaction surfaces in three dimensional decision space describes the Nash equilibrium conditions.

We have illustrated this approach in two dimensions (Fig. 2). For any choice that Player 1 makes, Player 2 has a best choice it can make, here plotted with the dashed line. Meanwhile, for any choice that Player 2 makes, Player 1 has a best choice as shown by the thick line. An iterative method for identifying intersections (Krawczyk and Uryasev 2000; Contreras et al. 2004) is illustrated by the thin line. The method is based on the Nikaido-Isoda function (Nikaido and Isoda 1955) and implemented in Matlab (R2014a, Mathworks). Player 2 makes an initial choice indicated by the small circle. Player 1 makes their optimal response (a point on the reaction surface, line 1), and then Player 2 optimally re-assesses their decision. The choices alternate between players (lines 2-5), and eventually converge at the Nash equilibrium (the intersection of the curves) where neither player can unilaterally improve their decision (large circle). In our model each organization has a reaction surface in three dimensions. We randomized starting points and the first mover choice for the relaxation algorithm and used repeated runs to identify the Nash equilibrium (convergence to Nash equilibrium occurred 82-95 % of runs depending on parameter and first mover choice). The number of species protected by each organization at the Nash equilibrium set of choices is the expected solution of the multiplayer game.

Illustrative examples:

We analyze this basic model framework using common conservation organization priority configurations. These examples were chosen to explore how conservation benefit changes due to strategic interactions between organizations.

1) High priority alignment

Funding allocation decisions would appear straightforward when the priorities of funders and recipients are closely aligned. For example, external funders (e.g, a foundation) often outsource biodiversity protection by providing grants to local conservation organizations with similar priorities (Gunter 2004; Emerton et al. 2006; McBryde and Stein 2011). This funding model is commonly used by land trusts that aim to maintain greenspace (McQueen and McMahon 2003; Hopper and Cook 2004). For example, the Open Space Institute in New York State provides funding to land trusts in the Appalachian and Cumberland regions of the US through their Southern Cumberland Land Protection Fund (David Ray, Open Space Institute Conservation Capital and Research Program, *personal communication*). The institute funds fee simple acquisition or easement purchases (Kilpatric et al. 2004) within focal areas identified in their "Protecting Southern Appalachian Wildlife" study. Local land trusts in the focal regions apply for matching funding to support projects that meet predetermined conservation criteria, particularly land acquisition projects that allow for climate change adaptation of species within the region. The funding recipients all pursue land conservation in their region, and although they also have other objectives, climate change adaptation may be a significant shared objective (David Ray, *personal communication*). Current recipients of this funding include the Land Trust for Tennessee, The Tennessee Parks and Greenways Foundation, Georgia Department of Natural Resources, The Nature Conservancy — Alabama Chapter, and The Nature Conservancy —Tennessee Chapter.

To reproduce the essential elements of these dynamics, organizations in our first example have a high priority alignment of 50 % ($\Gamma_{1F} = \Gamma_{F2} = \Gamma_{12} = 0.5$). We assumed that each of the three organizations had enough funding to each protect 10% of their region of interest ($\beta_F = b_1 = b_2 = 0.1$). The funder could therefore double the budget of one land trust or allocate the money across both land trusts.

We calculated the Nash Equilibrium to predict the combined choices of rational organizations for this example, and then studied the benefit accruing to each organization. There were two Nash Equilibria: $(p_1, p_2, p_F) = (0.12, 0, 1)$ or $(0, 0.12, 0)$, indicating that only one of the land trusts would allocate efforts towards funder priorities, and even then only a small amount. The two equilibria were symmetric, since the land trusts were identical. Essentially, the first land trust willing to spend any resources in the funder's priority region received the funder's full budget. At this point, the other land trust was unwilling to compete, and chose to focus on its own region. These results are robust to variation around our specific parameter choices: neither land trust could ultimately secure additional benefit by offering to spend more than a small proportion of its total budget on the funder's priorities. In this high overlap scenario the funder was able to protect about 70% of its priority species (Fig. 3a) and one local land trust received additional investment from the funder (LT2 in Fig. 3a) and protected about 80% of its species. The other land trust received no investment from the funder and protected about 76% of its species. In comparison, any organization working on its own could expect to protect about 56% of its priority species, and 75% of all species were protected. These proportions depend on the parameters of the species area relationship underlying our benefit function, but it is important to note that all organizations benefited from the presence of other organizations compared to if they were working with only their budget.

The equilibrium solution constrains local spending on funder priorities to a minimal amount, despite the funder's attempt to incentivize the land trusts to compete for its funding, and the high overlap between the funder and land trust objectives. The funder would maximize protection of its species if it could induce a land trust to spend its entire budget on the funder's priorities. However, that is counter to either land trust's best strategy because they each also want to maximize spending on species they care about. Thus, the land trusts focused on their own priorities and only spent on funder priorities in relation to their potential gain due to overlap.

2) Low priority alignment

We next examined the case where the priorities of the funder and the land trusts were minimally aligned. Minimal overlap in organizational priorities is not uncommon in conservation deals. Biodiversity has a large number of facets, often with very low spatial congruence (Orme et al. 2005). Moreover, conservation projects often include partners with different organizational priorities. For instance, in 2010, The Nature Conservancy's Australia Program orchestrated the Fish River Station conservation project in the Northern Territory (Fitzsimons and Looker 2012). This 180,000 ha property was acquired because The Nature Conservancy guaranteed some of the purchase funding but also coordinated other funding sources and partners to enable the Indigenous Land Corporation to buy the site with the intent of eventual transfer to the indigenous Traditional Owners. Indigenous Land Corporation is a national government-established corporation with an objective to assist indigenous people in acquiring land, but it does not primarily focus on biodiversity conservation. For this project, the Australian Government provided two-thirds of the purchase price. The Nature Conservancy provided one-sixth, and the remainder came from the Pew Charitable Trust via an agreement with Greening Australia and Indigenous Land Corporation. Thus, significant

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biodiversity outcomes were a result of coordinated efforts by organizations with minimal institutional priority alignment.

To model the minimal alignment scenario, we set the objective overlap between the funder and the land trusts to 10% ($\Gamma_{1F} = \Gamma_{F2} = \Gamma_{12} = 0.1$), while holding all other model parameters as previously. The resulting Nash equilibrium for the three organizations, (p_1, p_2, p_F) = (0.05, 0, 1) and (0, 0.05, 0), showed that the land trusts were even less willing to compete for the funds than in the high overlap scenario. The low competition negatively impacted the funder which was only able to protect about 31% of its priority species (Fig. 3a), lower than in the high alignment scenario (70%), and lower even than if it undertook action itself (56%). Meanwhile, one land trust was able to double its budget (land trust 2 in Fig. 3a) and protect 69% of its species. This was substantially more than it could have achieved with its own budget (56%), but less than if there was high priority alignment across the organizations (80%). The land trust that received no additional funding (land trust 1 in Fig. 3a) was able to protect 60% of its species, with species gains due to the small overlap in priority species with the funder, and 51% of the species in the region were protected.

Important dynamics can be observed in the way land trusts respond to the amount of priority overlap. The two land trusts had an incentive to spend a minimal amount on the funder's objectives because of the level of overlap, and the strategies available to the funder could not persuade the land trusts to spend more (within a cost/benefit target for the funder. See discussion below). Because the local land trusts acted in their own self-interest and could not out-compete each other, only the amount of priority overlap determined the benefit that the funder receives. For this study we focused on two levels of priority overlap, but benefit scaled with overlap across the players (Supplementary figure S2).

Using contracts to encourage investment in funder priorities

The land trusts obtained benefit from funder investment into the region even without directly receiving the funding. First, spending by the other land trust on funder priorities protected some species due to overlap (1.2% more species), and second, the land trust shifted what it otherwise had spent on the funder's priorities towards its own priorities instead (0.7% more species). In our case, the small gain that a land trust obtained by shifting its spending corresponded with a crowding out loss of approximately 1% of benefit for the funder. This crowding out is a theoretically predicted response of conservation organizations to additional investment (Abrams and Schitz 1978; Steinberg 1991), particularly noticeable when private land trusts shift investment in response to governmental acquisition (Albers et al. 2008; Parker and Thurman 2011).

We briefly explored some common contracting strategies for counteracting the effects of misalignment between funder priorities and local spending. One strategy was for the funder to contractually obligate the land trusts to spend contributed money only on the funder's priorities (we call this the "Request for Proposals" (RFP) strategy). This strategy increases the spending on funder priorities as compared to the equilibrium case, but was subject to crowding out. To understand the dynamics, we compared the RFP strategy with the outcomes if the funder did not spend in the system. When the funding organization offered no budget ($\beta_F = 0$), one of the land trusts would nevertheless allocate a small increment of its budget to the funder's priorities (p_1, or $p_2 = 0.02$). This was because the land trusts received diminishing marginal returns with increasing investment in their own region, so after a point they can do better by investing elsewhere (i.e. the funder's region), even if that other location had a lower proportion of their species. The funder therefore obtained protection for some of its species, even though it made no investment. However, once the funder demanded that the effort was applied to its priorities (RFP strategy Fig. 3b), neither land trust would choose to allocate anything further because allocation towards the funder's region had already experienced diminished marginal returns.

Cost-sharing is another strategy to counteract crowding out that requires a land trust to commit some of its own budget to receive grant money (Fig. 3b). We modeled cost sharing by requiring that any grant funding (p_F) had to be matched by some increment of spending on funder priorities by the land trust (formulation details in *Supplementary Information*). This cost sharing requirement incrementally improved the funder's benefit, but only counteracted crowding out if the match amount was larger than the available budget. The funder's best option was to offer a 20:1 match which, for our parameterization, would protect a tenth of a percent less species than the scenario with crowding out. Here, the amount necessary to counteract the crowding out merely replaced the shifted funding, and the cost share did not incentivize the land trusts to behave differently.

The funder's inability to incentivize land trust behavior could result from the funder being constrained to spend its entire budget. We examined how the ratio of the benefit to the cost varied with funder budget. The funder's willingness to spend its entire budget in the system depended on the benefit to cost ratio it was willing to accept. For our example budget level (β_F = 0.1), the funder would be willing to contribute the entire amount for any non-zero benefit to cost ratio of return (Figure 4).

Discussion

Current estimates of global conservation funding need rely on theory that ignores multiplayer interactions. We asked how strategic interactions between a given configuration of organizations influenced the biodiversity conservation obtained from spending. Our results suggested that the projected funding necessary to reduce biodiversity loss (e.g. McCarthy et al. 2012; Waldron et al. 2013; Tear et al. 2014; Venter et al. 2014) may be misestimates of actual need. This is because interactions between the organizations change the decisions made by individual organizations and the overall conservation benefit that can be achieved for a given budget. Because conservation organizations have different objectives, the necessary funding could be much higher than anticipated. Importantly, we found that a funder would struggle to incentivize recipient organizations to perform desired actions, even when it controls substantial amounts of funding and relies on common contracting approaches.

It was surprising that the conservation funder could not incentivize land trust behavior because, since both land trusts would benefit from additional funding, we expected that their competition for funding would benefit the funder‘s objectives. This effect may be observed if the local organizations chose to compete for funding by adjusting their allocation towards funder priorities. In our model, because the two land trusts had similar budgets and potential benefits and neither could outbid the other in competing for the funder's investment, they were indifferent between competing for funding or simply pursuing their own objectives. Accordingly, the budget incentive could not influence the land trusts to change their behavior and increase the funder's gain. We were documenting the general dynamics so we examined the simplified case with symmetric overlap across the three organizations. However, an interesting line of future research would be to look at asymmetric cases or more organizations.

The effectiveness of a funder's spending was highly dependent on its priority alignment with the local land trusts. With high priority alignment, greater biodiversity outcomes of the funders’ spending result from multiple organizations acting strategically. However, with low priority alignment, the funding organization's spending effectiveness was decreased by strategic interactions between multiple organizations. This information could prove valuable if funders can identify high-alignment subsets of trusts to negotiate with. However, gauging priority alignment is difficult in practice (Gronbjerg et al. 2000), particularly when conservation objectives are multidimensional and not explicitly stated. Our discussions with funders suggest that conservation inefficiencies can be minimized by contracting with organizations that focus on a tight mission and have a demonstrated history of overlap on desired objectives. A fruitful avenue for further study might therefore be to identify a heuristic for deciding how the funder should act given varied overlap.

Caveats and assumptions

A primary simplifying assumption of our model is that each organization pursues funding that supports it conservation objective and does not change its objectives during the funding round.. An alternative formulation could allow organizations to revisit their objectives to better position themselves for funding. This mission drift (Jones 2007) would move land trusts away from their original priorities towards those of the funder. The result could be more closely aligned with the priorities (and implicitly, the beliefs and values) of broader society, as represented by the pooled conservation resources. Non-profit organizations could also choose to split their resources between both sets of objectives rather than pursuing a compromise objective with all available resources (Steinberg 1986; Hewitt and Brown 2000; Brooks 2005).

We use the species area relationship to relate conservation spending to biodiversity outcomes. However, other benefit functions (e.g., relationship between ecosystem services, or population persistence, and spending) also would be appropriate. The benefit obtained by each organization depends on the value of the z parameter, but a sensitivity test suggested that all players would obtain at least some benefit for any value of z (Supplementary Figure S1).

We also note that the effectiveness of conservation spending is perspective dependent. For this study, we examined scenarios from the perspective of a conservation funder that was working towards a conservation outcome that it perceived to be important. However, the relative effectiveness of different strategies varies if you considered the outcome from the perspective of other organizations.

Conservation implications

Conservation professionals need to consider the influence of interactions between multiple players when they estimate what a conservation program could achieve. Meanwhile, conservation planners need to design projects and resource allocation strategies in a way that acknowledges the role of such interactions. These suggestions are based on our representation of conservation projects as a noncooperative game with multiple players, a modeling approach little used in conservation studies. Our formulation recognizes explicitly that the biodiversity outcomes for both recipient and funding organizations are subject to the actions of other organizations in the system. Taken together, these recommendations reiterate this study's primary message for policy makers and planners: insights from studies that assume a single decision maker may not translate well to on-the-ground conservation with its multiple players.

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Supporting Information

Solution details and supplementary tables (Appendix S1) are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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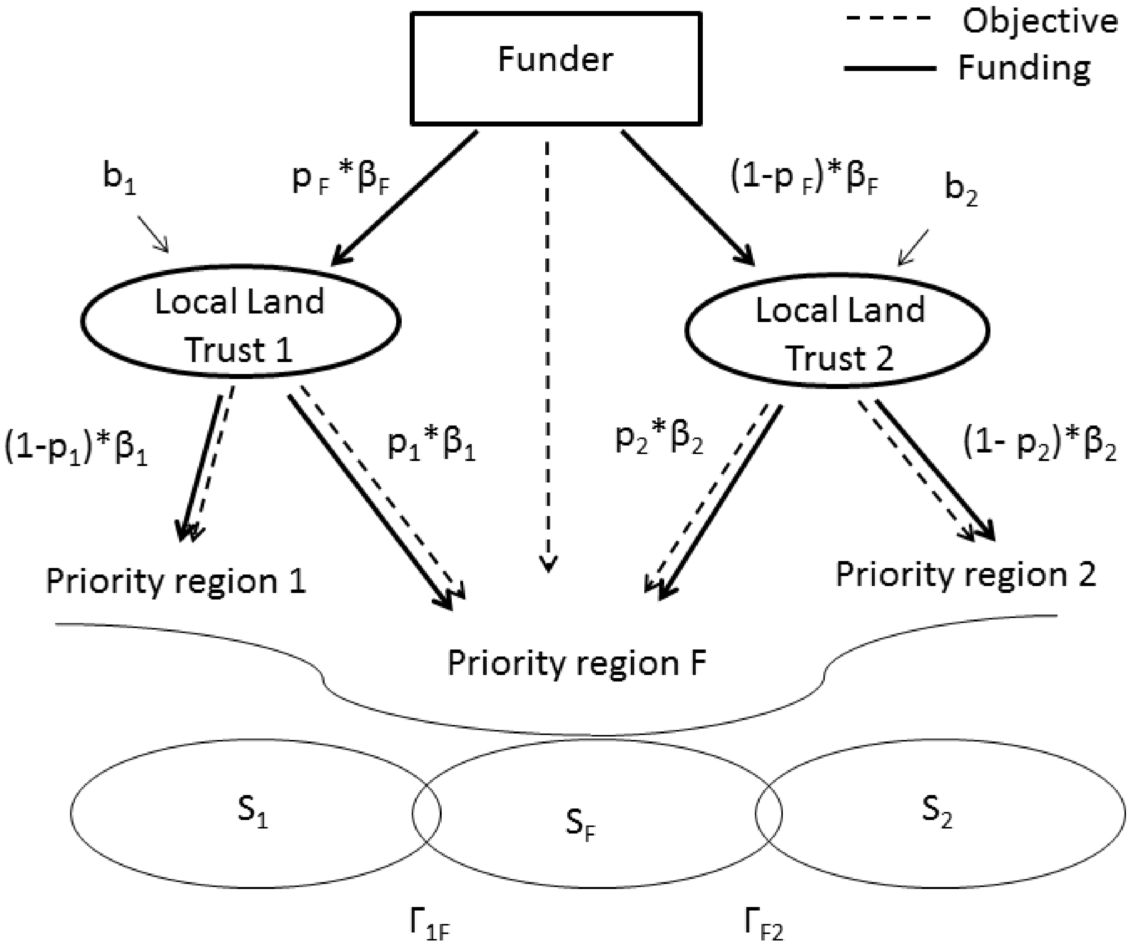
Figure 1: Conceptual model of multiplayer system with the flow of funding represented by solid arrows and the objectives of the organizations represented by dashed arrows. The funding organization has an objective to protect species in region F but does not have any on-the-ground operations of its own. It obtains a conservation benefit by supplementing the budgets (b) of land trusts that work in the region. These land trusts decide what proportion (p_1, p_2) of their total budget (β) to allocate toward funder priorities in order to incentivize the regional conservation organization's decision of how to proportionally allocate its budget (p_F). Species (S) are protected according to the spending in each region, but there is some overlap (Γ) across the different organizations' priority species.



Variables and Parameters :
subscript indicates funder ($_F$), land trust 1($_1$) or land trust 2($_2$)

p	% of budget allocation decision
β	Total budget
b	Local land trust budget without funder grant
Γ	% species overlap between organizational objective

Figure 2: Simplified illustration of how reaction curves (surfaces) can be used to identify the Nash equilibrium. Here the axes represent each player’s choice — which for our problem is how much of their budget they will spend on funder priorities. The dashed curve is Player 2's best choice for any choice made by Player 1. The solid curve is Player 1's set of best choices. The thin line shows the iterative method for identifying the Nash equilibrium (large circle) from any starting player's choice (small circle).

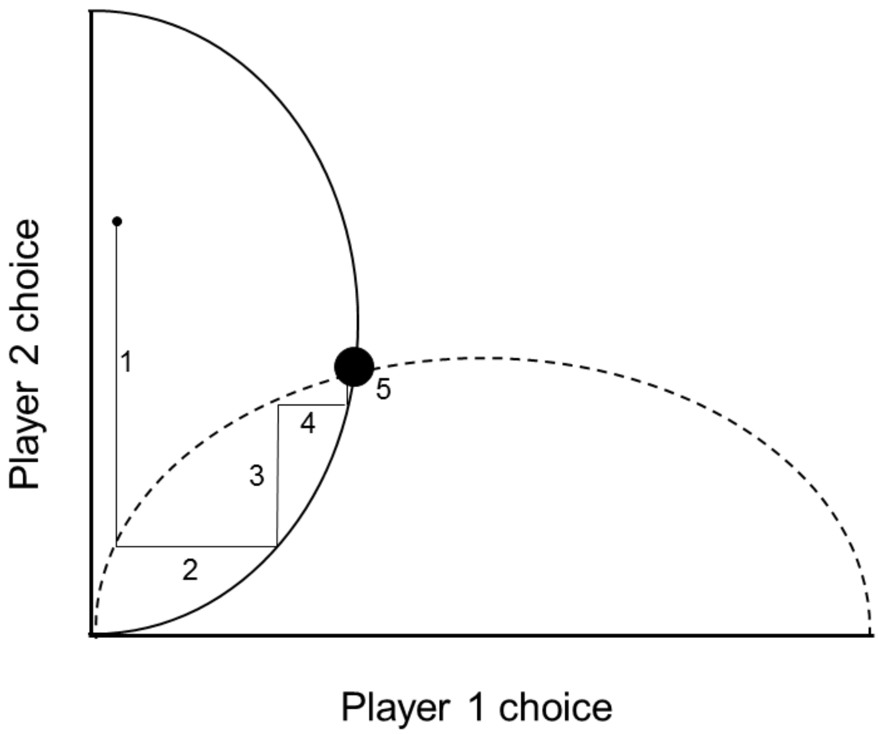


Figure 3: Nash equilibrium benefit per organization and in total, when there is low objective alignment (black bars, $\Gamma = 0.1$) or high alignment (white bars, $\Gamma = 0.5$). In a), the grey bar indicates the benefit the funder would obtain from this budget if it could engage in on-the-ground projects by itself, and b) shows funder benefit across different investment strategies. None is when the funder does not invest at all but existing spending in the system protects some of its focal species. ``Request for Proposals'' (RFP) represents when the land trusts are contractually obligated to spend contributed funding on funder priorities. The two cost share (CS) scenarios illustrate funder benefit when the funder invests 10 and 20 times the land trust investment in the region.

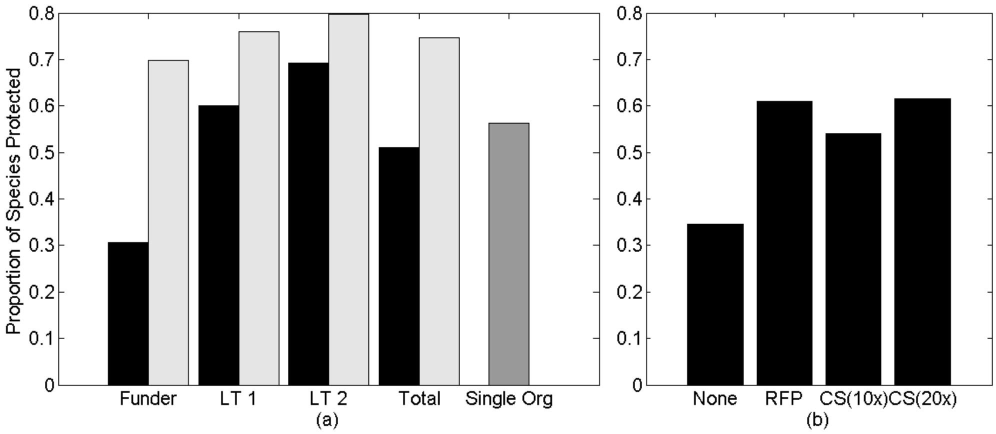


Figure 4: This figure illustrates the results of our sensitivity test exploring the funder benefit/cost ratio across the budget allocation scenarios we tested. It suggests that, although the expected gain decreases as the proportional spend on the project increases, the funder will continue to invest in a region if it is satisfied with any positive gain.