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Iacona, Gwenllian D; Sutherland, William J; Mappin, Bonnie; Adams, Vanessa M; Armsworth, Paul R; Coleshaw, Tim; Cook, Carly; Craigie, Ian; Dicks, Lynn V; Fitzsimons, James A; McGowan, Jennifer; Plumptre, Andrew J; Polak, Tal; Pullin, Andrew S; Ringma, Jeremy; Rushworth, Ian; Santangeli, Andrea; Stewart, Annette; Tulloch, Ayesha; Walsh, Jessica C; Possingham, Hugh P

Conservation Biology

DOI:
10.1111/cobi.13195

Published: 01/10/2018

Peer reviewed version

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This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1111/cobi.13195.

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Keywords: conservation accountancy, cost-benefit; effectiveness; conservation evidence, return-on-investment

Running head: Conservation cost standards

Article Type: Conservation Practice and Policy

Article impact statement: Standardized reporting of conservation costs means data in published studies can be transferable and interpretable for improved conservation.

Abstract

Effective conservation management interventions must combat threats and deliver benefits at costs that can be achieved within limited budgets. Considerable effort has focused on measuring the potential benefits of conservation interventions, but explicit quantification of the financial costs of implementation is rare. Even when costs have been quantified, haphazard and inconsistent reporting means published values are difficult to interpret. This reporting deficiency hinders progress toward a collective understanding of the financial costs of management interventions across projects and thus limits the ability to identify efficient solutions to conservation problems or attract adequate funding. We devised a standardized approach to describing financial costs reported for conservation interventions. The standards call for researchers and practitioners to describe the objective and outcome, context and methods, and scale of costed interventions and to state which categories of costs are included and the currency and date for reported costs. These standards aim to provide enough contextual information that readers and future users can interpret the cost data appropriately. We suggest these standards be adopted by major conservation organizations, conservation science institutions, and journals so that cost reporting is comparable among studies. This

would support shared learning and enhance the ability to identify and perform cost-effective conservation.

Importance of improved cost reporting

Effective biodiversity conservation interventions must achieve maximum conservation benefit within the limits of available funding (Joseph et al. 2009, Wilson et al. 2009). Choosing cost-effective interventions requires understanding both the benefits and the costs of potential actions (Cook et al, 2017). The benefits can be determined by impact evaluations that measure the conservation outcomes of previously implemented actions (Pullin and Knight 2001, Sutherland et al. 2004). However, estimating the costs of an intervention is difficult and such costs include financial expenditures and nonmonetary costs that make up the remainder of total economic value (Barnett 2009). Data on the financial costs of an intervention may exist, yet these data are difficult to use to improve conservation efficiency and effectiveness (Armsworth et al., 2014, Cook et al., 2017). Thus, reported estimates of the costs of conservation are rare and inconsistent, despite their importance in decision making (Naidoo et al. 2006, Wilson et al. 2006).

The financial costs of an intervention represent what has been spent by an organization to achieve a conservation outcome. Improved reporting on the financial costs of conservation interventions could enhance outcomes in 3 ways. First, it could improve understanding of the cost of delivering an individual conservation outcome by indicating the efficiency and impact of conservation interventions within agencies (Margoluis et al. 2009) and informing cross-organizational comparisons of efficiency and accountability (Jepson 2005). Second, it would allow for valid comparisons costs across studies that reveal how intervention costs vary with context and accurately predict the costs of future interventions to ensure appropriate resourcing (e.g. Bayraktarov et al. 2016). Finally, it would allow identification of appropriate cost data for quantitative decision-support tools and enable improved prioritization of conservation actions (e.g., Carwardine et al. 2015).

Gathering data on the costs of interventions remains a conservation priority (Sutherland et al. 2009). There has been a push to improve cost accounting within agencies through initiatives such as the Open Standards for the Practice of Conservation (CMP 2013) and the World Commission on Protected Areas framework (Hockings et al. 2006). Ideally, reported financial costs should be easy to interpret and transfer to support conservation decisions (Cook et al. 2017). Decisions depend on cost data that are clear about the units, scale, and context of the costed intervention (Armsworth 2014) and the intervention outcomes and cost conversion factors (Bayraktarov et al. 2016).

Yet, most calls for improved understanding of the economics of conservation provide little guidance on how to achieve it (e.g., Naidoo et al. 2006) and no practical recommendations for obtaining the consistent financial cost reporting necessary for understanding economic trade-offs (Armsworth 2014, Cook et al., 2017). In a review of 30 peer-reviewed articles with costings for a conservation intervention (Supporting Information), we confirmed that critical information was often omitted, ultimately hindering comparison across studies (Supporting Information). These studies showcase the limitations of status quo reporting. This inconsistent reporting may be because financial record keeping is designed for business, so it is difficult to relate costs to benefits because institutional constraints often limit the resolution at which cost records are documented or shared and because the true costs of conservation actions are invariably underestimated due to factors such as institutional overheads, temporal economic discounting, and free or subsidized labor.

A lack of experience in determining what cost data are relevant to report may also hinder conservation. Therefore, improving the methods of collecting and reporting financial cost data is critical to enhancing the data available for conservation decision making. Good cost reporting summarizes financial cost data so they can be confidently and transparently used

for assessment of costs relative to benefits and for decision support (Drummond et al. 2005). Financial cost data are valuable on their own and can contribute to a full economic costing of an intervention when paired with nonmonetary costs, such as opportunity costs (Drummond et al. 2005).

We devised standards for reporting on the financial costs of conservation interventions and a worksheet (Supporting Information) for reporting intervention costs according to these standards. We encourage authors to include a completed version of this spreadsheet as appendices in papers or reports that describe intervention cost data.

These standards were designed to guide the collection of data on financial expenditures and provide information on their context and details. They are flexible but targeted toward reporting cost data related to common conservation interventions, such as invasive species management, prescribed fire, or regulation enforcement. We built on existing good practice of organizations that developed detailed cost-accounting systems to improve decision making (e.g., New Zealand Department of Conservation, Bush Heritage Australia, Northwest Florida Water Management District).

Many fields, particularly those focused on profit (e.g., agriculture) or public accountability (e.g., public health), recognize the importance of accurate cost accounting that permits transparent analysis of the cost-effectiveness of alternative actions. These data contribute to evaluations of the return-on-investment for an action (Drummond et al. 2005; Shelmit et al. 2008). Different forms of economic evaluation require standard and comparable reporting of financial costs and resulting benefits of an action (Samuelson & Nordhaus 2005). Although standardized mechanisms for estimating benefits require methods such as impact evaluation (Ferraro & Pattanyak 2006, Stem et al. 2005), comparisons of cost-effectiveness also require a framework for consistent cost reporting (Hockings et al. 2009). Standardized accounting of

financial costs is facilitated by listing the categories of costs to be included in an estimate (e.g., GRADE guidelines in health care [Brunetti et al. 2013]) or by providing estimates of the total costs of common actions (e.g., farm management actions in the United Kingdom [Redman 2016]). Although the specific costs estimated vary among fields, the generic categories of costs are often similar (e.g., equipment, human resources, consumables [Brunetti et al. 2013]). Other disciplines also provide lessons on how to report costs in a transparent manner, such as capturing generic units (e.g., person hours or days) rather than monetary estimates due to context dependence (e.g., geographic and temporal variation) of costs (Baltussen et al. 2003). In generating our recommendations, we drew on lessons from other fields that are advanced in developing financial costings to guide cost-effective decisions.

Recommended standards for cost accounting

To generate these standards, we examined current practice and developed recommendations based on our experience and knowledge of the literature. As conservation researchers and practitioners across universities, government, and nongovernmental organizations (NGOs) who regularly work with conservation intervention and cost data, we suggest the following 5 reporting standards be followed to compile and report conservation intervention costs (outlined in Supporting Information).

Reporting Standards

First, state the objective and outcome of the costed intervention. Stating the objective permits appropriate future use of cost data because it outlines what the incurred cost aimed to achieve. For instance, the objective may indicate the intensity of an intervention (e.g., eradicate invasive weed versus maintain invasive cover at 5%) or describe the scope of the intervention (general protected-area management). Some interventions may address more

than one objective, but we suggest highlighting the primary objective unless additional objectives significantly alter the project context.

Second, define the context and method of the intervention. Describing these permits interpretation of the costs relative to what was done under what conditions. Minimum basic details include intervention approach, starting conditions, if possible (e.g., species abundance), and intensity of the intervention (e.g., frequency of treatments). Ideally, management and monitoring aspects should be separated, and differences in costs for initial versus follow-up interventions should be noted. Note whether configuration of interventions in the landscape affects costs. The social context of the project may also be important if ecological outcomes are not the only goal (e.g., Working for Water program [McConnachie et al. 2012]).

Third, state when, where, and at what scale interventions were implemented. The scale of the intervention determines the magnitude of recorded costs. Spatial scale can be the length of boundary surveyed, number of individuals treated, etc. Area of intervention is also important to record because economies of scale often mean costs accumulate at a decreasing rate. The length of time an intervention is applied can also influence the cost per unit time or area if learning or other efficiencies occur (e.g., Adams & Setterfield 2013).

Fourth, state which of the following categories of cost are included: labor, capital assets and equipment, and overhead. Broad cost accounting categories describe project components, and we suggest the following similar categories for conservation cost reporting. Within these categories, it is helpful to consider whether costs can be classified as fixed (unchanged as the project changes scale) or variable (change as the project scale changes and often ongoing). Examples of common fixed costs are buildings (capital assets) and office expenses (overhead). These costs cannot be eliminated and do not change as the scale and scope of a

business expands or retracts. Common variable costs are fuel for vehicles, herbicides, and equipment rentals. These naturally scale as the size of the project changes. Some costs (e.g., manager costs) may be categorized as fixed or variable depending on the project and should be carefully considered when estimating costs. Identifying fixed and variable costs permits estimation of how costs may scale across projects. It also allows accurate estimation of potential economies or diseconomies of scale as projects change in size (Armsworth et al. 2011; Armsworth 2014).

Labor costs should be detailed because staff time is a large cost in most projects. It can include paid employees directly involved in project implementation, managers, and support staff, such as administration or fundraising. It also includes time for staff training. Volunteers commonly contribute to project success, and their time has significant value (Armsworth et al. 2013; Santangeli et al. 2016). Noting volunteer time permits benchmarking of labor costs across projects.

Capital assets and equipment costs are those of the tools and infrastructure necessary to implement the project. Examples of organization-level costs include vehicles, machinery, instruments, and buildings. Many projects use existing equipment, which should be listed if critical to project success because they incur variable depreciation costs.

Consumable items are used up during the project. Examples include herbicide, fuel, airline flights, staff accommodation and meals, and equipment rentals. Meeting costs (other than staff time) can also be considered consumables costs.

Overhead is the cost of administrative and logistic necessities that ensure a project can be implemented. Examples include electricity for the office and registration and insurance for vehicles. Overhead may also include labor costs of managers and support staff in an

organization, such as administration, fundraising, or legal. These staff may not directly participate in a project, but their costs cannot be eliminated.

Fifth, state currency and date for which costs were incurred. Providing this information enhances future interpretation because purchasing power and the value of money vary with time and location. We suggest reporting costs in the original currency, noting the date and conversion rate, and reporting whether discounting or inflation correction was applied to standardize costs over time.

Reporting level

Cost data that are collated and reported in a study can include different information depending on how the data were recorded (Fig. 1). Intervention-level cost data are the additional specific costs to an organization of carrying out a given project, such as removal of invasive species. Program-level cost data are the shared costs of running an entire program (e.g., costs of removing an invasive species as a part of an island-restoration program). Organization-level cost data are the estimated cost of the intervention as a proportion of the total cost of running the organization. The reporting level should be noted because it permits interpretation of which project costs are likely included in cost categories (Table 1).

How standards complement existing strategies

The Open Standards for the Practice of Conservation, and the associated software Miradi, is a well-known planning tool for conservation actions (CMP, 2013). Cost reporting is greatly simplified for projects that use Miradi because costs are generally developed at the intervention level, but they can show costs at project and program levels (https://www.miradi.org). However, Miradi currently provides no guidance to users on what costs to report and the details of setting up the system to relate costs to benefits is left to

project developers. Our cost-reporting standards provide developers with guidelines on what is appropriate to build into the reporting system. These standards build on several steps outlined in the Open Standards for the Practice of Conservation (CMP, 2013) and encourage a description of the conservation project (Open Standards step 1B), development of a project budget (Open Standards step 3A), and an informed analysis of project outcomes (Open Standards step 4B). By calling for standardized and transparent cost reporting in studies and reports, we hope to promote the use of systems such as Miradi that enhance conservation-project support and decision making.

Our standards are also closely linked to the goals of the evidence-based conservation movement (Sutherland et al. 2004, Cook et al. 2017; Dicks et al. 2014). Compiled evidence informs conservation decisions by allowing managers to quickly identify what the expected outcomes of potential interventions may be . Additional information is needed so that managers can identify expected costs of alternative interventions. Appropriate cost data are not yet available to quantify the cost-effectiveness of interventions, but our cost standards are the first step toward achieving that goal.

Examples of cost reporting

We applied our standards to the common intervention of invasive species management. We first show how to ideally report on the costs of a hypothetical conservation intervention. However, because only new data collection is likely to permit this level of resolution, we worked an example of the intervention costs incurred by 2 case studies that report on existing data. These examples involve existing data sets for which all ideally reported information is not available. Until financial cost data are reported such that interpretation is transparent, researchers are limited to using such cost data, despite missing attributes. These examples show how to provide metadata for such cost data.

Invasive species management

This hypothetical project of invasive species management was costed at the intervention level (Fig. 1, Table 2). The objective was to eradicate invasive weeds from a small island accessible by boat from the management office. In a 2 -year initiative herbicide was applied to remove a low-level infestation across the island. Available intervention-level data allowed fine-scale reporting across the cost categories, including details on different labor costs, quantities and types of consumable items required, and proportional costs attributable to existing assets. Reporting costs at this resolution enables full comparison of the costs of different types of conservation interventions, but few current data sets permit such reporting.

Israeli invasive plant management costs at the intervention level

This is an example of the cost of managing the invasive tree species golden wreath wattle (*Acacia saligna*) in national protected areas along the coast of Israel (Oron & Hamod 2008). Golden wreath wattle is native to Australia and in Israel it creates harmful single species stands. The NGO and government funding agencies aimed to eradicate the tree in protected areas and monitor for future establishment (Table 3).

The project was costed at the intervention level. The initial eradication consisted of cutting down the trees and applying herbicide to the stumps or uprooting and piling removed trees within the treatment plots. Dry wood piles were burned to destroy dormant seeds. New shoots or seedlings were sprayed with herbicide or manually removed. The treatment period was followed by 1 year of monitoring. In total 600 ha were treated and approximately 60 m^3 of cut wood was removed at a cost of NIS17,600. Monitoring showed regeneration of local native vegetation, but new golden wreath wattle shoots and seedlings persisted, so the project is ongoing.

U.S. costs of invasive plant management at the program level

This is an example of the costs of invasive plant management on 46 publicly owned protected areas in Florida (U.S.A.) (Iacona et al. 2014). The Florida legislature approves an annual budget for invasive plant management and the Florida Fish and Wildlife Conservation Commission (FWC) is responsible for allocating the funds to protected area managers who apply for them (Cleary 2007). The data (Supporting Information) are accounts of allocated funds.

This project was costed at the FWC program level. Objectives are site dependent, but an agency goal is to maintain invasive cover on protected areas at or below 5%. This objective indicates the data likely represent actions that include intensive initial treatment followed by long-term, low-intensity actions, such as annual herbicide treatment, as opposed to the more intensive follow-up treatment necessary for complete eradication. Management techniques vary, but in this data set they primarily consisted of herbicide and mechanical treatments. The reported costs describe state funding provided from 1999 to 2010 for protected areas covering 69,996 ha. The agency cost-reporting data set did not separate costs allocated to the different categories, but we indicated the likely cost categories included in the total cost to interpretation of the data in context.

Future of conservation cost accounting

Achieving an understanding of intervention costs to support good conservation decisions remains a long process with many hurdles. Our experiences suggest the process will require progress on several fronts. First, financial cost values that are compiled for reports and publications need to be accompanied by information that allows interpretation and transfer. Second, new financial cost data need to be collected and recorded in a format that facilitates decision support. Third, conservation accounting systems need to be designed to collect

intervention cost data and relate it to conservation outcomes at a resolution to support decisions. Fourth, conservation and funding organizations need incentives to share data on the costs of achieving conservation outcomes so that other organizations can learn from those experiences. Fifth, synthesis of compiled data are needed to enable understanding of the most cost-effective management options and how the costs of achieving conservation benefits vary across contexts.

We have outlined a mechanism to achieve the first steps by providing standards for how the financial costs of conservation interventions are collected and reported. We aimed to encourage the use of these standards for publications that include intervention cost data. The journals *Conservation Biology, Journal of Applied Ecology, People and Nature,* and *Conservation Evidence* have agreed to encourage these standards for publication, and we hope *Conservation Letters* will in the future . We suggest these reporting standards be translated into other major languages and promoted across scientific journals and organizations.

But these standards are only the first step. If conservation decision making is to achieve its goal of stemming the loss of biodiversity, a better understanding of the cost of attaining conservation benefits is needed. This understanding requires increased consistency in how conservation cost data are collected by and related to conservation outcomes and that the costs of interventions be routinely reported.

Achieving the next steps will be difficult because it entails enacting a change in conservation practice. Conservation practitioners in governments and NGOs implement the majority of the conservation work globally, and a chronic shortage of time and resources means documenting their experiences to permit learning is rarely a high priority (Leverington et al. 2010, McKinnon et al 2015, Pullin et al. 2004, Walsh 2015). Our experience suggests that although

relevant cost data are valuable to both the institution and external researchers, there is a disconnect between those who collect data and those who analyze and use these data. Competition for limited financial resources means there is little incentive for organizations to share cost information. Acknowledging that such hurdles exist and working together to counteract them is similar to the process faced by the open-access and evidence-based conservation movements (Walsh 2015).

The evidence-based conservation and evaluation movements recognize that conservation has limited capacity to report on effectiveness (Keene and Pullin, 2011). Thus, other strategies could be pursued to enable necessary data sharing (Pullin and Knight, 2001). For instance, to encourage free sharing and careful collection of cost data at the agency level, it needs to be demonstrated that the data are immediately beneficial to those doing the work and that the benefit of the data outweighs the cost of its collection. This has occurred in cases where governmental regulations or funder requirements prescribe detailed cost reporting (e.g., NWFWMD [Dumolin et al. 2014]), but quantification of local benefits and cost-benefit trade-offs need to improve. There are some sectors where it is more likely that such quantification can be achieved, and we focused on invasive species management because it is a possible sector (Wenger et al 2017). It is also possible that strategies to share information can be designed to allow the whole sector to learn and share while respecting confidentiality and privacy requirements. For instance, a partially open strategy can be implemented with tools such as Miradi Share. In such a model, data can be stored privately but made available as averages across projects or on request if confidentiality and intended use in an appropriate context are assured.

Ultimately, we aim to work with the conservation-effectiveness community to spearhead the creation and population of a centralized database of intervention costs (Cook et al. 2017), similar to the database of conservation evidence (www.conservationevidence.com), that

would permit broad assessment of the cost-effectiveness of different interventions. Such a resource would support decisions that can improve conservation outcomes by providing transparency for investors and facilitate budgeting. Improved knowledge of the costs of conservation interventions allows one to answer big questions, such as how much funding would it take to secure all species (e.g., McCarthy et al. 2015).

Acknowledgments

Funding was provided by CEED (G.D.I. and workshop), an ARC Laureate Fellowship (H.P.P., B.M., V.A., and J.M.), Arcadia (W.J.S.), the Natural Environment Research Council (L.V.D., NE/K015419/1; NE/N014472/1), and the Wildlife Conservation Society (A.J.P.).

Supporting Information

A cost-reporting workbook (Appendix S1) and details on methods and supplemental tables (Appendix S2) 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 caption

Figure 1: Schematic of an operating budget of a conservation organization that simplifies consideration of data-reporting levels (y-axis). Three different programs are shown (solid-line rectangles: islands, land acquisition, and fire management), each with several interventions (labels at top). Reported costs for invasive species removal could include only those of the specific intervention (intervention level, black boxes), the cost of the intervention including a proportion of the total cost of the island program (program level, hatched shading within program box), or the cost of the intervention including a proportion of the total cost of running the organization (organization level, hatched shading within dashed box).

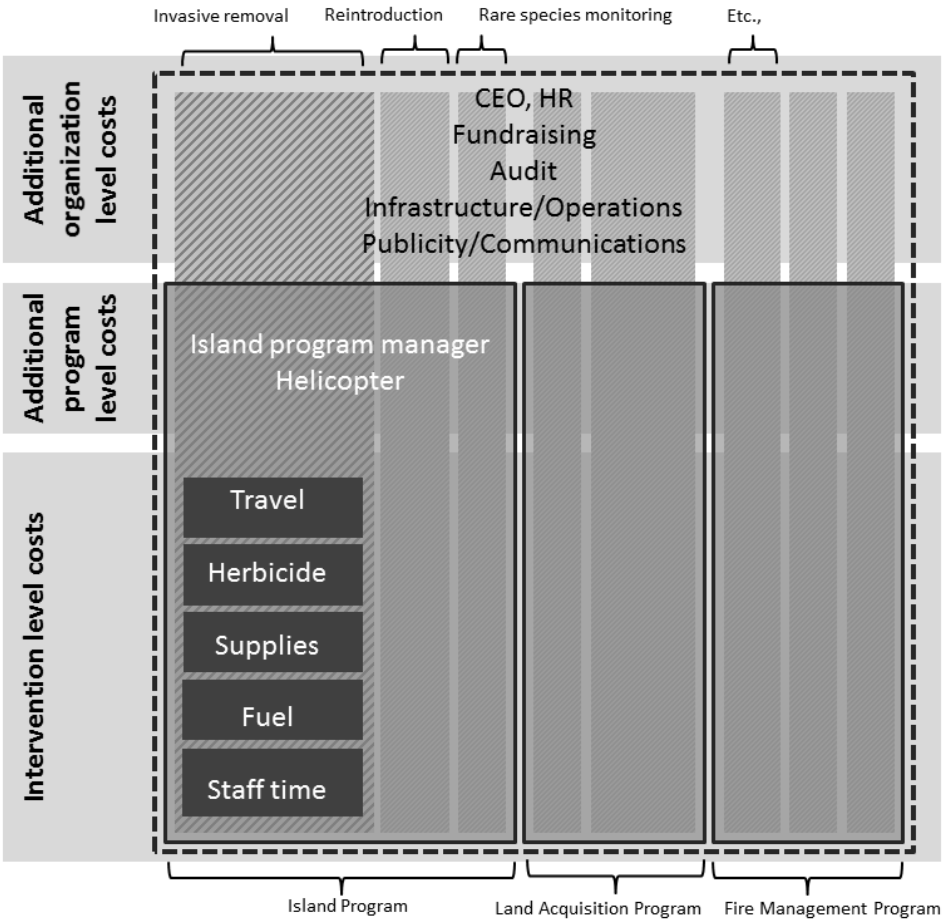

Table 1: Possible cost categories in conservation interventions, when data are reported at the intervention, program, and organizational levels.

	Intervention	Program	Organization
Labor	time actively spent on the project, including training of volunteers, reporting, travel between sites, and planning for later implementation; type of staff involved and whether labor cost is fixed or variable noted; description of individuals' roles (e.g. driver, security, technician) and their level of training and salary and whether the labor was contracted or in-house is useful; volunteer and landholder time clearly identified; whether listed costs are salary costs only or include benefits stated	intervention costs plus time spent monitoring (either before or after the project implementation), project management costs, such as planning and implementation, on-site management, and finalization intervention and program costs plus proportional time of organization staff allocated to project	such as human resources, research, finance, fundraising, and legal (generally report as overhead so beware double counting)
Capital assets	equipment purchased solely for the costed intervention (e.g., personal protective equipment, wheelbarrow, etc.); if equipment is for multiple projects only a proportion of the purchase price is recorded; fractional vehicle cost calculated with standard mileage rates (e.g., federal tax rate including depreciation); other equipment noted as already possessed intervention costs plus equipment and infrastructure necessary for the program (land for the	project, buildings for the management, etc.); estimate of fractional cost provided (can be based on capital depreciation calculations) if total cost of equipment or capital relates to multiple programs	intervention and program costs plus buildings, infrastructure, and maintenance
Consumables	cost of items used up during intervention, e.g., herbicide, fuel, food for the crew, accommodations, etc.	training fees for project managers or consultancy fees for project design, legal fees, incentive payments to landowners (only if not counting landowner time), etc.	intervention and program costs plus organization insurance premiums
Overhead	generally included in contracted project costs via the use of multipliers	include agency administration and management costs such as support function staffing costs, utility costs, general operating expenses (Many organizations apportion administration staff costs to projects with overheads. If this is the case, then do not double count	this cost by including the administration labor costs above.) intervention and program overhead costs

Table 2: Cost reporting for a hypothetical eradication of island invasive species at the intervention level. *

Objective of costed intervention	invasive plant species eradication on island
Methodology of costed intervention	herbicide treatment at six month intervals
Context of costed intervention	5% cover herbaceous invasive plants. Island habitat primarily grassland and rocks.
Intervention scale	20 ha, entire island
Duration of intervention so far (years)	2-year program completed 2016
Was the objective achieved?	yes
Categories included in costs (further breakdown below)	labor, capital assets, consumables
Describe discounting or inflation correction if applicable	inflation corrected to 2016 value of the British Pound using the consumer price index (CPI)
Organizational level of cost data	Intervention-level costs

Total cost of intervention: 2370 GBP

Cost Category	Description	Unit Cost	Units	Fixed/Variable	Currency	Date	Notes
Labor	4 days staff time for treatment	20	32 hours	variable	GBP	Aug 2015 - Aug 2016	
Labor	0.5 day training by manager	25	4 hours	fixed	GBP	Aug 2016	
Consumable	fuel	3	120 L	variable	GBP	Aug 2015 - Aug 2016	
Consumable	herbicide	50	25 L	variable	GBP	Aug 2015 - Aug 2016	
Capital asset	protective equipment			fixed		Aug 2015 - Aug 2016	already possessed
Capital asset	boat		8 hours	fixed		Aug 2015 - Aug 2016	already possessed
Capital asset	backpack sprayer	20	1	fixed	GBP	Aug 2015 - Aug 2016	bought secondhand

* Blank worksheet available in Supporting Information

Table 3: Case study of cost reporting for an invasive plant species eradication program in Israel costed at the intervention level.

Objective of costed intervention	This data set describes the costs of management interventions to treat the invasive plant species golden wreath wattle (*Acacia saligna*) on national protected areas along the coast of Israel (Akhziv National Park-Rosh Hanikra Beach Nature Reserve). An NGO (INHF) provided funding to the national conservation agency (INPA) to complete the project. The INHF's objective is to eradicate existing patches of invasive plants and preventing the establishment of new patches within the nature reserve.
Methodology of costed intervention	Two initial treatment methods were applied: cutting down the tree and applying herbicide (Garlon 15% in diesel) to the stump and cutting down the tree, uprooting the stump, and stacking the removed trees and leaving them in the treatment plots. Follow-up treatments included burning the dry wood piles, spraying herbicide to remove new shoots and seedlings, and manual removal of shoots and seedlings.
Context of costed intervention	Starting site condition varied from low to high levels of invasive cover. These data are not present in the data set, but were derived from personal communications. No data are available for invasive cover prior to treatment, but treatment removed invasive plants from 600 ha
Intervention scale	Invasive plants were treated across 600 ha resulting in the removal of about 60 m^3 of wood
Duration of intervention so far (years)	September 2005 until December 2007
Was the objective achieved?	not yet
Categories included in costs (further breakdown below)	labor, consumables
Describe discounting or inflation correction if applicable	all reported values corrected to 2005 value of New Israeli Shekel
At what organizational level was this project costed?	intervention-level costs
Total cost of intervention	17,600 NIS, 2005 values;

Cost Category	Description	Unit Cost	Units	Fixed/Variable	Currency	Date	Notes
Labor	hired personnel	5000	151.5 hours	variable	NIS	2005	total costs reported
Labor	monitoring	1200	2 days	variable	NIS	2005	
Consumable	herbicide (Garlon)	9000	11 L	variable	NIS	2005	
Consumable	rented digger for tree removal	2400	2 days	variable	NIS	2005	
Labor	INPA worker	N/A	8 hours				not costed in report
Labor	volunteer work	N/A	127.5 hours				volunteers were allowed to take cut golden wreath wattle trees to use as firewood